Market integration of renewable energies

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Poll (1)

Why are you interested in attending this training module?

a) Because the jurisdiction I am located in has already a significant share of renewable energy in the electricity system

b) Because the jurisdiction I am located in will soon have a significant share of renewable energy in the electricity system

c) Because I am advising jurisdictions with an increasing shares of renewable energy in their electricity system

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Poll (2)

On the basis of your experience, do you expect onshore wind energy to need support to be integrated into the electricity market?

a) Yes, for a long time to come

b) Yes, but it will soon reach economic sustainability

c) No, it does not need support as it has already achieved economic sustainability

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Poll (3)

On the basis of your experience, do you expect offshore wind energy to need support to be integrated into the electricity market?

a) Yes, for a long time to come

b) Yes, but it will soon reach economic sustainability

c) No, it does not need support as it has already achieved economic sustainability

Poll (4)

On the basis of your experience, do you expect solar energy to need support to be integrated into the electricity market?

a) Yes, for a long time to come
b) Yes, but it will soon reach economic sustainability
c) No, it does not need support as it has already achieved economic sustainability

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Poll (5)

On the basis of your experience, do you expect the integration of renewable energy into the electricity system to be challenging for the system operator?

a) Yes, very challenging, putting the electricity system at risk

b) Yes, but the challenge is manageable

c) Not particularly challenging, given the current technologies

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Outline

- Renewable energy in the global context
- The challenges of integrating renewable energy
- Cost competitiveness of renewable energy
- Supporting renewable energy and promoting adequacy
- Regulatory challenges and opportunities for our energy markets
- Several market tools available to integrate massive RES

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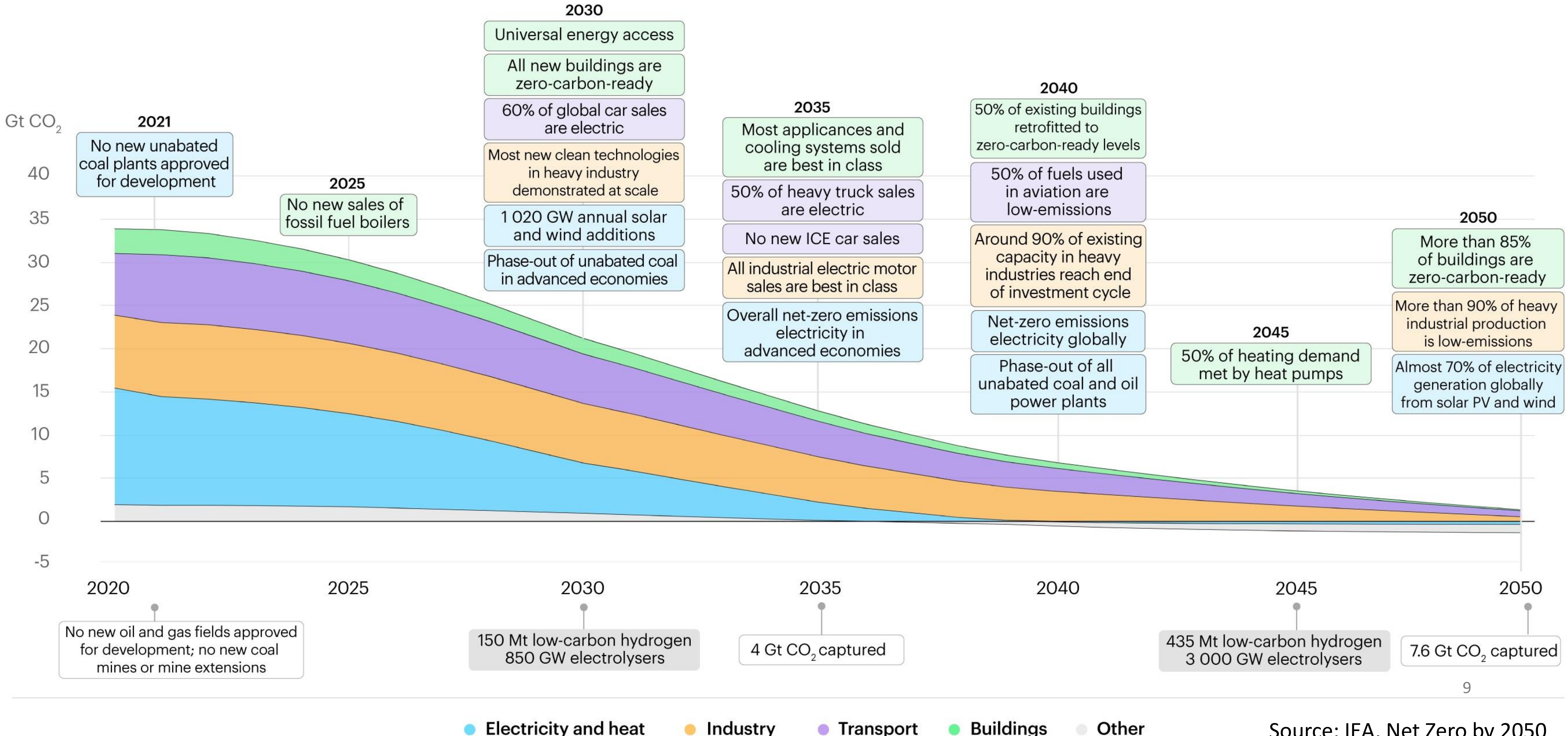
Goal: Net zero economy by 2050



Source: IEA, Net Zero by 2050

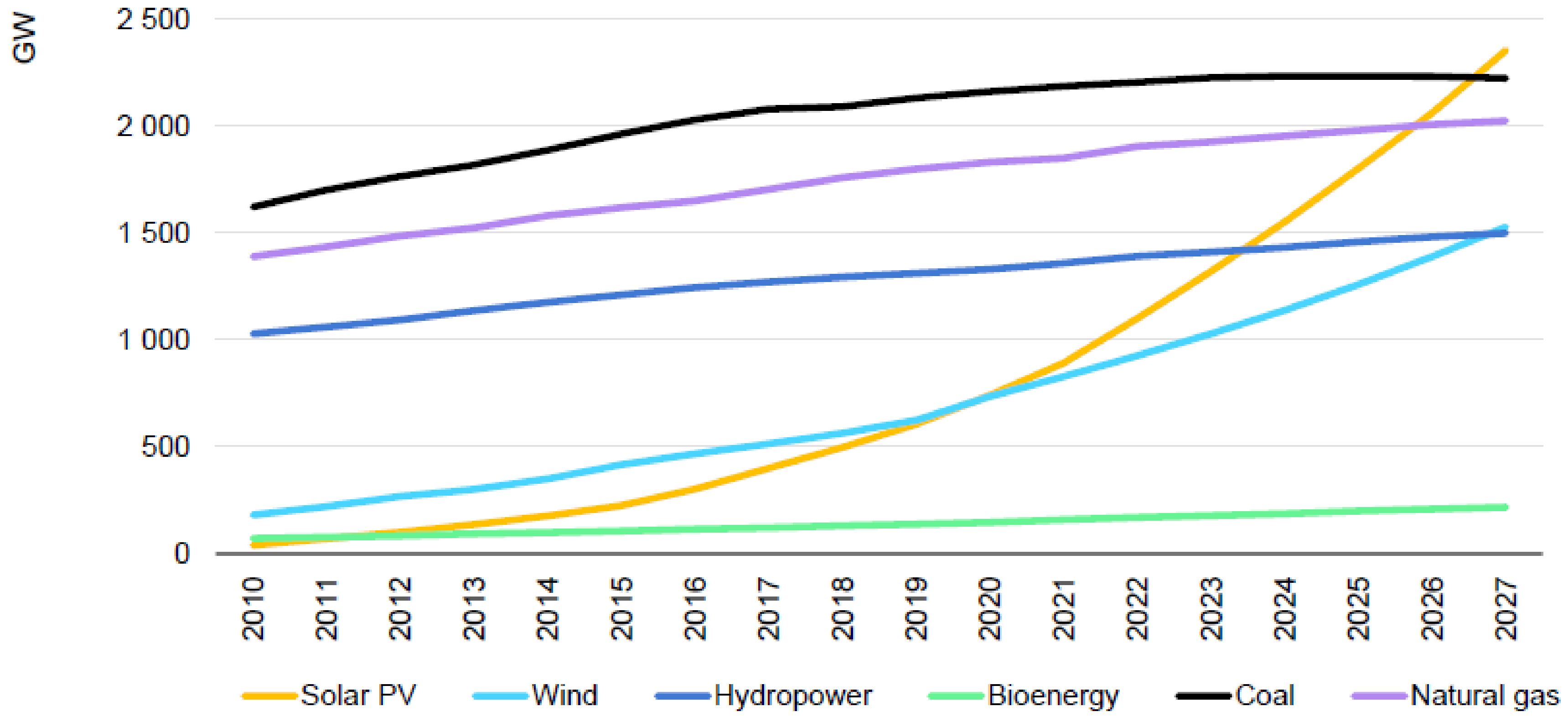
The current share of renewables in global electricity generation

28.1%

Renewables-based generation capacity is rapidly increasing …

- Solar PV is expected globally to become the first technology by installed capacity later in this decade, surpassing hydropower in 2024, natural gas in 2026 and coal in 2027

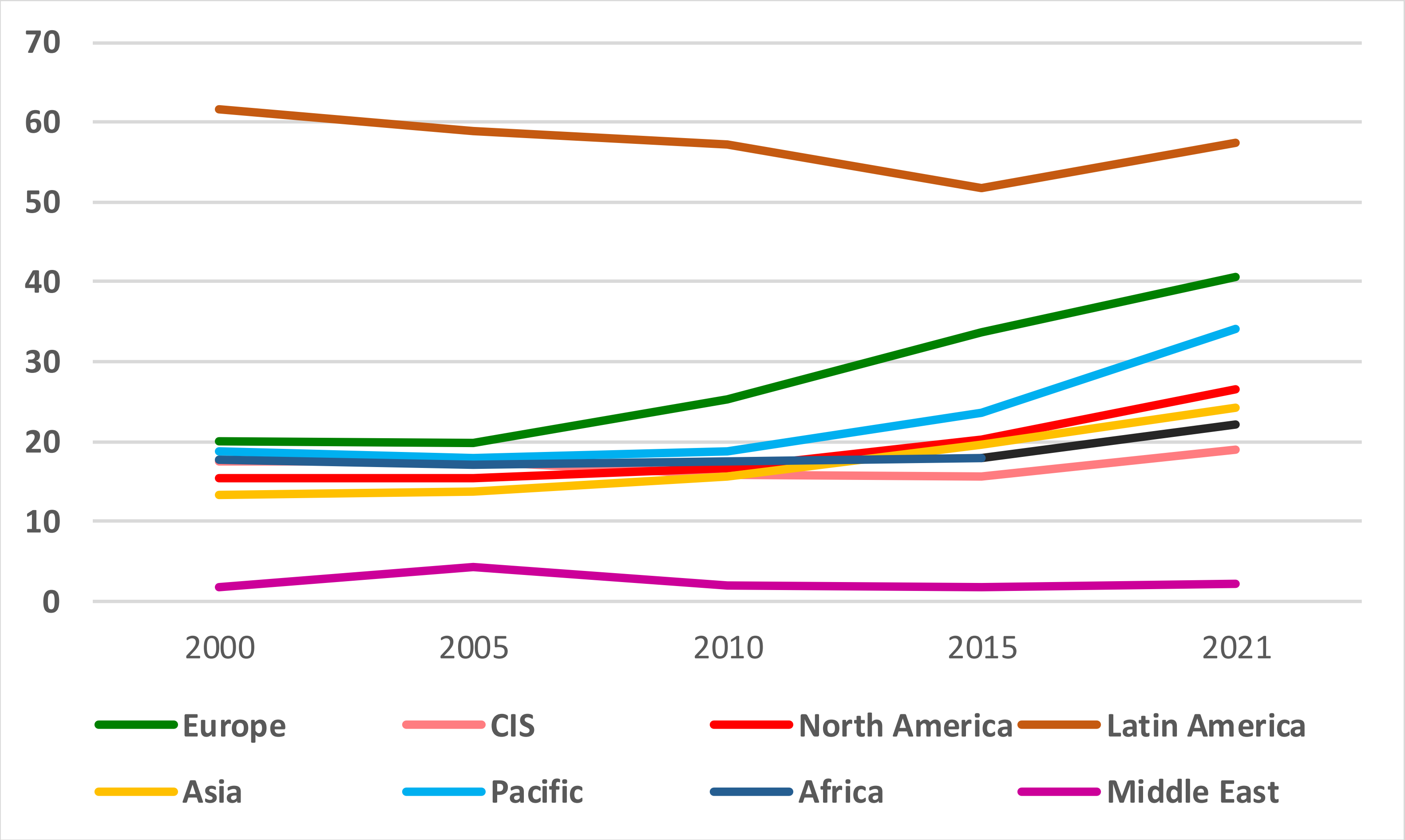
Cumulative power capacity by technology, 2010-2027



Source: IEA, Renewable 2022 – Analysis and forecasts to 2027, January 2023

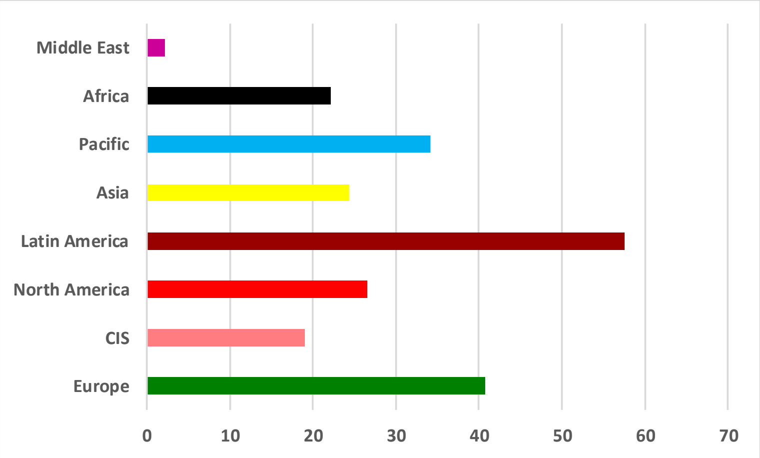
… but renewables share in the electricity generation mix varies across regions …

Share of renewables in the electricity generation mix (%) – 1990 - 2021



- Over the last 20 years, the share of renewables in electricity generation has increased in all region, except in Latin America, which has however the larger share, and in the Middle East

Share of renewables in the electricity generation mix (%) 2021



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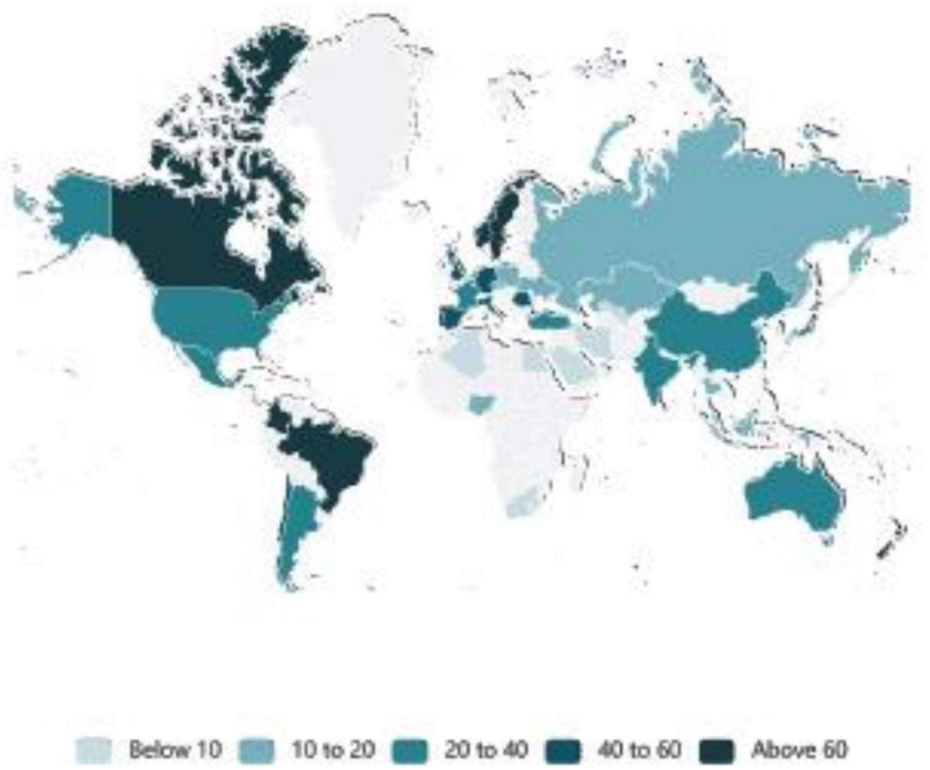
… and across countries

Share of renewables in the electricity generation mix by country (%) 2021



Countries with the largest share (%) of renewables in the electricity generation mix	
Norway	99.0
New Zealand	80.9
Brazil	78.4
Colombia	74.5
Canada	68.0
Sweden	68.0
Portugal	65.5

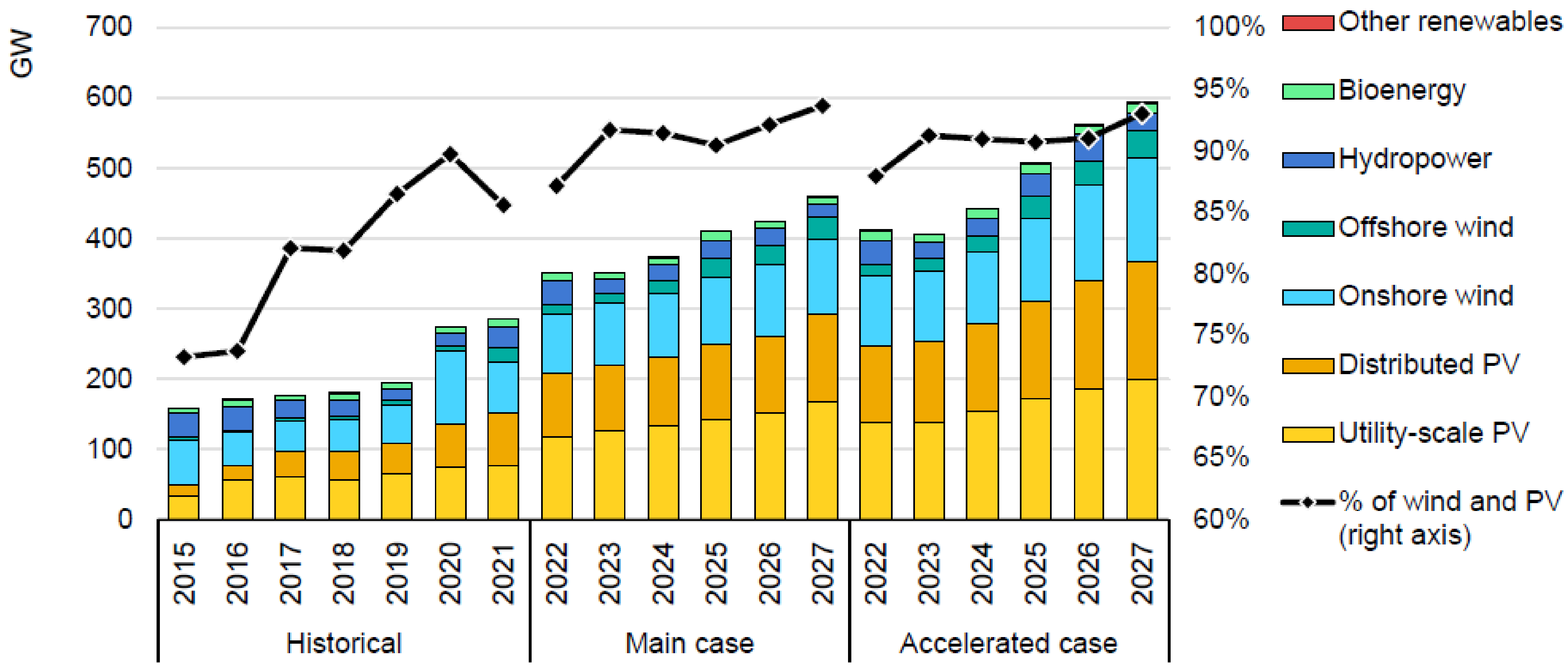
Source: Enerdata 2023. https://yearbook.enerdata.net/renewables/renewable-in-electricity-production-share.html

Wind and solar are expected to increase their shares in renewable-based generation

Over the next 5 years:

- Wind and solar are expected to account for close to 95% of all renewable capacity expansions
- Solar PV alone is expected to account for over 60% of all renewable capacity expansions

Renewable annual net capacity additions by technology, main and accelerated cases, 2015-2027



Source: IEA, Renewable 2022 – Analysis and forecasts to 2027, January 2023

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The challenges of integrating increasing shares of renewable-based generation in the electricity system

Some renewable-based generation (wind, solar, …) is non-dispatchable

Characteristics of non-dispatchable generation		Implication in terms of required resources
Unreliable	E.g., the sun cannot be relied upon to shine at night	**Back-up capacity**
Variable	E.g., the sun rises and sets	**Flexibility resources**
Unpredictable	E.g., a day may unpredictably turn cloudy	

Market integration of renewable energies

Is support needed to achieve any predefined renewable penetration target in the electricity system?

If yes:	What is the best/most market-friendly tool to promote renewable penetration?

Is the short-term market able to ensure the required back-up capacity and flexibility resources?

If not:	What are the best/most market-friendly mechanisms to attract the needed resources?

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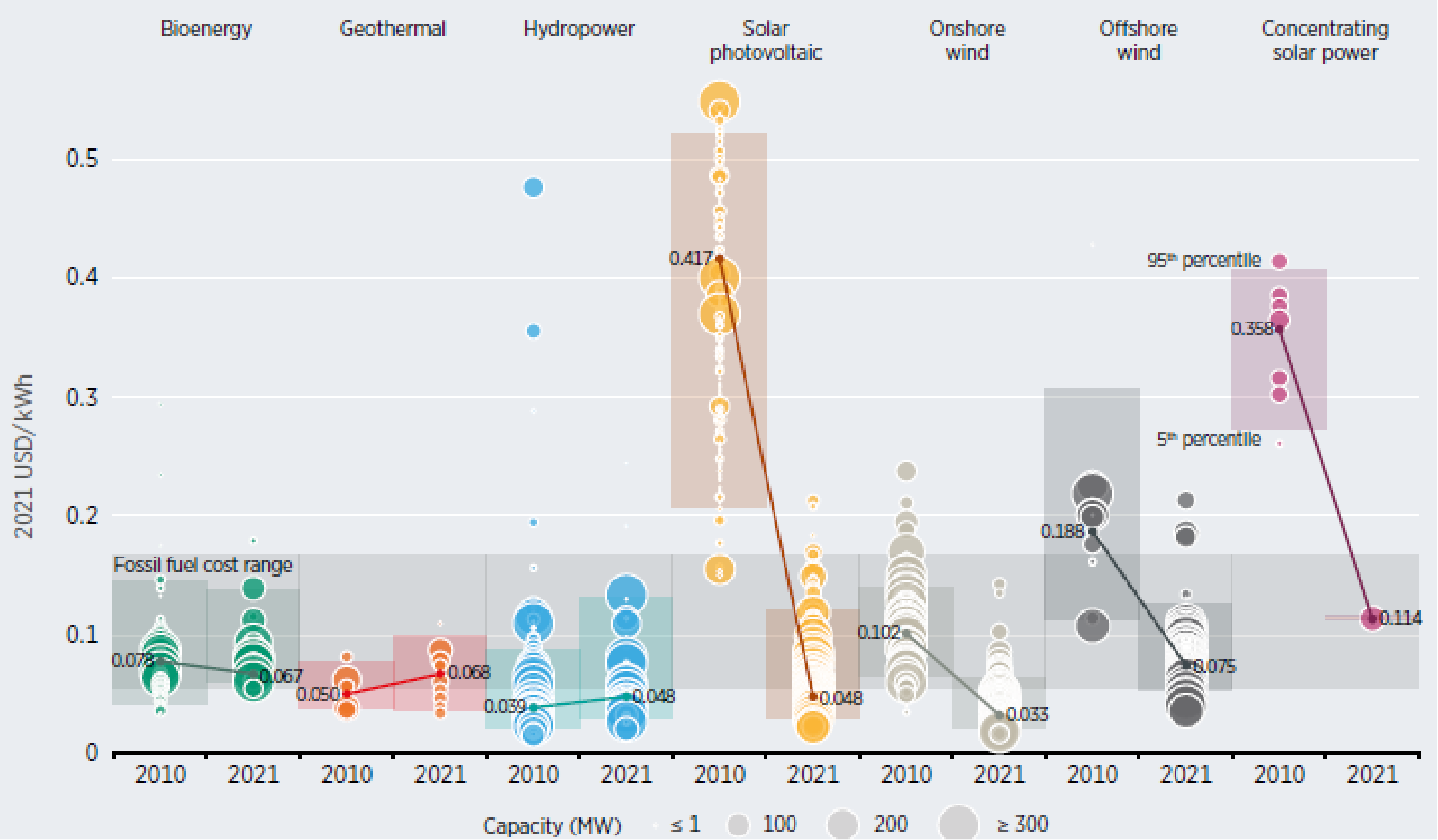
Solar and wind energy costs have significantly fallen over the last ten years

Global weighted average LCOEs of newly commissioned, utility-scale renewable power generation, 2010-2021



Source: IRENA, Renewable Power Generation Costs in 2021, 2022

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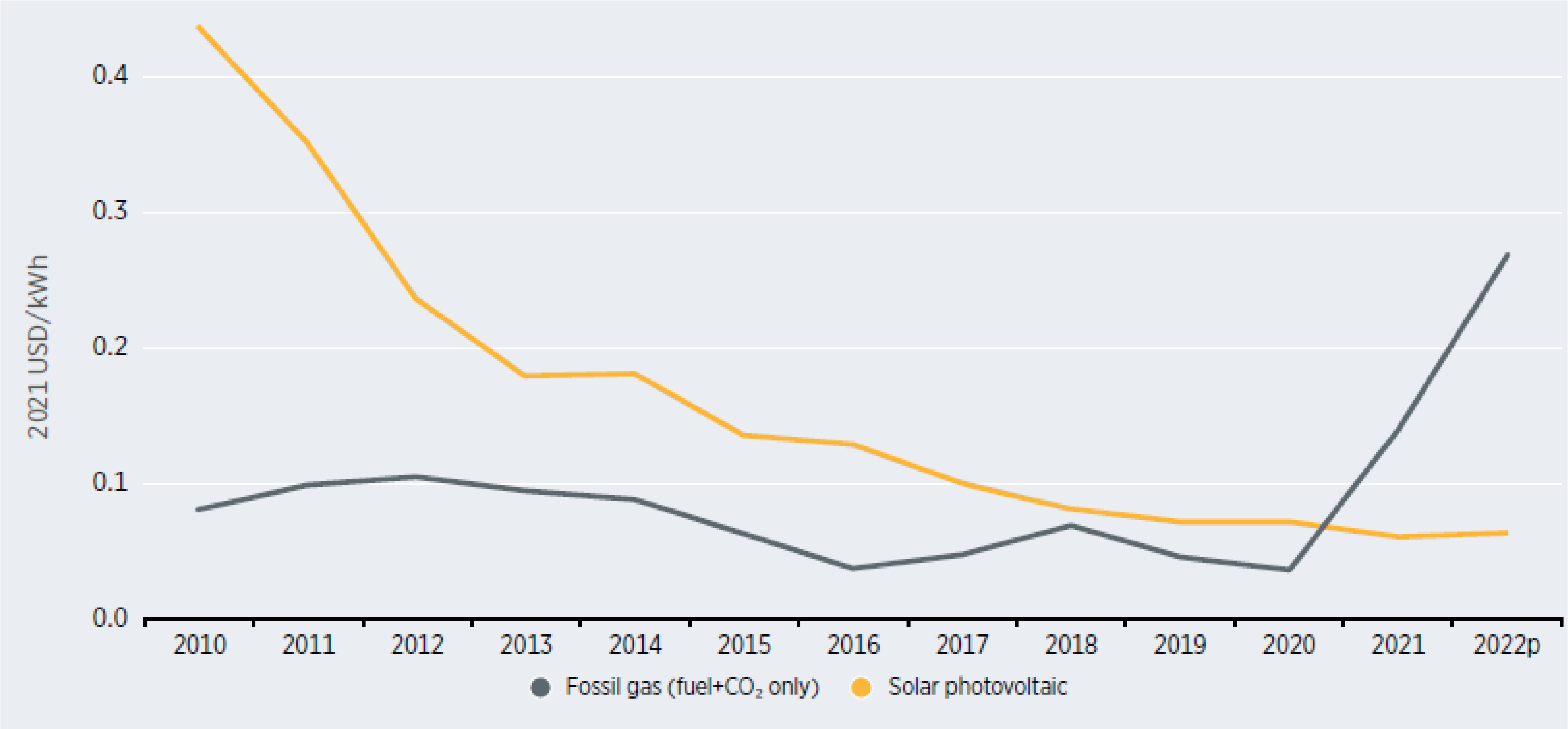
Some renewables were becoming competitive with respect to conventional generation even before the latest crisis

The weighted average LCOE of utility scale solar PV compared to fuel and CO2 cost only for fossil gas in Europe, 2010-2022

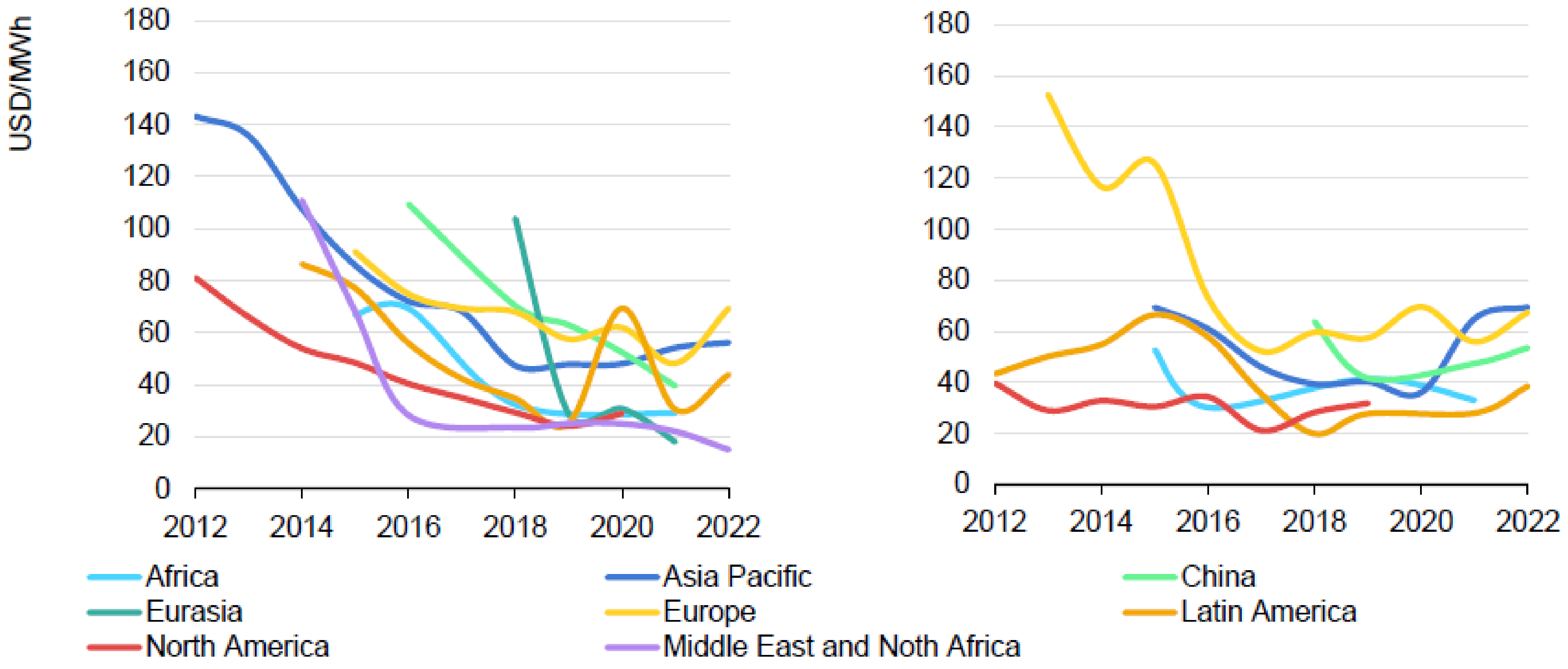


Source: IRENA, Renewable Power Generation Costs in 2021, 2022

The cost of renewables had been falling for years, but not any longer

- Increasing commodity prices, high freight costs and ongoing supply chain disruptions have recently caused investment costs for onshore wind to increase by 15-25% and for solar PV by 10-20% w.r.t. pre-Covid levels

Auction contract prices for utility-scale solar PV (left) and onshore wind (right) by region

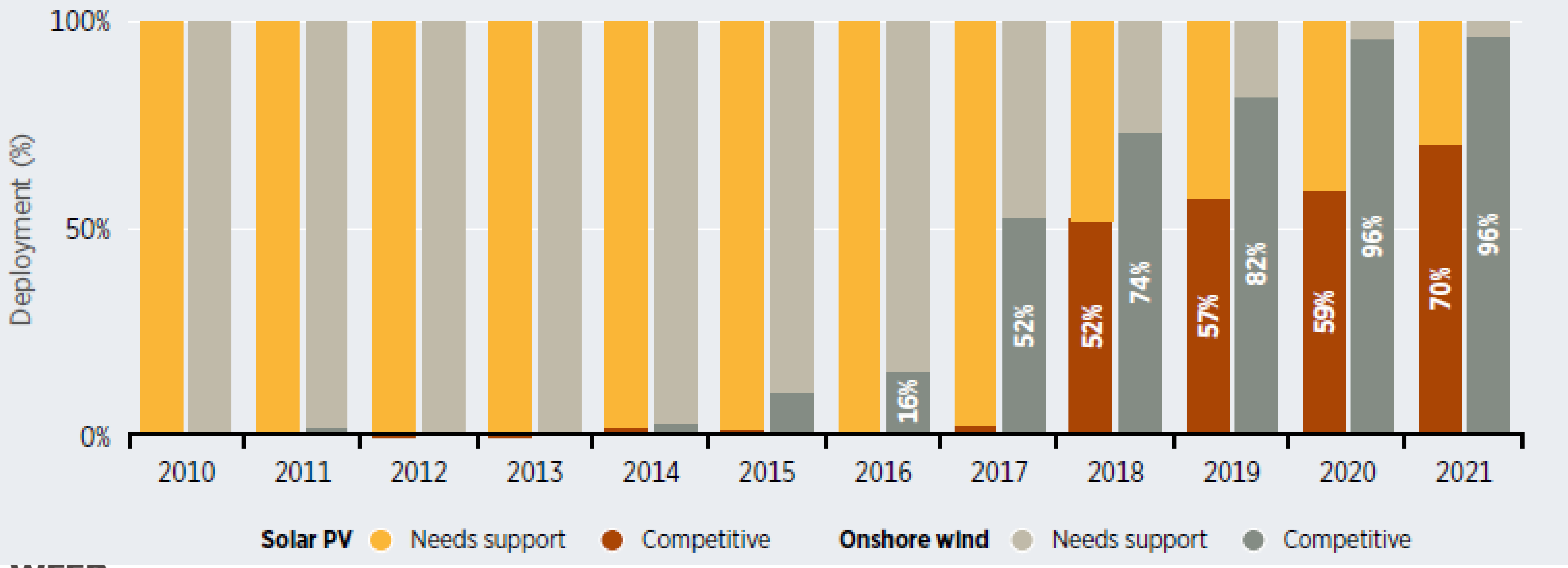


Source: IEA, Renewables 2022 Analysis and forecasts to 2027, January 2023

Cost competitiveness of renewable generation (1)

- An increasing share of the new renewable-based generation capacity is competitive in the market

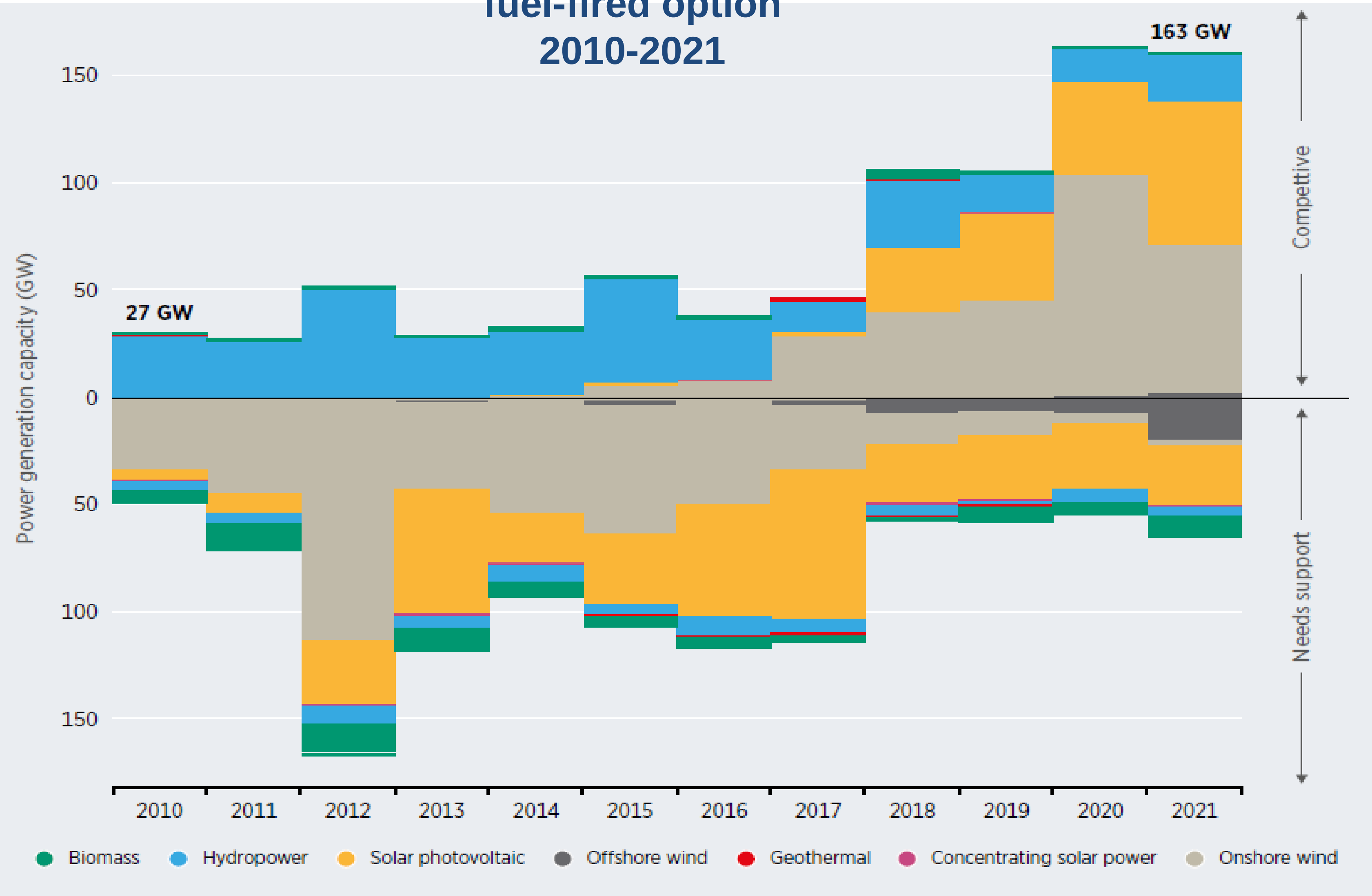
Share of the annual new renewable power generation capacity added at a lower cost than the cheapest fossil fuel-fired option 2010-2021



Source: IRENA, Renewable Power Generation Costs in 2021, 2022

Cost competitiveness of renewable generation (2)

Annual new renewable power generation capacity added at a lower cost than the cheapest fossil fuel-fired option 2010-2021



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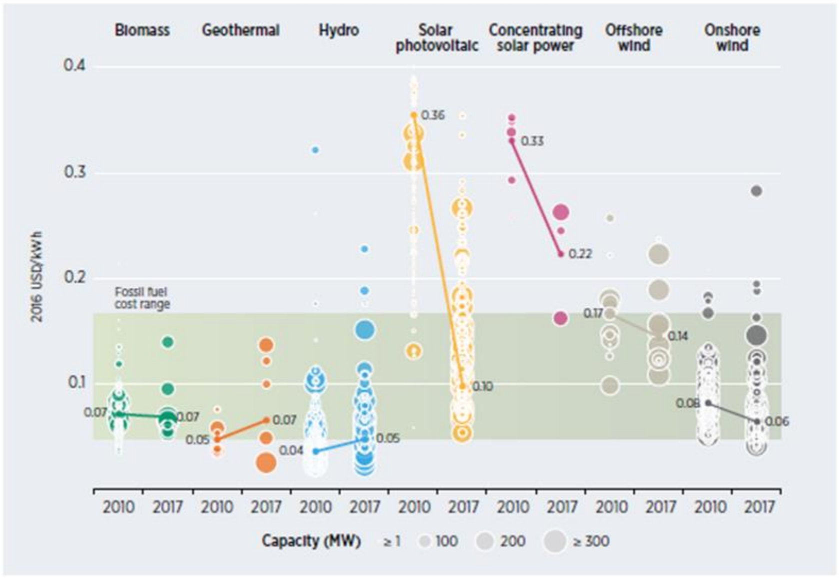
Why is renewable energy typically supported? (1)

- RES (used to) have higher average costs and suffer from some 'weaknesses' in their output
  - ➢ Dependency on natural endowment
  - ➢ Intermittency
  - ➢ Lower 'density'
- But their development presents several positive externalities
  - ➢ Security of supply
  - ➢ Environmental sustainability
  - ➢ Increased competition in electricity markets

Figure ES.1 Global levelised cost of electricity from utility-scale renewable power generation technologies, 2010-2017



Source: IRENA Renewable Cost Database.

Note: The diameter of the circle represents the size of the project, with its centre the value for the cost of each project on the Y axis. The thick lines are the global weighted average LCOE value for plants commissioned in each year. Real weighted average cost of capital is 7.5% for OECD countries and China and 10% for the rest of the world. The band represents the fossil fuel-fired power generation cost range.

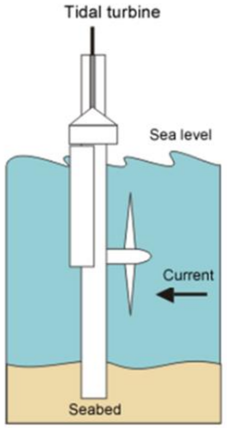
Source: IRENA (2018), p. 17

Why is renewable energy typically supported? (2)

- Immature technology with significant potential (nascent industry)
  - ➢ First-mover advantage in international markets
  - ➢ Local employment opportunities in rural areas
- Lack of a level playing field
  - ➢ Unpriced negative externalities by other energy sources
  - ➢ Market design tailored for conventional sources

- BUT not all RES are the same
  - ➢ Technology and market maturity not homogeneous
  - ➢ Different cost structure and output characteristics

⇒Needed support may vary



Source: Adapted from National Energy Education Development Project (public domain)

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Many ways to support renewables

- Choice of support mechanism based on several criteria
  - ➢Policy objectives and relevant market failures
  - ➢Technology and market maturity level
- Technology-push vs market-pull
  - ➢R&D funding for early stage technologies
  - ➢Fostering deployment for technologies near maturity
- Direct vs indirect support
- Many forms of indirect support
  - ➢Carbon pricing
  - ➢Favourable balancing arrangements, connection terms & charges, dispatch conditions, etc.

Classification of renewables support schemes

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="2">Direct</th><th rowspan="2">Indirect</th></tr>
<tr><th>Price-driven</th><th>Quantity-driven</th></tr>
<tr><td rowspan="4">Regulatory</td><td rowspan="2">Capacity-based</td><td><u>Investment grants</u></td><td rowspan="2">Tendering systems for capacity</td><td rowspan="4">Environmental taxes</td></tr>
<tr><td>Tax incentives on investment</td></tr>
<tr><td rowspan="2">Generation-based</td><td><u>Feed-in tariffs (FiT)</u>
<u>Feed-in premia (FiP)</u>
<u>Contracts for Difference (CfD)</u></td><td><u>Quota obligation based on Tradable Green Certificates (TGC)</u></td></tr>
<tr><td>Tax incentives on production</td><td>Tendering systems for generation</td></tr>
<tr><td rowspan="2">Voluntary</td><td>Capacity-based</td><td>Shareholder programmes & donations</td><td rowspan="2"></td><td rowspan="2">Voluntary agreements</td></tr>
<tr><td>Generation-based</td><td>Green tariffs</td></tr>
</table>

Source: adapted from Haas (2000), p. 10

Overview of the main direct renewable energy support mechanisms

Feed-in Tariffs (FIT)	Predefined price (typically above market prices) paid for energy produced from renewable sources and fed into the grid
Feed-in Premia (FIP)	Top-up contribution, paid on top of revenues from the market, for energy produced from renewable sources and fed into the grid
Contracts for Difference (CfDs) (Two-way Feed-in Premia)	Right to receive (if positive) or obligation to pay(if negative) the difference between the contracted 'strike price' and the market price for energy produced from renewable sources and fed into the grid
Green Certificates (GC)	Certificate proving the renewable origin of energy. It acquires a value from the obligation (imposed e.g. on non-renewable energy producers or consumers) to submit a certain quota of GCs. The GCs can be traded separately from the energy
Investment Grants	Grants or other types of financial advantage allocated to investment in renewable generation capacity

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The impact of larger shares of renewable-based generation on the electricity market

Electricity markets based on ***average-cost pricin***g

- Might lead to other technologies being crowded out
- Is likely to be priced at full (and not marginal) costs and therefore the impact on the average cost/price of electricity supply is uncertain (depending on the total cost comparison with traditional technologies)

Electricity markets implementing the ***marginal system pricing***

- ***Renewable*** technologies likely to be ***offered in the market at a low price***
- Therefore, they will ***rank high in the merit order of offers,*** which might lead to:
  - Other technologies being crowded out
  - Prices in the electricity market to be reduced

Renewable penetration impacts electricity prices …

Much greater penetration of renewable electricity with zero or near-zero marginal costs (and ill-designed support schemes)

In an auction-based market design, does this mean frequent negative, zero or near zero market prices?

How would the renewable capacity recover its fixed costs?

What happens in those hours when renewable capacity is not sufficient to cover demand?

Beyond demand response, back-up (conventional) capacity is needed, which would run a lower and more variable number of hours

This capacity would need to recover its fixed costs over such a lower number of hours

Shall we expect a few hours with very high prices, possibly as high as the value of lost load (VOLL)?

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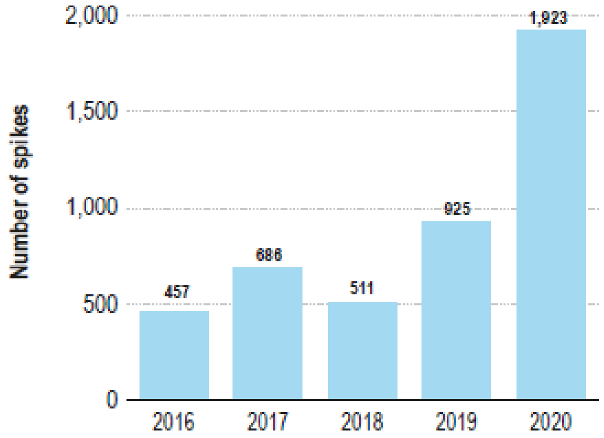
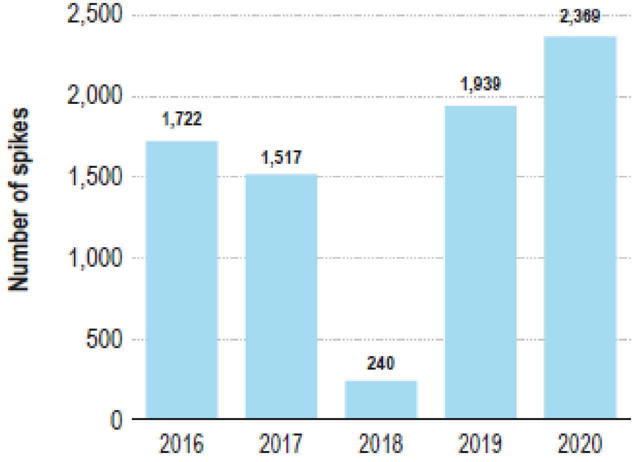
… towards a more binomial distribution of wholesale electricity prices

Renewables-based generation characterised by zero or very low marginal costs	Variability of production of renewables-based generation requires back-up resources
Many hours with very low or zero (or even negative) electricity prices	Price spikes to allow the recovery of fixed costs of renewables-based generation and back-up resources

Day-ahead negative prices in Europe





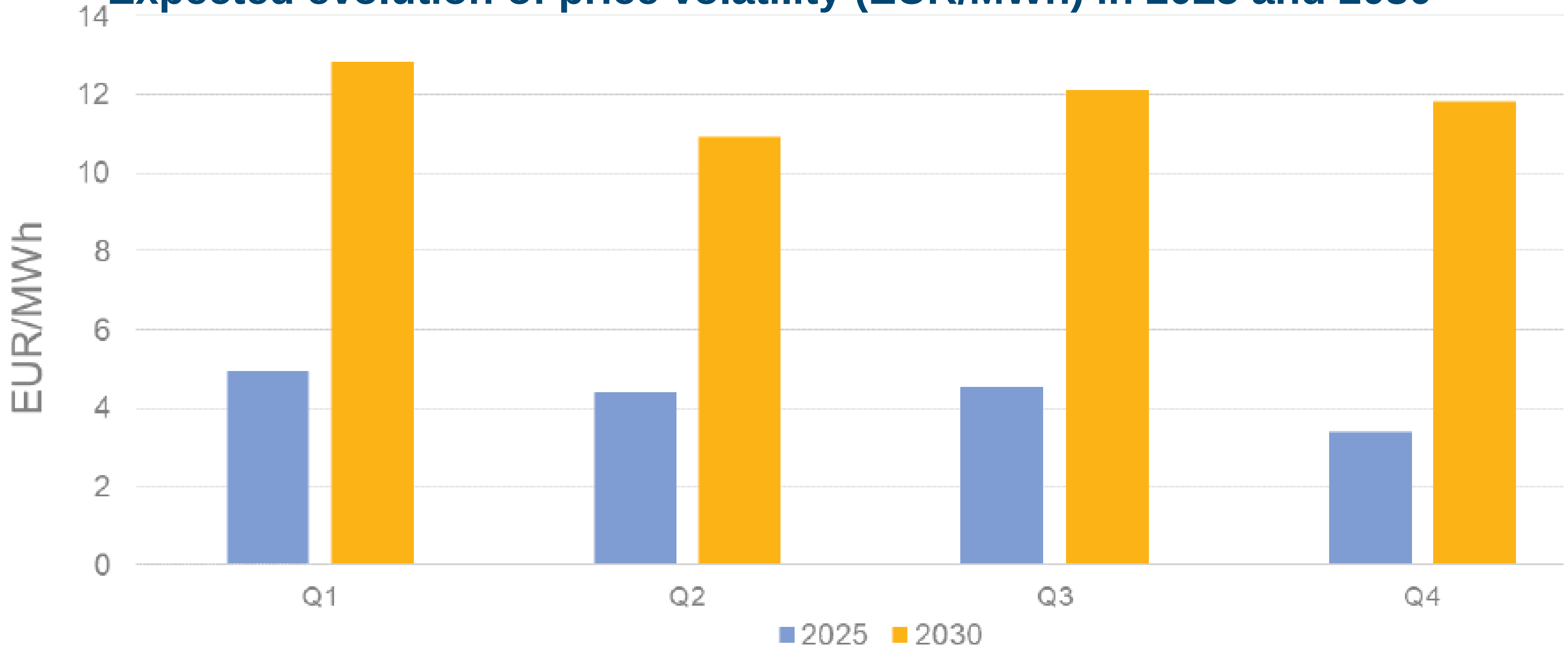
Day-ahead price spikes in Europe

Source: ACER

Electricity price volatility is expected to increase in the future

- Electricity price volatility is expected to increase due, *inter alia*, to:
  - Numerous market entries (renewables, new demand) and exits (carbon-intensive units)
  - The impact of intermittent generation on the system
  - Volatility of other underlying market fundamentals (e.g. fuel and CO_2 prices)

Expected evolution of price volatility (EUR/MWh) in 2025 and 2030



Source: ACER based on simulations made by the Joint Research Centre

Different electricity price patterns might emerge in the future

Shall we expect a more "binomial" distribution of electricity market prices?

Possibly, but not necessarily to the extent that it might appear at first sight, as new technologies and capabilities will:

Increase demand at times of negative, zero or near-zero prices

- Storage charging
- Electric-vehicle charging

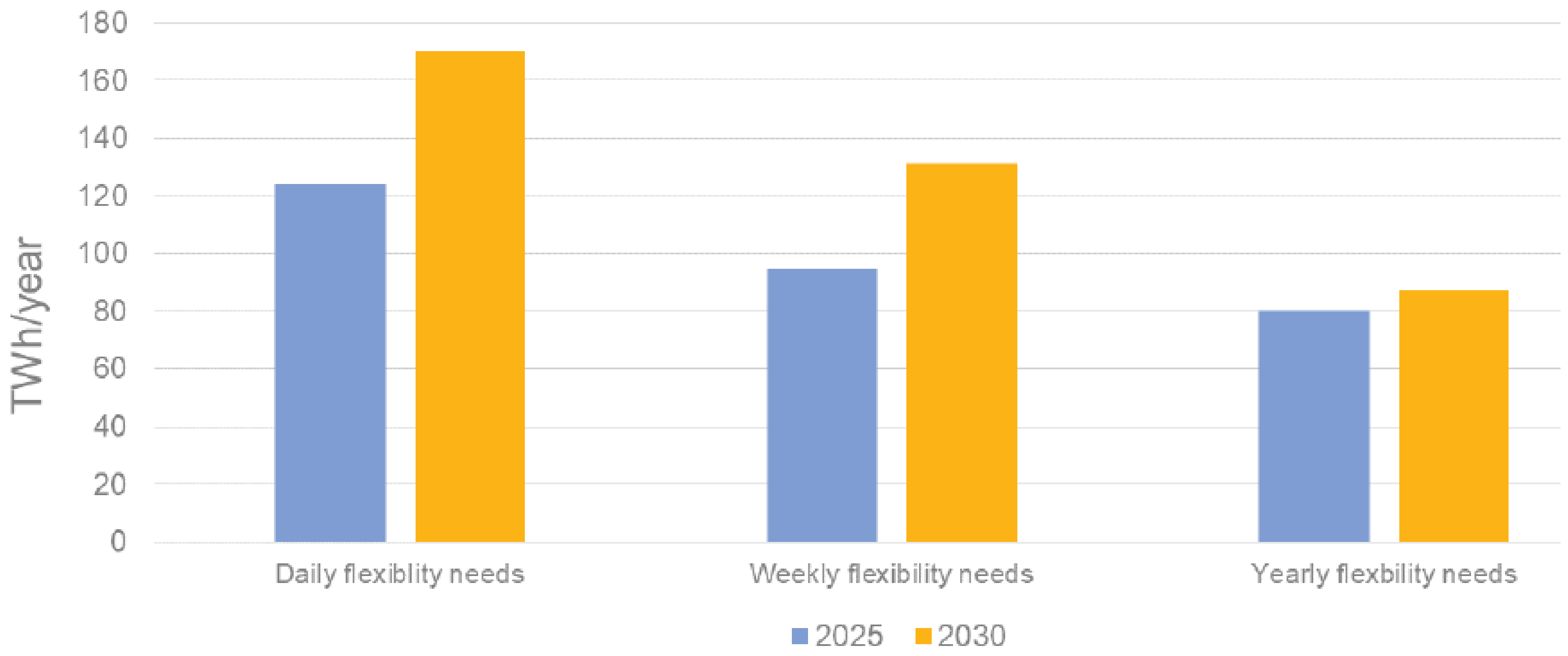
Reduce demand or increase supply at times of very high prices

- Storage discharging
- Demand response

Will the short-term market prices in the future provide sufficient revenues to ensure that sufficient back-up capacity and flexibility resources stay in or enter into the market?

A more flexible electricity system (1)

Expected evolution of flexibility needs (TWh/year) in the EU in 2025 and 2030

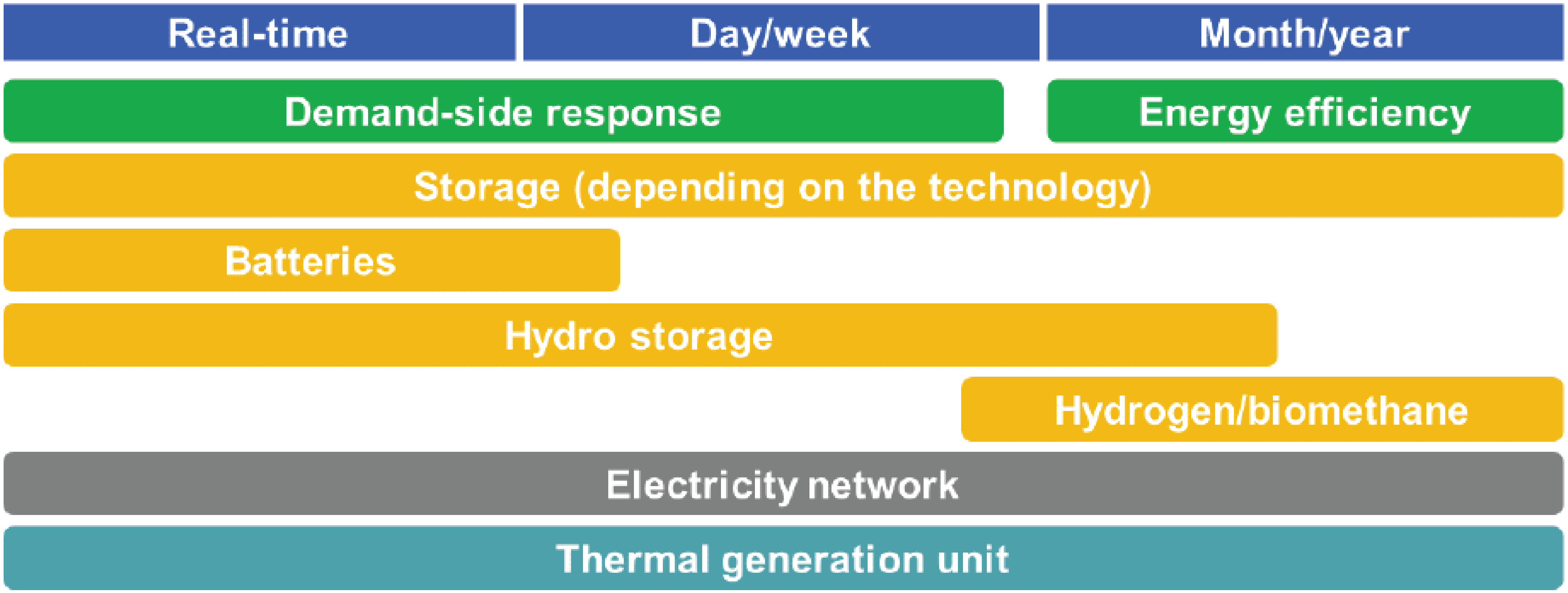


Source: ACER based on simulations made by the Joint Research Centre

- The power system will need significant and diverse flexible resources to optimise the value of growing shares of intermittent generation and to smoothen the increased volatility

A more flexible electricity system (2)

Flexibility services provided by various technologies



Source: ACER

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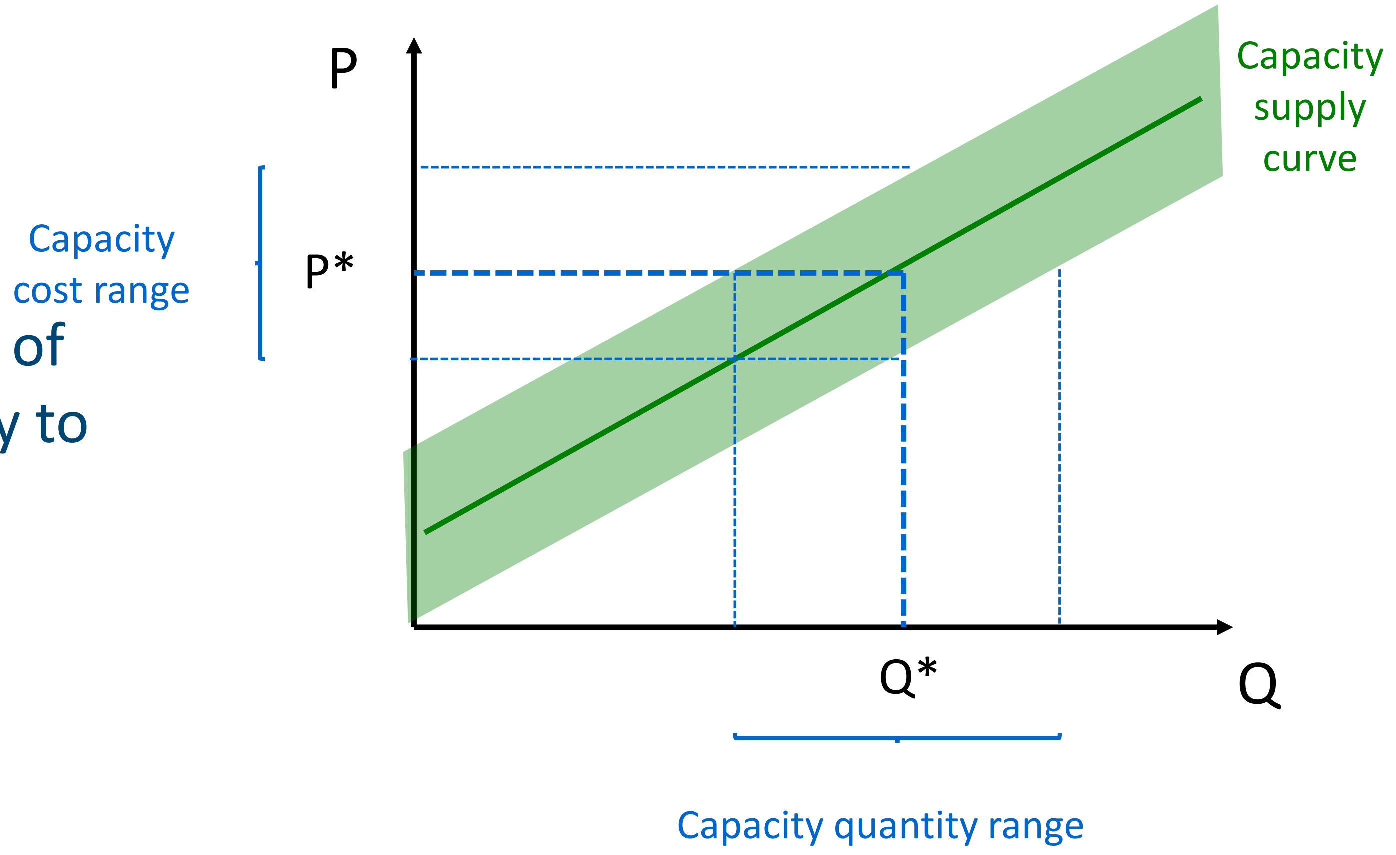
Capacity Remuneration Mechanisms

Scope / Approach	Targeted	Market-wide
Volume-based	**Strategic Reserve** (incl. Interruptibility Contracts) **Tender for New Capacity**	**Central Buyer** - **Capacity Contracts** - **Reliability Options** **Decentralised Obligations**
Price-based	**Targeted Capacity Payments**	**Market-wide Capacity Payments**

Volume-based vs Price-based CRMs

- ***Volume-based CRMs*** ensure the achievement of a target level of capacity, but with uncertainty regarding costs
- ***Price-based CRMs*** define the cost of contracted capacity, but the ability to achieve a quantitative targets depends on the knowledge of the capacity supply curve



Poll (6)

How many of you have more than 25% renewables in your energy system?

Poll (7)

How many of you have (at least some) renewables already in the market (i.e. without subsidies)?

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Poll (8)

How many of you have distributed renewable generation operating "behind the meter" (i.e. outside of the market)?

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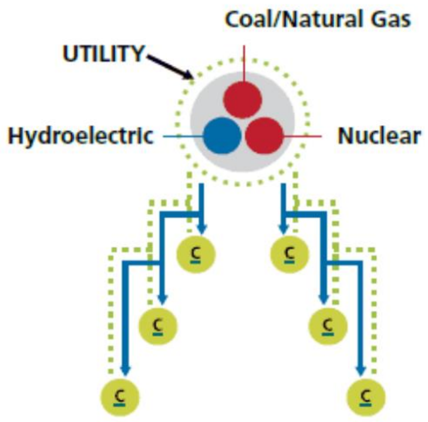
A system in transformation

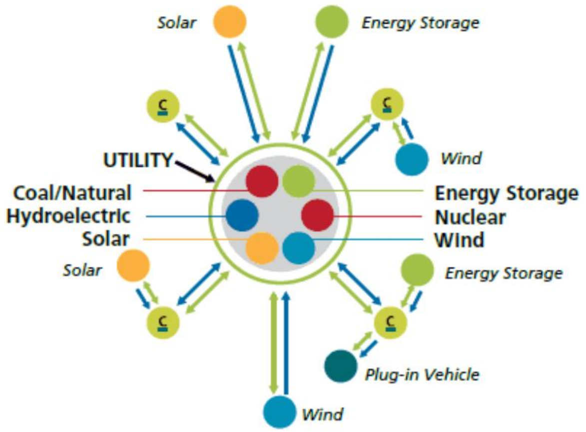
- ✓ Need to implemente the *Clean Energy Package*
- ✓ Democratisation of energy generation
- ✓ Descentralisation and new opportunities for local flexibility (*consumer-centric design*)
- ✓ *Energy Efficiency First*) principle

Yesterday
(Centralised)



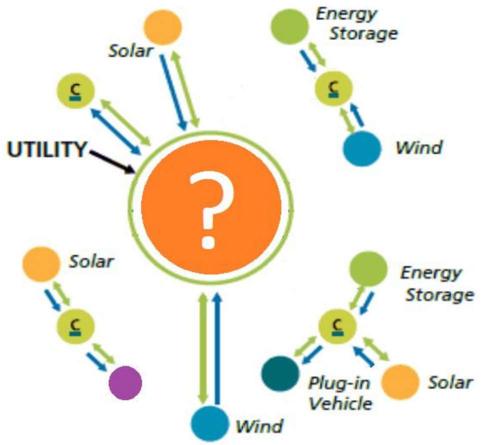
- Hierarchical
- Uni-directional flows

Today
(In transition)



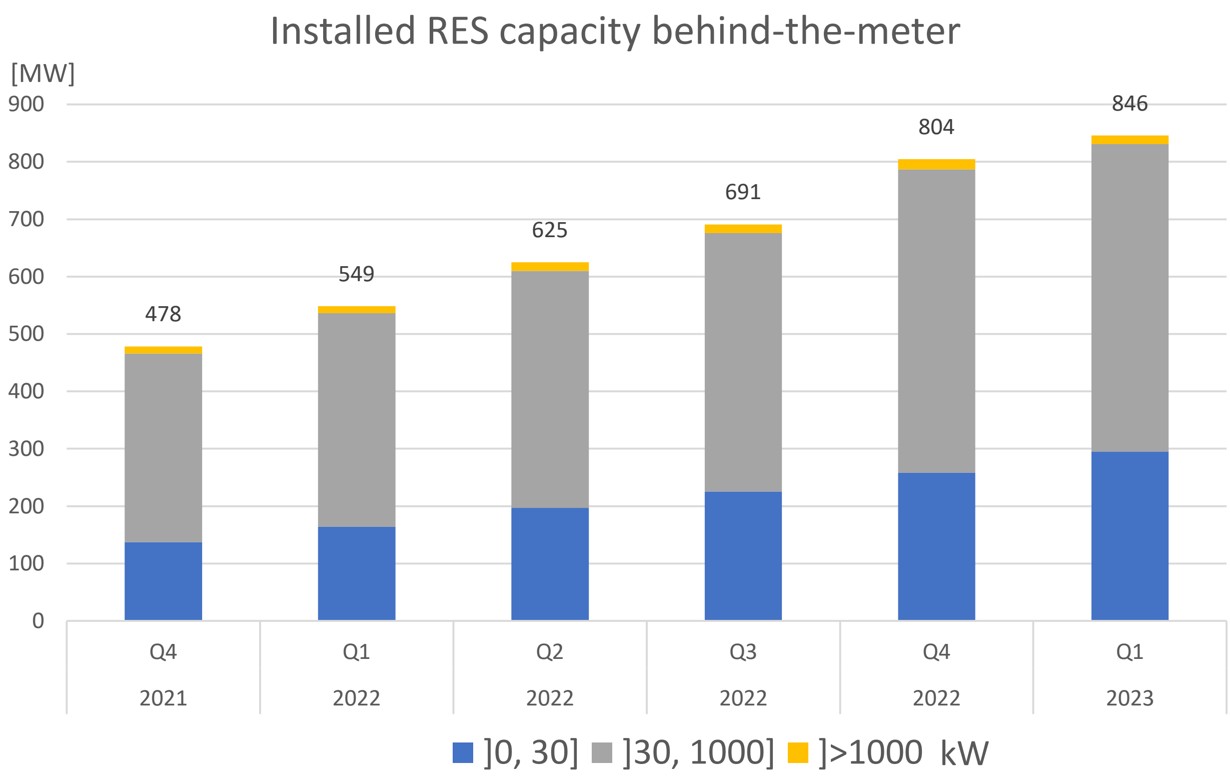
- Decentralised generation
- Centralised market
- Bidirectional flows

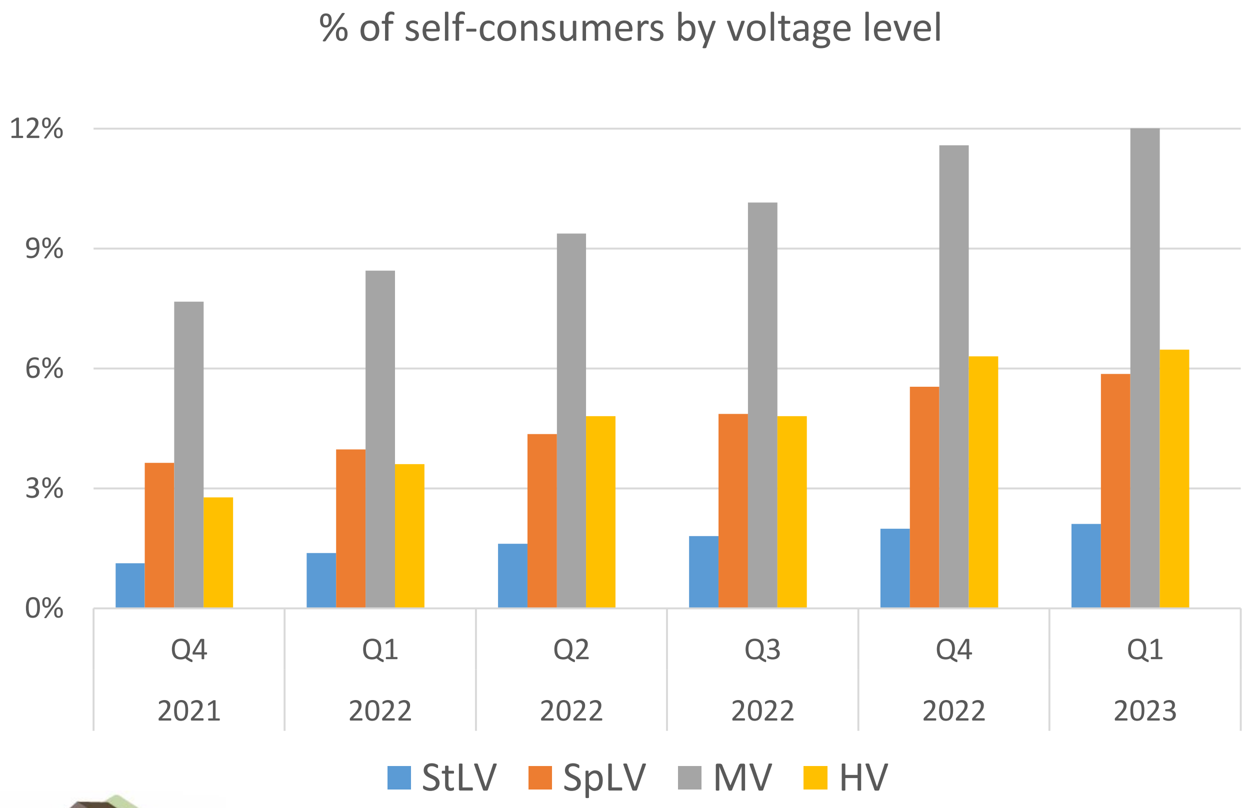
Tomorrow
(Hybrid)



- Decentralised generation
- Centralised market
- Decentralised market (P2P)
- Multidirectional flows

Renewable self-consumers (behind the meter) in Portugal





- 130k self-consumers: +66% from 2021->2022
- 846 MW Installed power: +68% from 2021->2022
- Represents ≥ 10% of peak load; 4% of total capacity

- 12% MV customers are SCs
- 2% Households are SCs

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Regulatory challenges and opportunities

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Markets & Regulation

Dynamic regulation which allows the sector's evolution and transformation

SoS

Diversification of energy sources and guaranteeing continuity of supply

Consumer Protection

Protecting the interests and needs of consumers, ensuring access to energy and quality of service at a fair price

Sustainability

Facilitation and reinforcement of renewable energy sources, whilst incentivizing energy efficiency and conscious consumption

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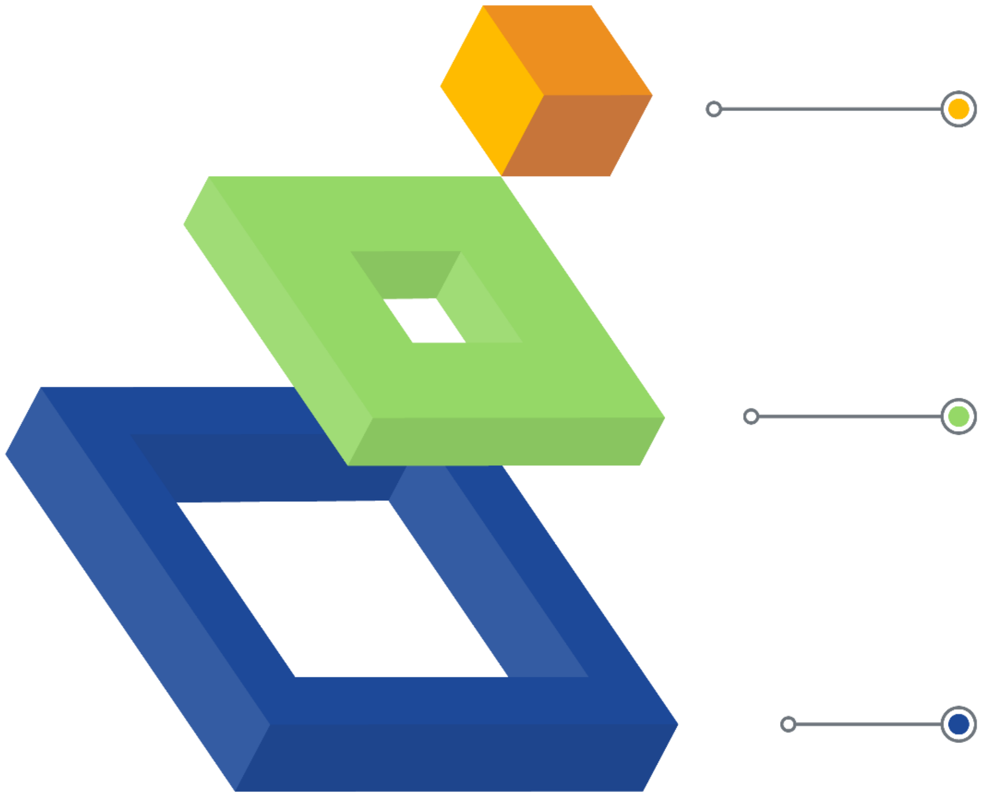
GLOBAL+LOCAL+CIRCULAR

GLOCAL

EU planning for the energy transition



Energy system integration and a CIRCULAR Energy Economy

- Green Deal & H2 & RES gas
- System integration
- New actors, technologies and business models
- Carbon neutral society
- Energy efficiency

Local integration and a LOCAL Energy Economy

- Clean Energy Package
- Consumer empowerment
- Self-consumption
- Energy communities
- Peer-to-peer

Deepening of market integration and a GLOBAL Energy Economy

- 1º, 2º, 3º EU Legislative Packages
- Liberalisation
- Unbundling
- Internal Energy Market
- New EU level bodies and codes

Outline

How can we reach a net zero society by 2050?

Renewable energy sources are the key!

Their capacity is growing and their cost is decreasing

But, how to integrate them?

Non-dispatchability and variability are a challenge

Cost business case improving rapidly. Several support and investment options!

Regulatory challenges and opportunities for our energy markets

Several market tools available to integrate massive RES

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Optimising network connection points in Portugal

Hybridisation: adding to an existing power plant or self-consumption unit new production units that use different primary sources of renewable energy, without changing the capacity injection of the pre-existing generation;

Hybrid: the power plant or generation unit for self-consumption that presents simultaneously more than one production unit that uses several primary sources renewable

Hybridisation of generation technologies at the same network connection point: optimising the already existing network use

Solar PV installed at the same location and using the same grid injection capacity of a hydro power plant

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Renewable power generation resources and security of supply timeframes in Portugal

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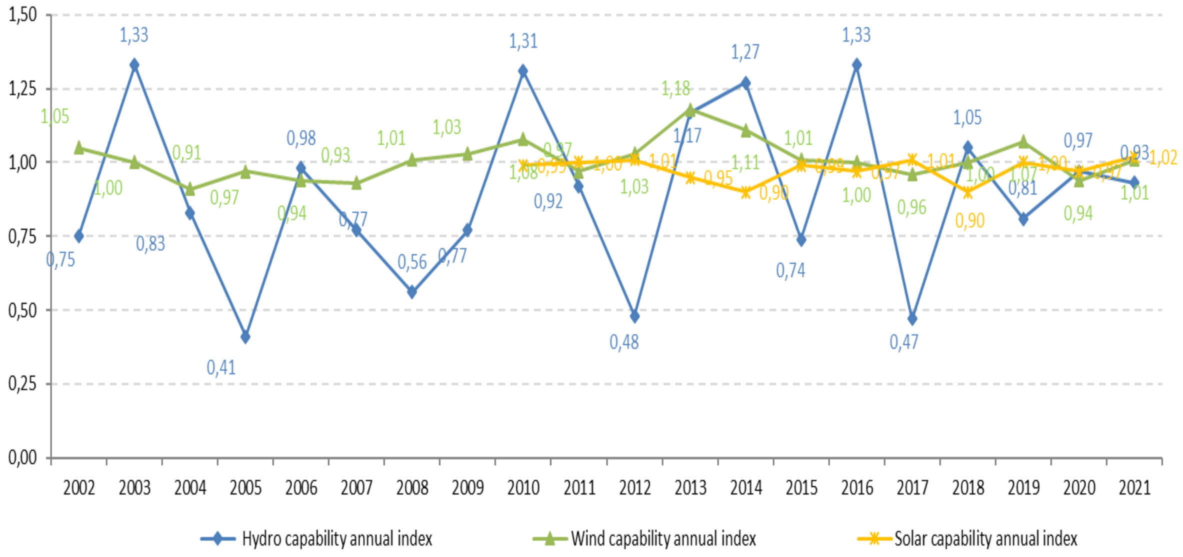
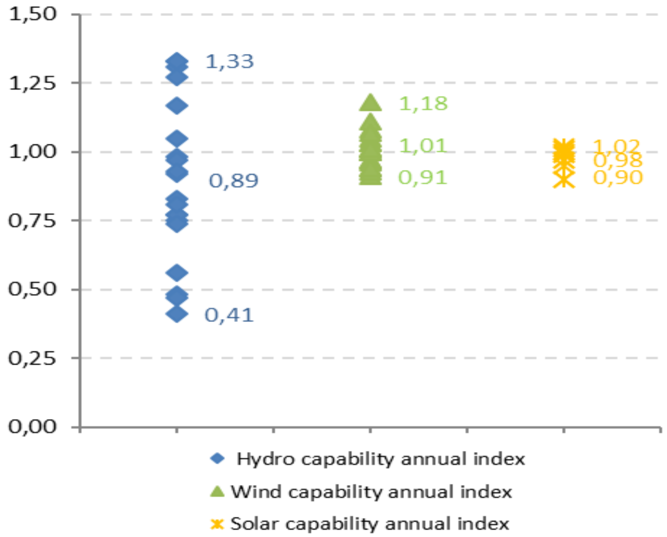
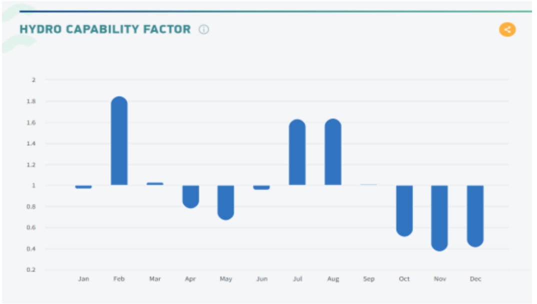
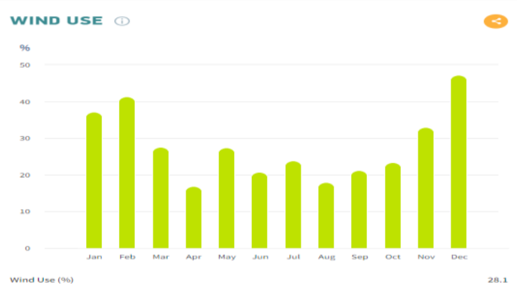
2002-2021

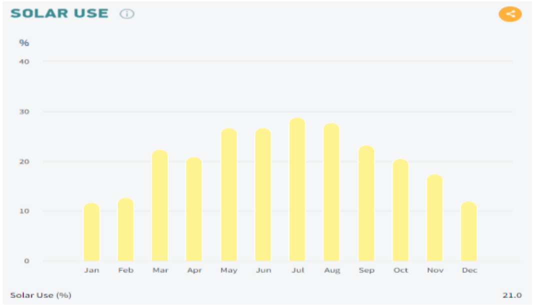




2021

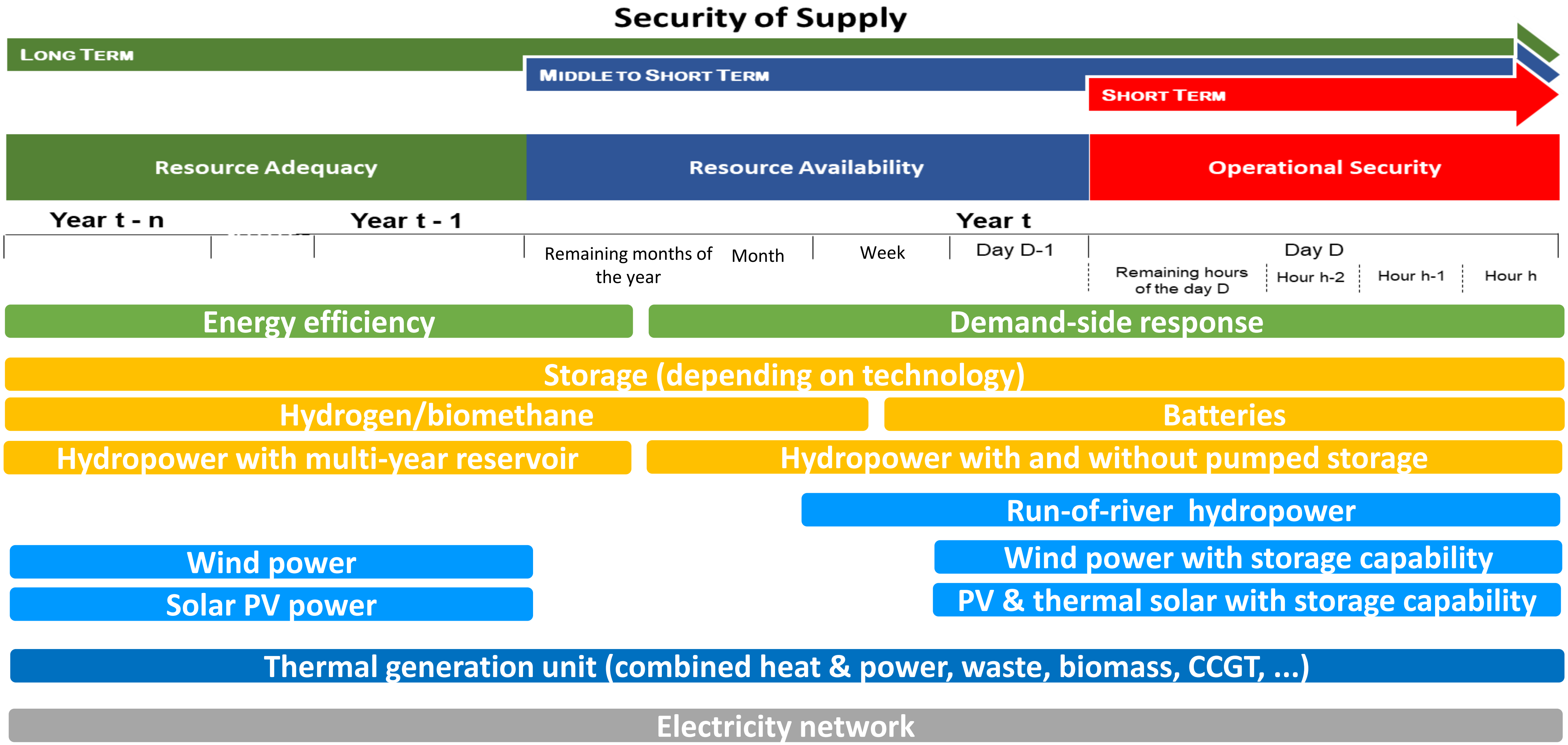






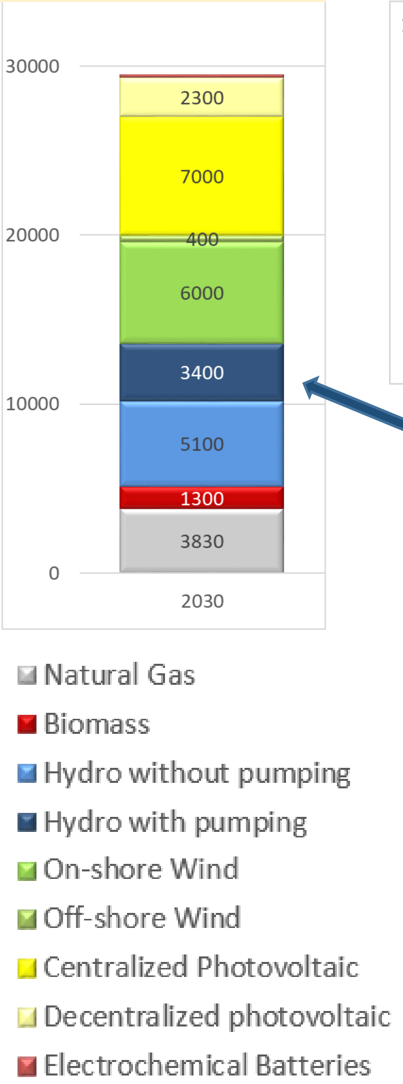
- Regularity during consecutive years from solar and wind resources shows that an adequate combination of solar and wind and storage could ensure long-term security of supply.
- Challenge for a 100 % renewable power sector is to find a solution for storing energy generated when resources are available and making it available when needed for consumption.

Power generation resources and security of supply timeframes

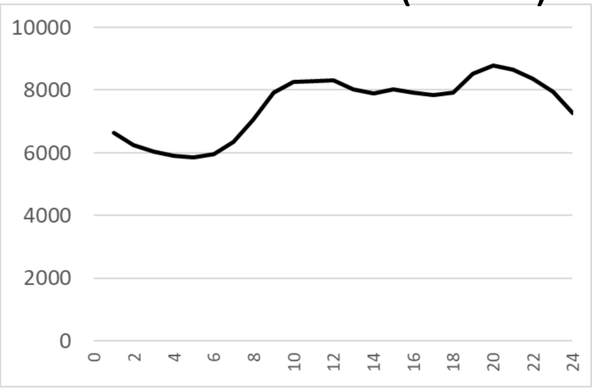


Pumped hydro can help solve daily storage needs, avoiding solar curtailment and ensuring operational security: Portuguese example

2030 Portuguese Power Mix

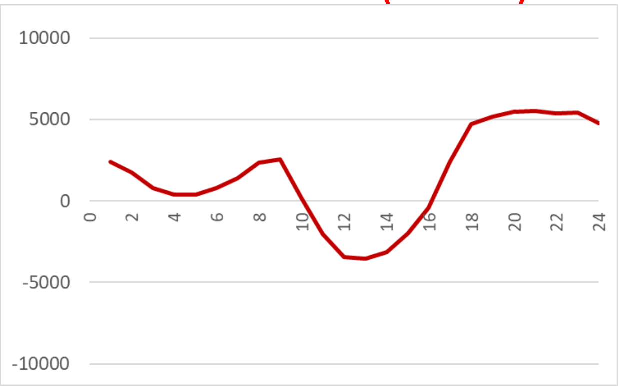


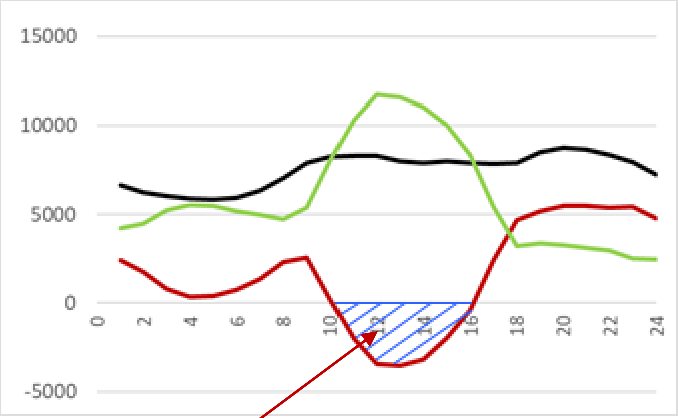
Power demand (MWh)



Wind+Solar (MWh)

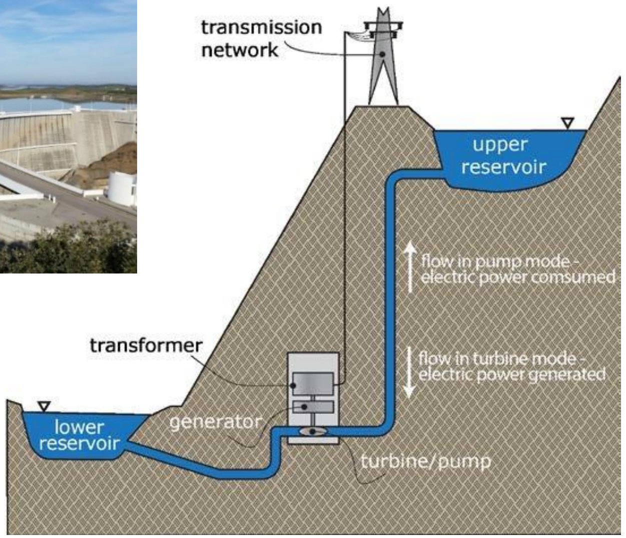
Residual Load (MWh)





Energy to be curtailed or stored for later use

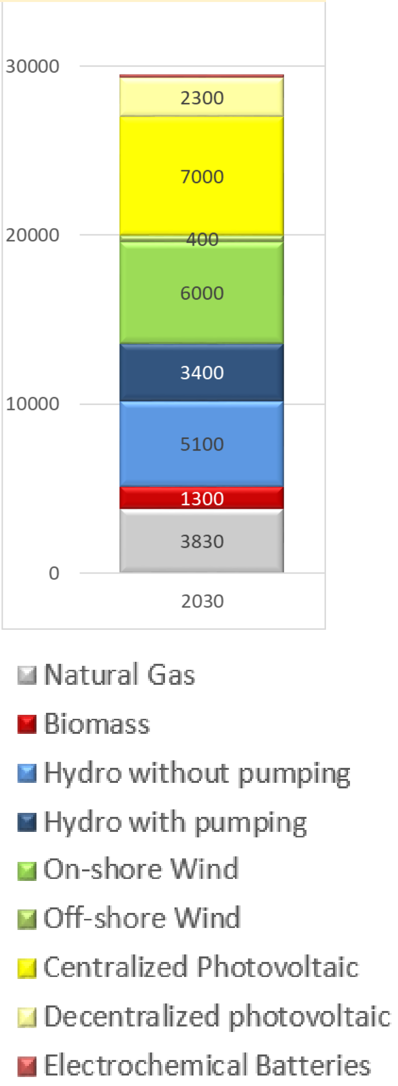
Alqueva hydropower plant: one of the pump hydro plants operating in Portugal helping to avoid daily wind and solar curtailments

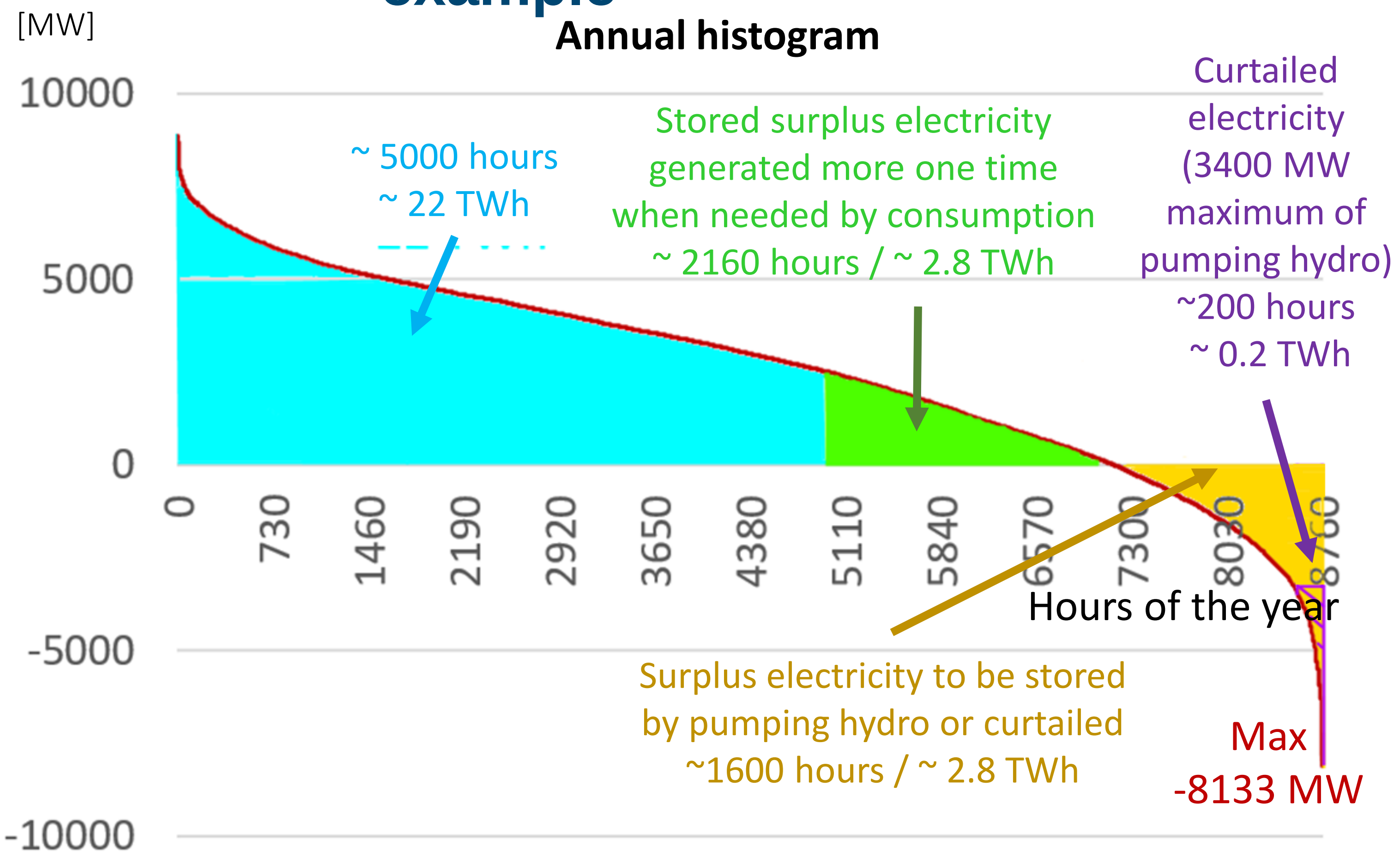


Source: Viadero, R et al. , *Hydropower on the Mississippi River*

More long-term storage needs for ensuring seasonal security of supply (resource adequacy): Portuguese example

2030 Portuguese Power Mix

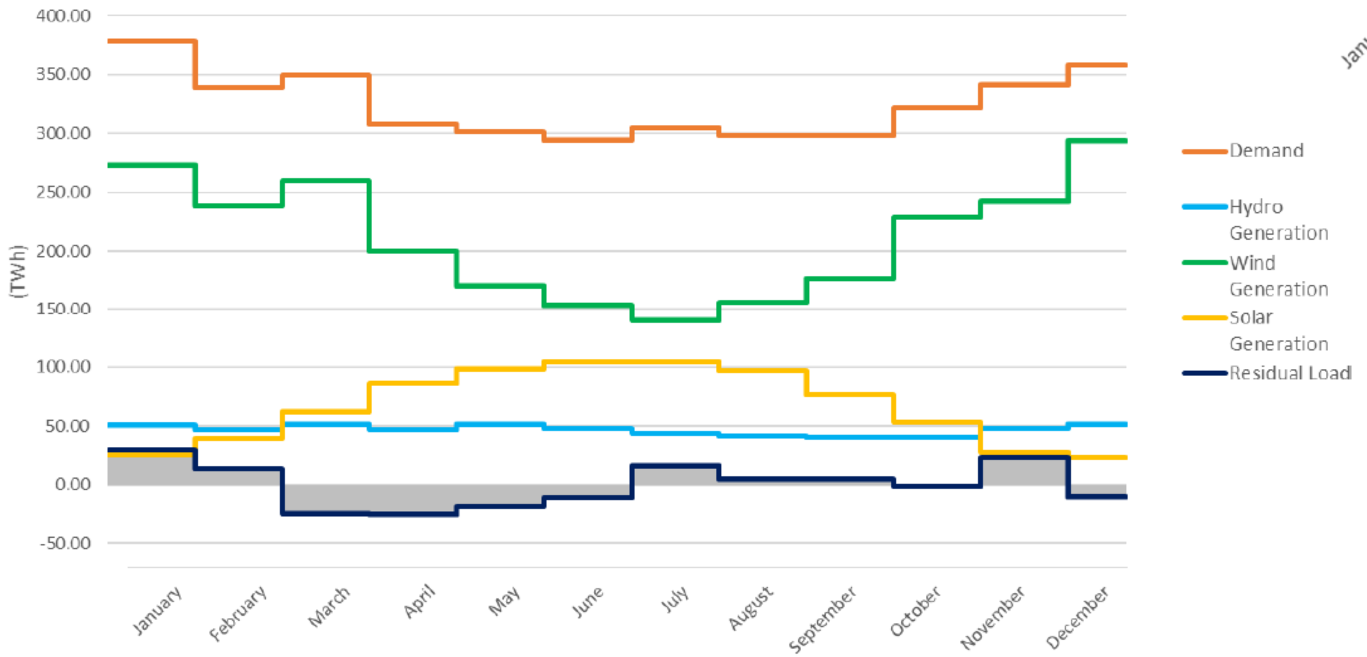




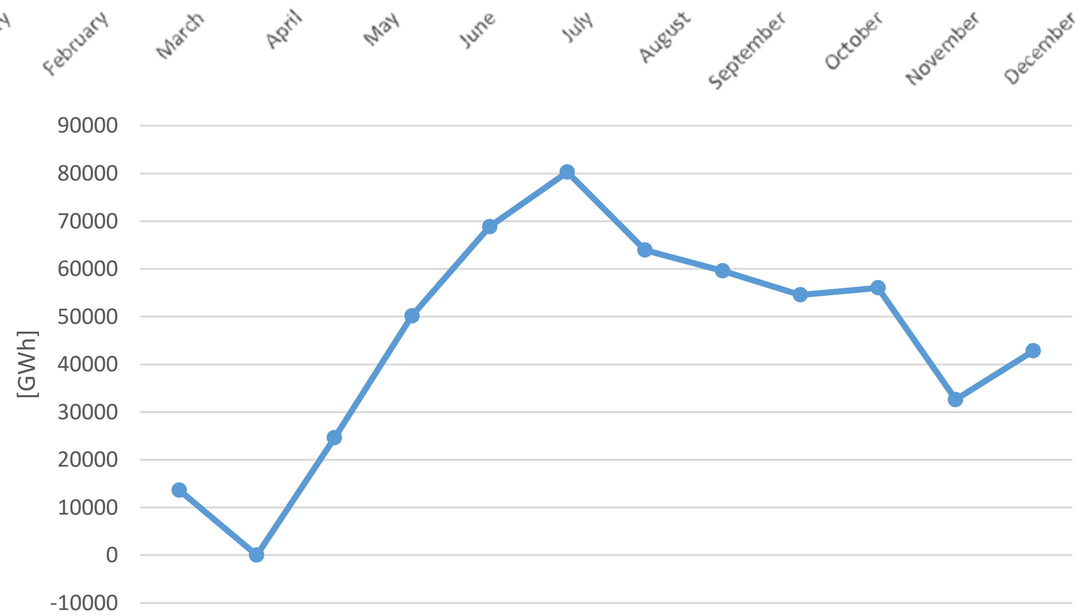
- Pumped hydro will solve storing problem for 2.8 TWh surplus electricity (yellow) generated when PV or wind resources were available and not needed for consumption. This stored energy will supply consumption when needed.
- Hydro and natural gas power plants will generate the additional 22 TWh annual energy needed.
- Any additional solar & wind with extra storage capability will reduce use of natural gas power plants

Resource adequacy at European level

European Residual Load for the ENTSO-E 100% RES 2040 scenario



Storage needs (monthly basis)



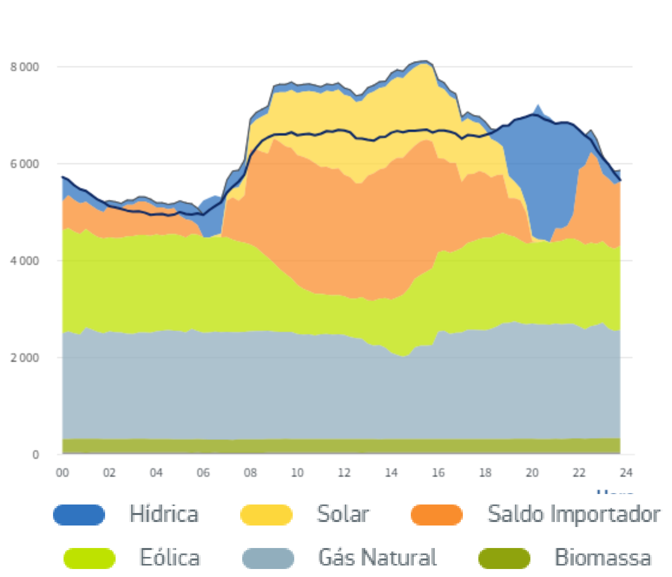
EU27 + UK + Norway Annual Storage Needs

Source: CEER, Long-Term Storage, CEER "European Green Deal" White Paper series (paper I), 15 February 2021, https://www.ceer.eu/documents/104400/7158746/C21-FP-48-03_CEER+White+Paper+on+long-term+storage-2.pdf/531b1a53-8bc9-7eb2-6da4-1e866fd867a0

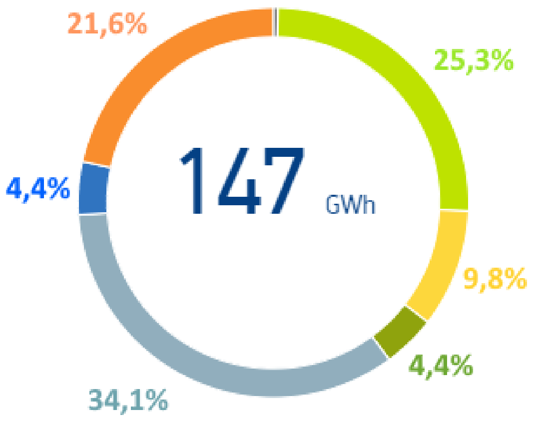
The “Residual load”

04 JUL 23

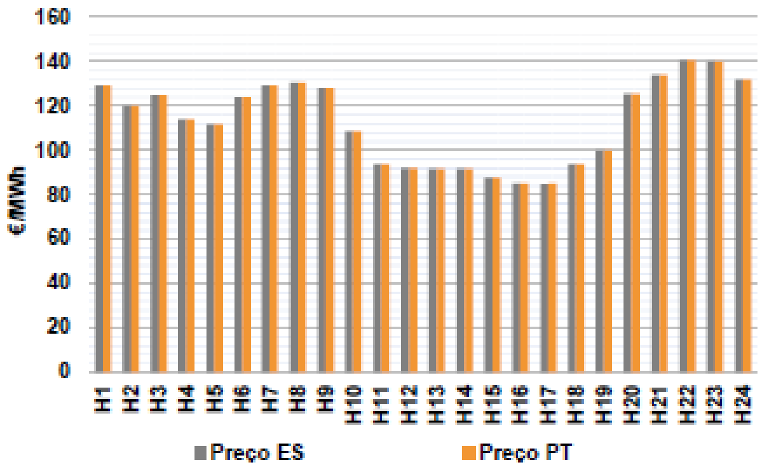
Power demand by generation technology in Portugal



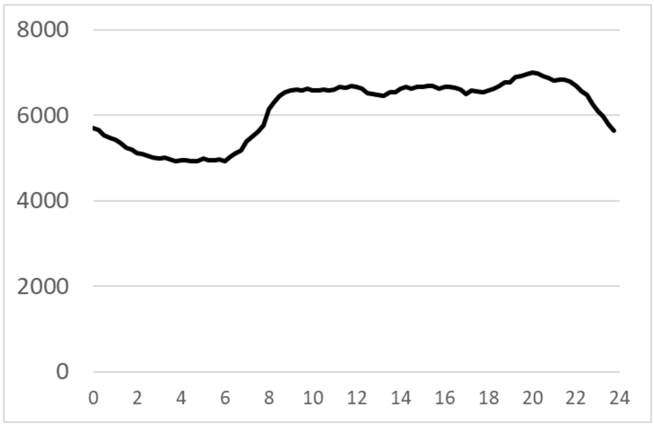
Daily consumption



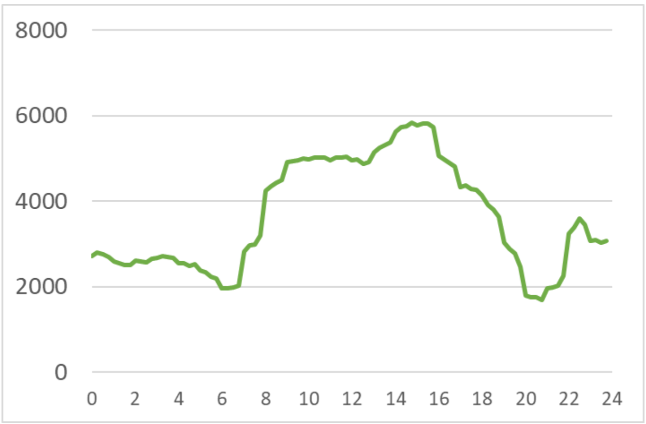
Day ahead market price (€/MWh)



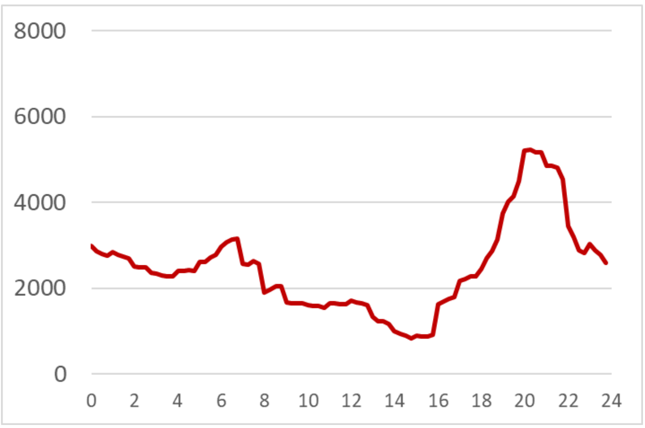
Power demand (MW)



Wind + Solar (MW)



Residual Load (MW)



The "Residual load"

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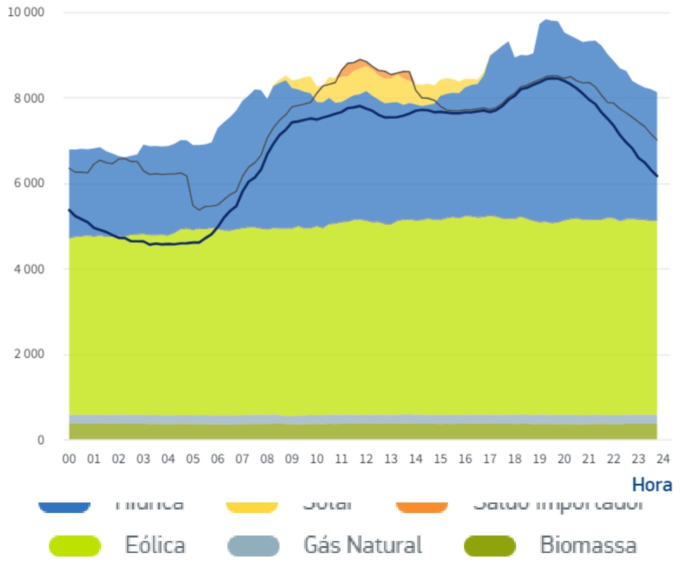
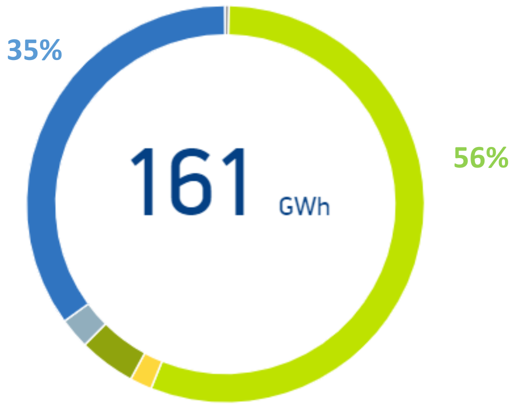
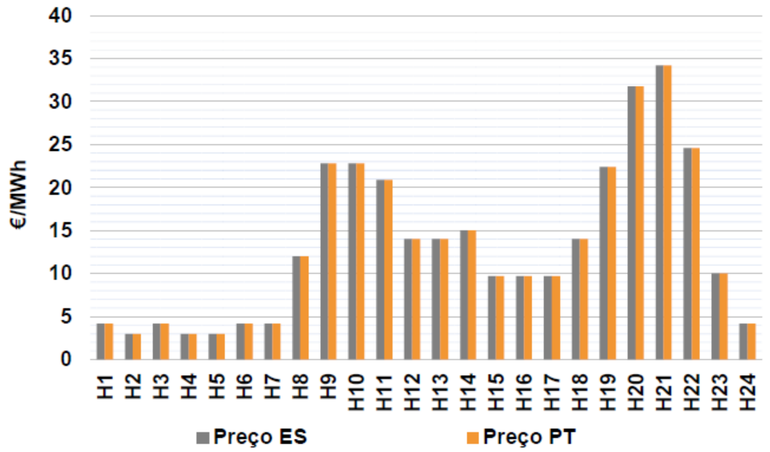
Power demand by generation technology in Portugal



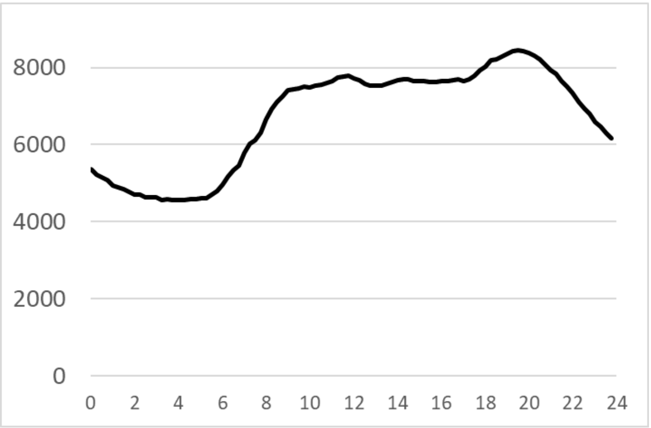
Daily consumption



Day ahead market price (€/MWh)

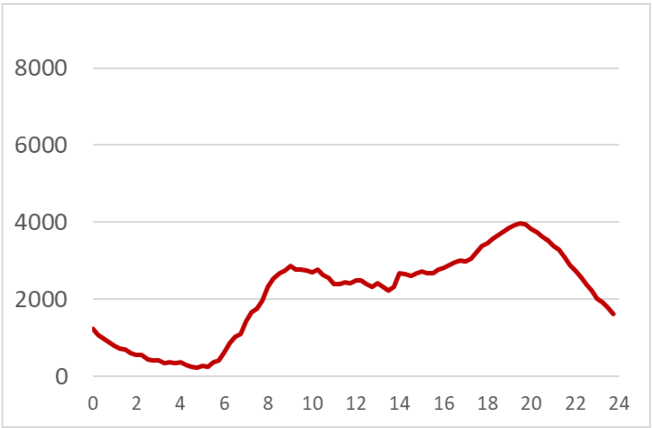


Power demand (MW)

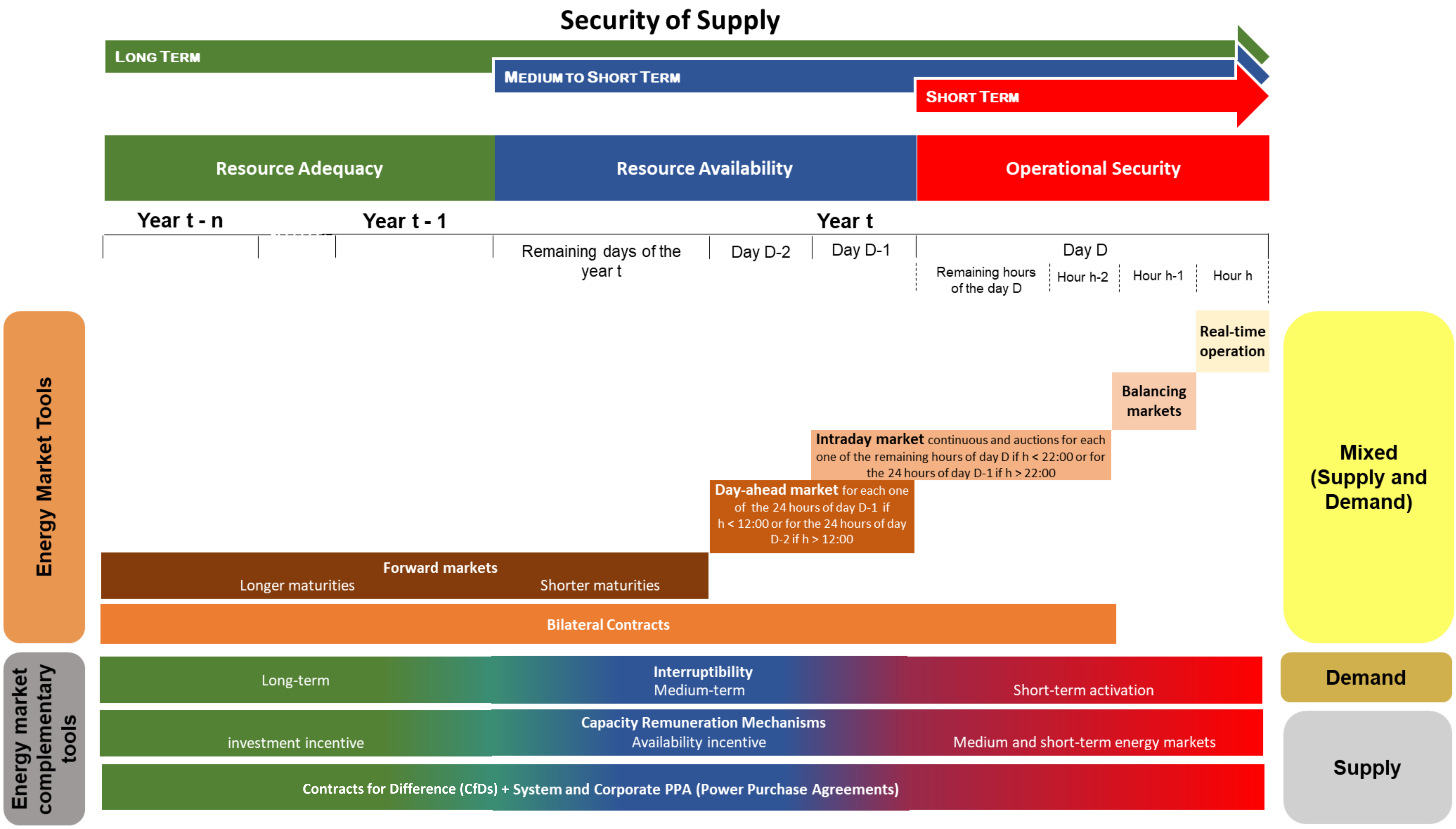


Wind + Solar (MW)

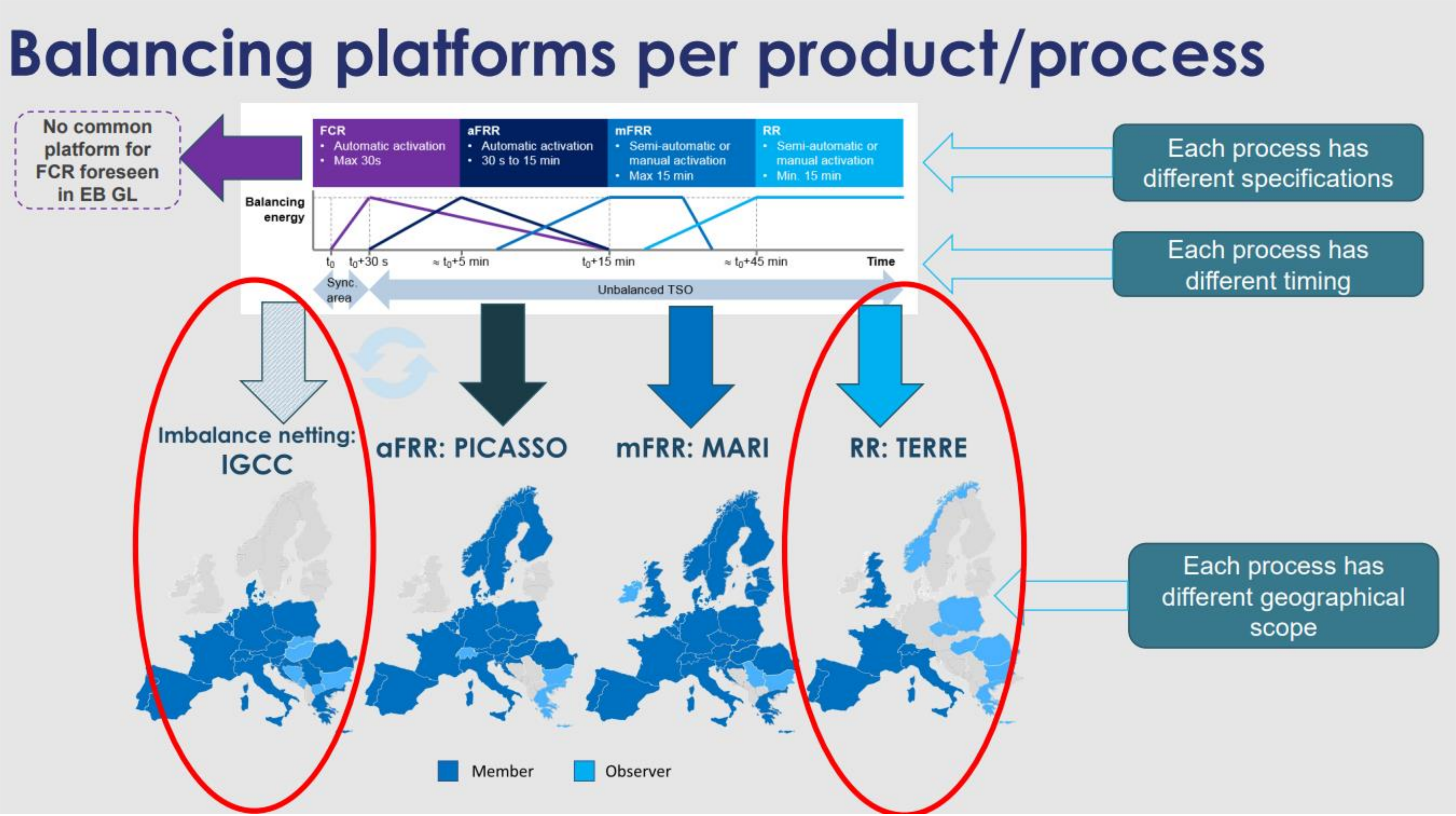
Residual Load (MW)



Tools for the future



European balancing market tools



Source: REN

IGCC: Integrated Grid Control Cooperation FCR: Frequency Containment Reserve FRR: Frequency Restoration Reserve RR: Replacement Reserves

Cooperation between European TSOs on imbalance netting

IGCC – **I**ntegrated **G**rid **C**ontrol **C**ooperation

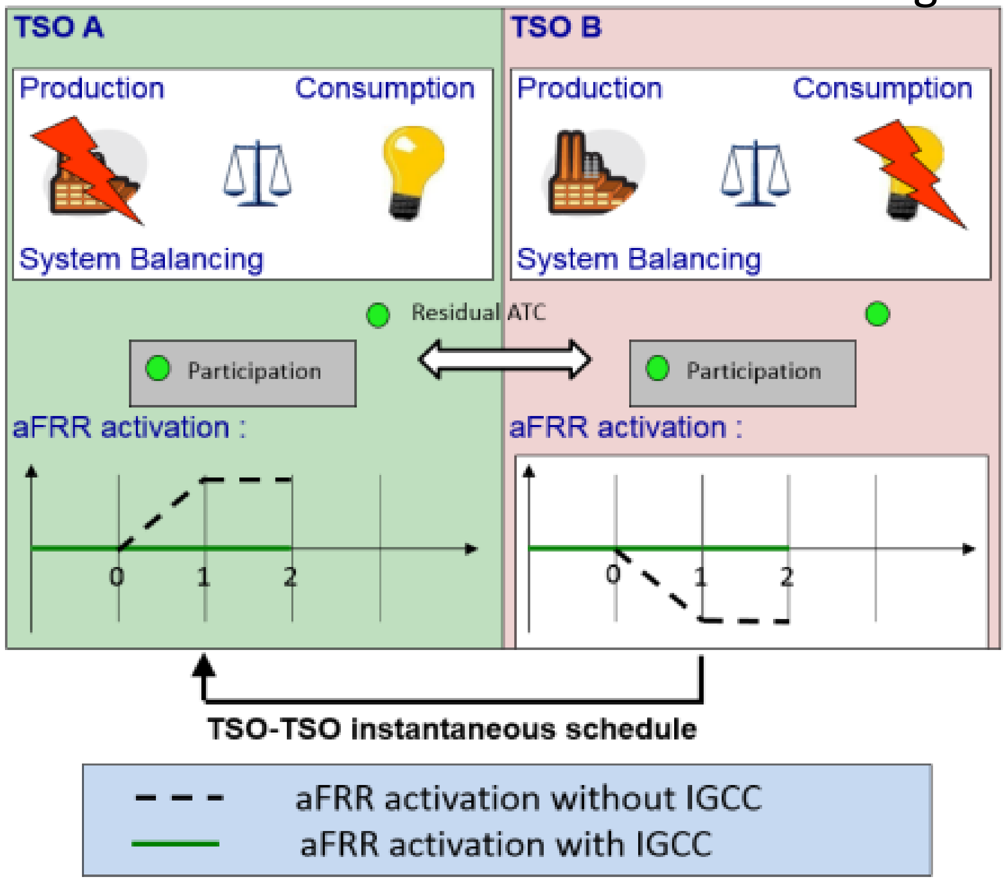
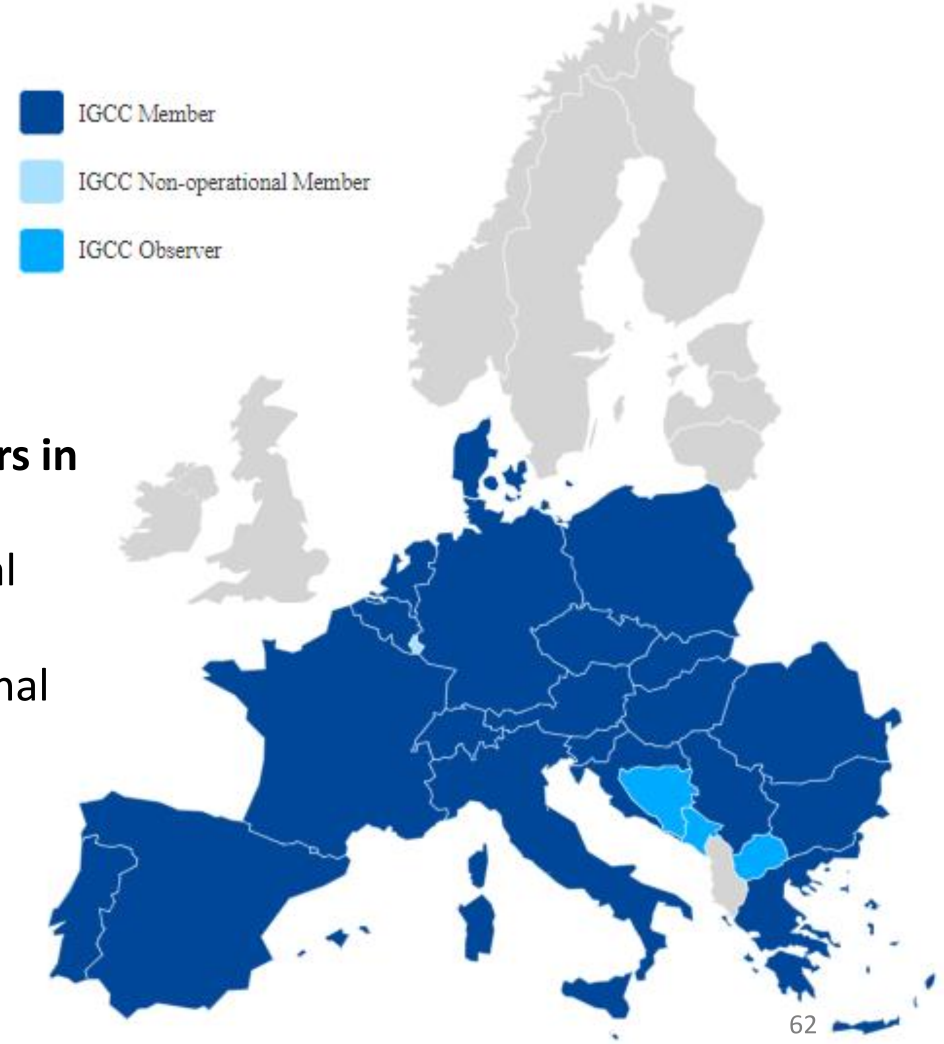


Figure 1-2: Operating principle of imbalance netting

aFRR – automatic Frequency Restoration Reserve

IGCC has 27 members in total, out of which:

- 23 are operational Members
- 1 is non-operational and
- 3 are observers



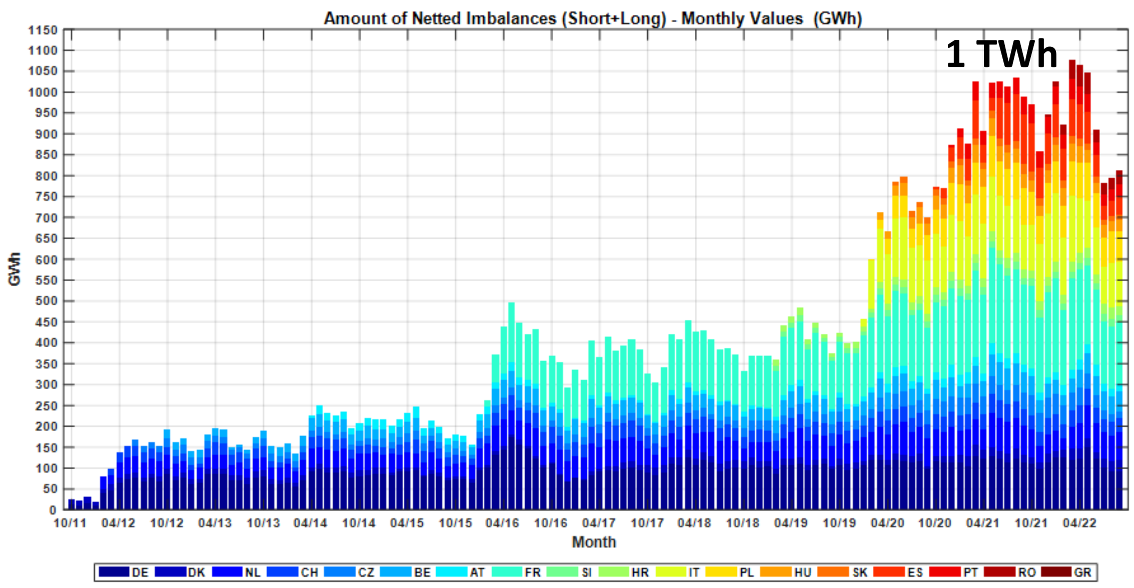
Source: ENTSO-E

Cooperation between European TSOs on imbalance netting

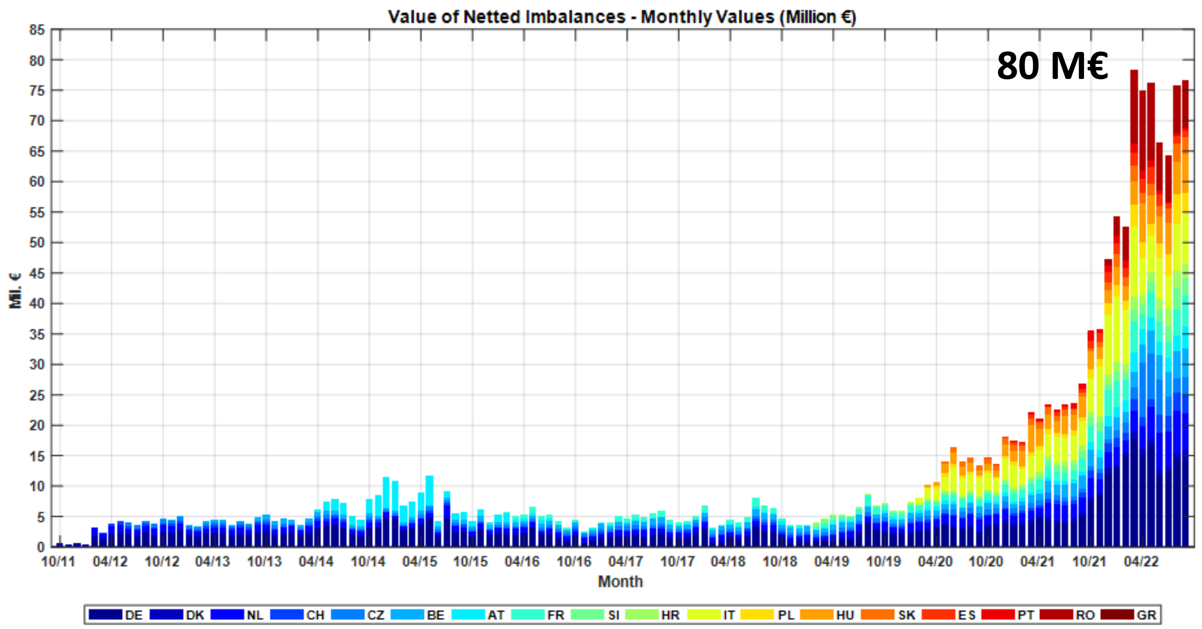
IGCC – **I**ntegrated **G**rid **C**ontrol **C**ooperation

Effectiveness of IGCC
• The quarterly energy savings in Q1 2022 reached 3021 GWh • The value of quarterly savings in Q1 2022 reached 185.27 million € • New record of monthly value amount of netted imbalances: more than 1 TWh in March 2022 • New record of monthly value amount of netted imbalances: nearly 80 million € in March 2022 (due to high energy prices) • Aggregated savings: surpassed 1 billion € savings.

Monthly Volumes of Netted Imbalances



Monthly Value of Netted Imbalances



Recap: key market challenges

Deep penetration of renewables

	Until 2030 (?) SRMCg > LRMCg	Beyond 2030 (?) SRMCg < LRMCg
Energy (decarbonised)	1)	? 3)
Capacity (firmness)	! 2)	? 4)

Regulatory intervention might be expected

SRMCg – Short Run Marginal Cost of generation technology

LRMCg – Long Run Marginal Cost of generation technology

CCGT – Cycle Combined Gas Turbine generation technology

DSM – Demand Side Management

VoLL – Value of Lost Load

1) With lower long run marginal costs, market delivers desired policy objectives toward decarbonisation with cost reduction for consumers.
2) How to monetise CCGT firm capacity in an environment where capacity usage is expected to decrease? Can volatility of market prices help?
3) With higher long run marginal costs, how can you monetise renewables to substitute the remaining fossil fuel generation to reach net zero (RES cannibalisation effect)? Can the carbon price provide a solution? Is further support for RES needed?
4) Use of controllable flexibility resources (short + medium term), can be monetised (reflecting the shadow price of DSM or of curtailment (VoLL)), but with such high price volatility how to address:
   - Consumer preferences for price stability?
   - Financing for technologies with fixed capacity costs?

Will short-term market prices in the future provide sufficient revenues to ensure that sufficient back-up capacity and flexibility resources stay in or enter the market? Can trends of Power-to-H_2 and H_2-to-Power help?


LET'S
DISCUSS

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Poll (5)

And now, do you expect the integration of renewable energy into the electricity system to be challenging for the system operator?

a) Yes, very challenging, putting the electricity system at risk

b) Yes, but the challenge is manageable

c) Not particularly challenging, given the current technologies

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RECAP

How can we reach a net zero society by 2050?

Renewable energy sources are the key!

Their capacity is growing and their cost is decreasing

But, how to integrate them?

Non-dispatchability and variability are a challenge

Cost business case improving rapidly. Several support and investment options!

Regulatory challenges and opportunities for our energy markets

Several market tools available to integrate massive RES

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THANK YOU VERY MUCH FOR YOUR ATTENTION!
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