AURORA ENERGY RESEARCH

Draft final version

Capacity remuneration mechanisms in Europe

January 2025

Prepared for BEYOND FOSSIL FUELS

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Executive Summary

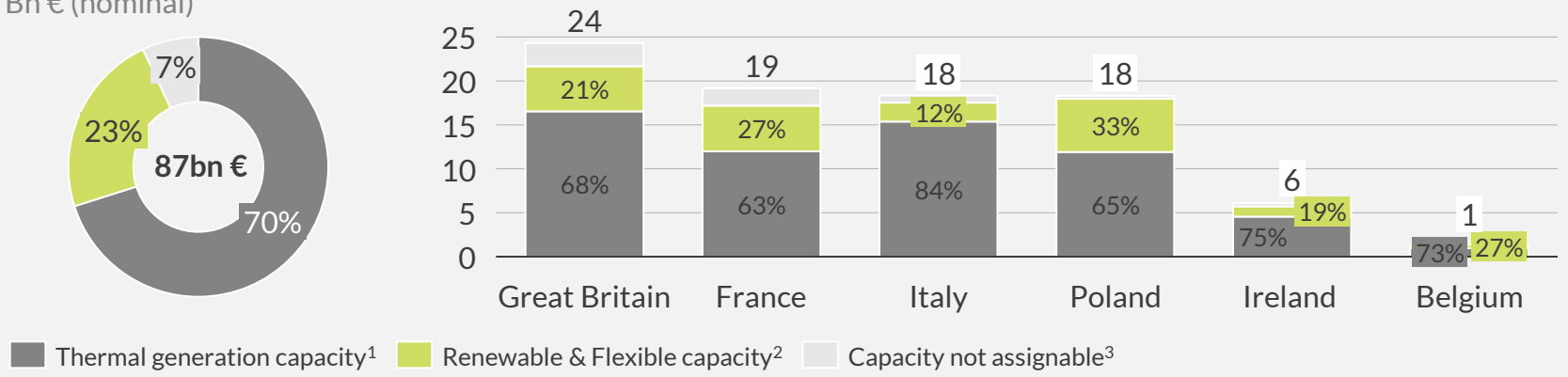
Background:

- Aurora Energy Research was engaged by Beyond Fossil Fuels (BFF) to conduct research on Capacity Remuneration Mechanisms (CRMs) in Europe, with a focus on the contracts and payments allocated to gas-fired assets.
- The analysis resulted in two products:
  - An **Excel database** of gas-fired power plants and projects in Europe for which payments are or have been contracted under CRMs (to be published by BFF).
  - **This report** that analyses CRMs qualitatively and provides a quantitative stock-taking of existing CRMs based on the data collected in the database and other data sources.

- **Strong wind and solar buildout** and **the phase-out of CO_2-intensive power generation** are **essential to meet Europe's renewable energy and climate targets.**
- The **increasing share of volatile renewable power requires more system flexibility** to ensure supply security. This can be achieved by **further integrating the European power system**, **leveraging demand-side response**, and **accelerating the buildout of flexible and dispatchable assets.**
- **Some European countries use capacity markets** (CMs) to ensure sufficient levels of flexible and dispatchable capacity.
- So far, **thermal technologies like gas, coal, and nuclear plants have received more than two-thirds of the 87bn € in capacity payments allocated**[1], with gas-fired assets accounting for about half.
- **30GW** of **new gas-fired capacity has been contracted in CMs over the last decade**. Many of these **assets' technical lifetimes extend beyond targets for climate neutrality.** To reach them, **action must be taken**, as options like CCS[2] or a fuel switch to hydrogen are costly, require planning and infrastructure, and exhibit other remaining uncertainties.
- **Even if CMs are security of supply measures,** they should therefore be **designed to incentivise emission-free options** like batteries and **enforce emission rules for thermal assets** to meet climate targets.

Aggregated contracted capacity market payments in Europe by category from 2015 to 2024

Bn € (nominal)



1) Allocated payments include payments secured for delivery of capacity in the future, i.e. payments that have not yet been made. 2) Carbon capture and storage. 3) Includes Gas, Coal, and Nuclear. 4) Includes storage assets, renewables and demand-side response (DSR). 5) Technology category not inferable from source data.

Sources: Aurora Energy Research, regional power system operators (Terna, RTE, SEM-O, NESO, PSE, Elia).

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I. What are CRMs and how should they be designed?

II. Stock taking of CRMs in Europe

III. Appendix

Rapid decarbonisation of the electricity system is the key to achieving renewable energy and climate targets

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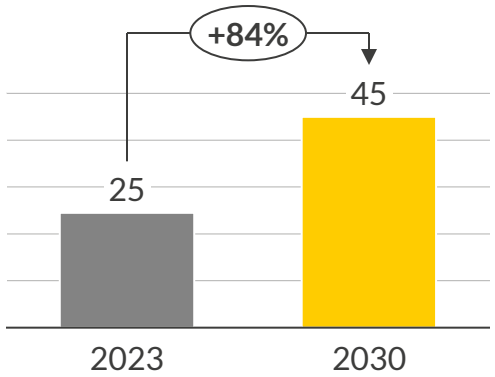
1 The EU targets a 45% renewable share in energy consumption by 2030 and Net Zero emissions by 2050, some countries have set more ambitious goals.

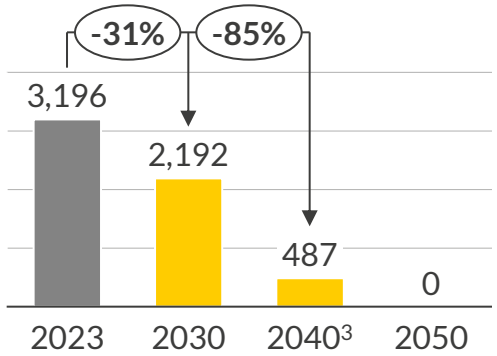
2030 EU renewable energy target[1]

%

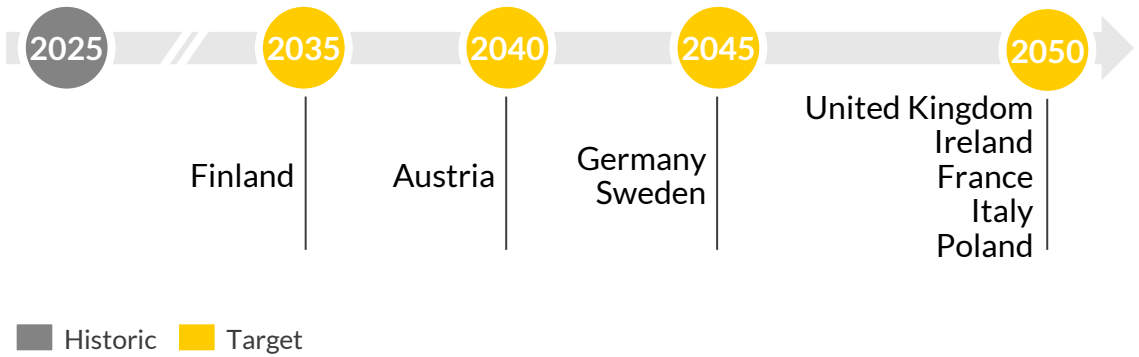


EU emission reduction targets[2]

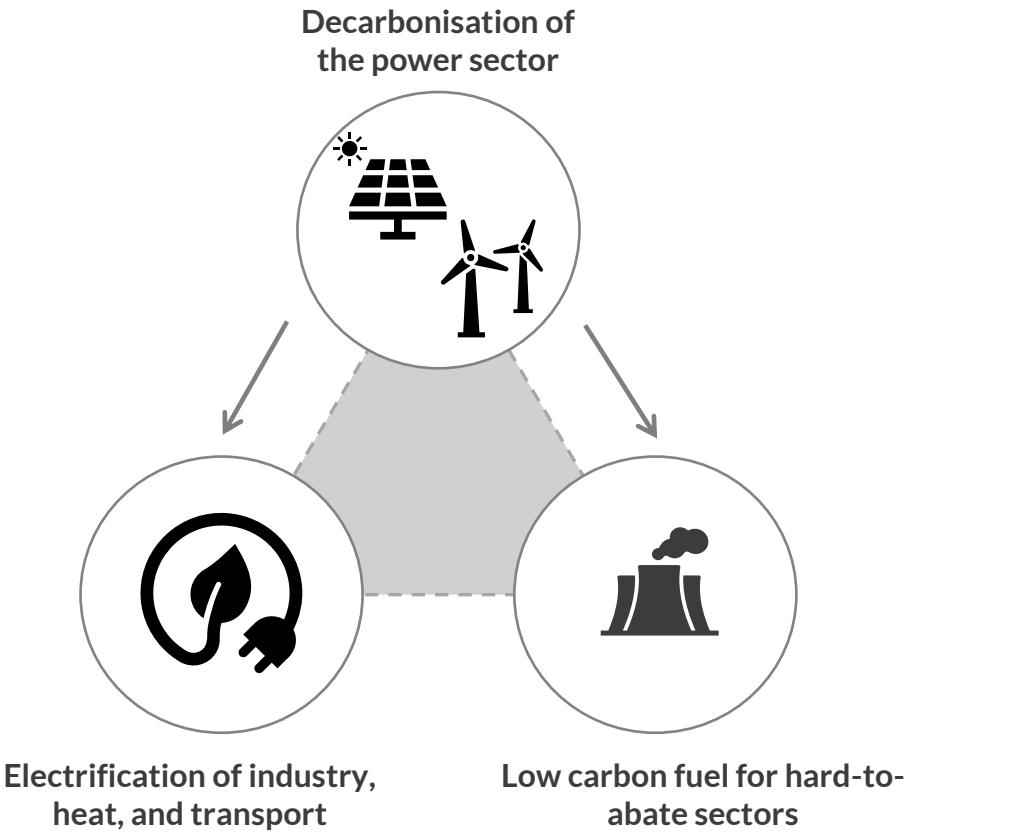
$MtCO_2e$



National Net Zero targets of selected European countries



2 A decarbonised power system is a requirement for achieving emission reductions through electrification in other sectors.



1) Renewable share in final energy consumption. 2) The targets were defined as % reductions compared to 1990 emission levels. The 2030 target corresponds to a 55% reduction to 1990, the 2040 target to 90%. 3) Non-binding recommendation of the European Commission.

´Sources: Aurora Energy Research, European Commission

The decarbonisation of the power system is inherently interrelated with energy affordability and security of supply

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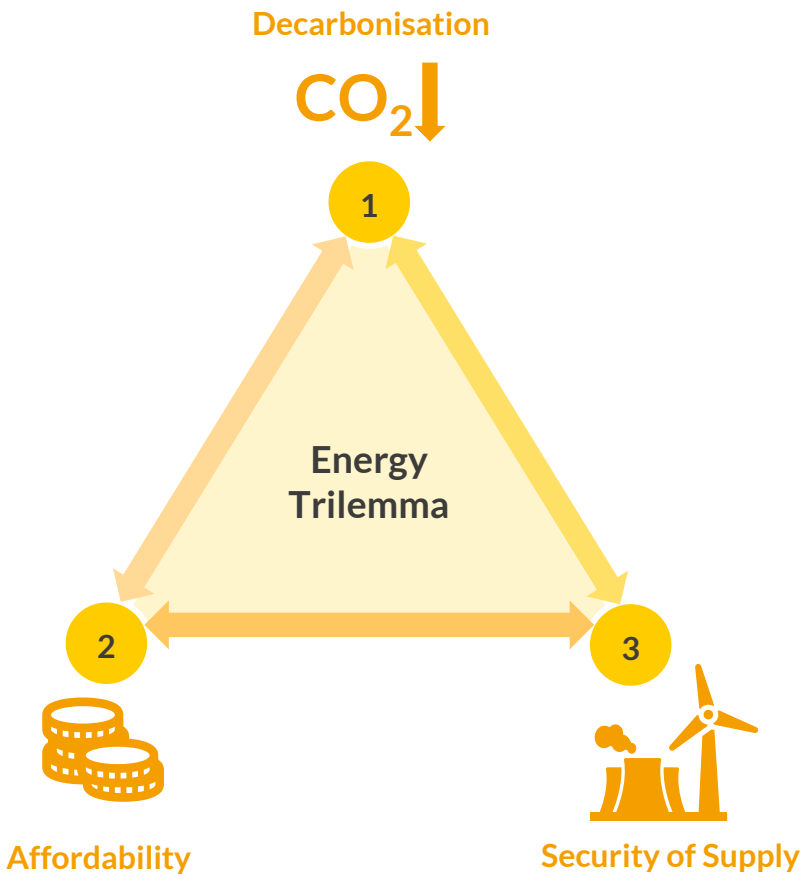
The energy trilemma sets the framework…



…for how decarbonisation policy will affect prices and security of supply

1 ↕ 2

Decarbonisation and affordability

- Renewable energy sources (RES) like wind and solar are characterized by low marginal costs, **more renewables buildout will thus reduce power prices for consumers** per se.
- **Countries that fall behind in phasing out fossil assets, might be faced with higher power prices**, as carbon pricing increases the marginal costs of carbon-emitting plants.
- Fuel costs are a major part of thermal power plant operation costs, so **commodity price shocks significantly affect power prices in fossil fuel-dependent systems** and can cause **price spikes**. The 2022 energy crisis highlighted this impact.
- **RES generation costs and power prices are (on average) more predictable** as with fossil generation, as marginal costs are independent from gas, coal, and carbon markets.

1 ↕ 3

Decarbonisation and security of supply

- **More generation from local RES** reduces reliance on imports of fossil fuels, and can **foster energy independence and energy security**.
- At the same time, the combination of variable RES and the **phase-out fossil generators requires a high level of interconnectivity between national power systems[1] and the deployment of new flexible and dispatchable assets** (e.g. energy storage, H2 turbines, etc.) to ensure power demand can be met in every hour of the year.

1) Power market coupling and the optimal utilisation and buildout of new grid infrastructure such as interconnectors.

Source: Aurora Energy Research

Many countries in Europe have chosen strategic reserves or capacity markets to ensure the provision of dispatchable capacity

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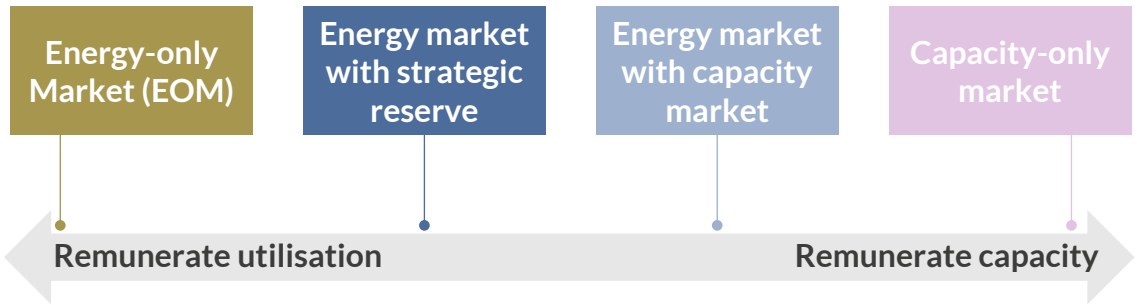
Power market design

- Strategic reserves (SRs) or capacity markets (CMs) are elements of power market design through which asset owners are paid to make capacity available for a given period in the future. Unlike in an EOM, producers receive remuneration regardless of whether generation occurs or not. Deep dive



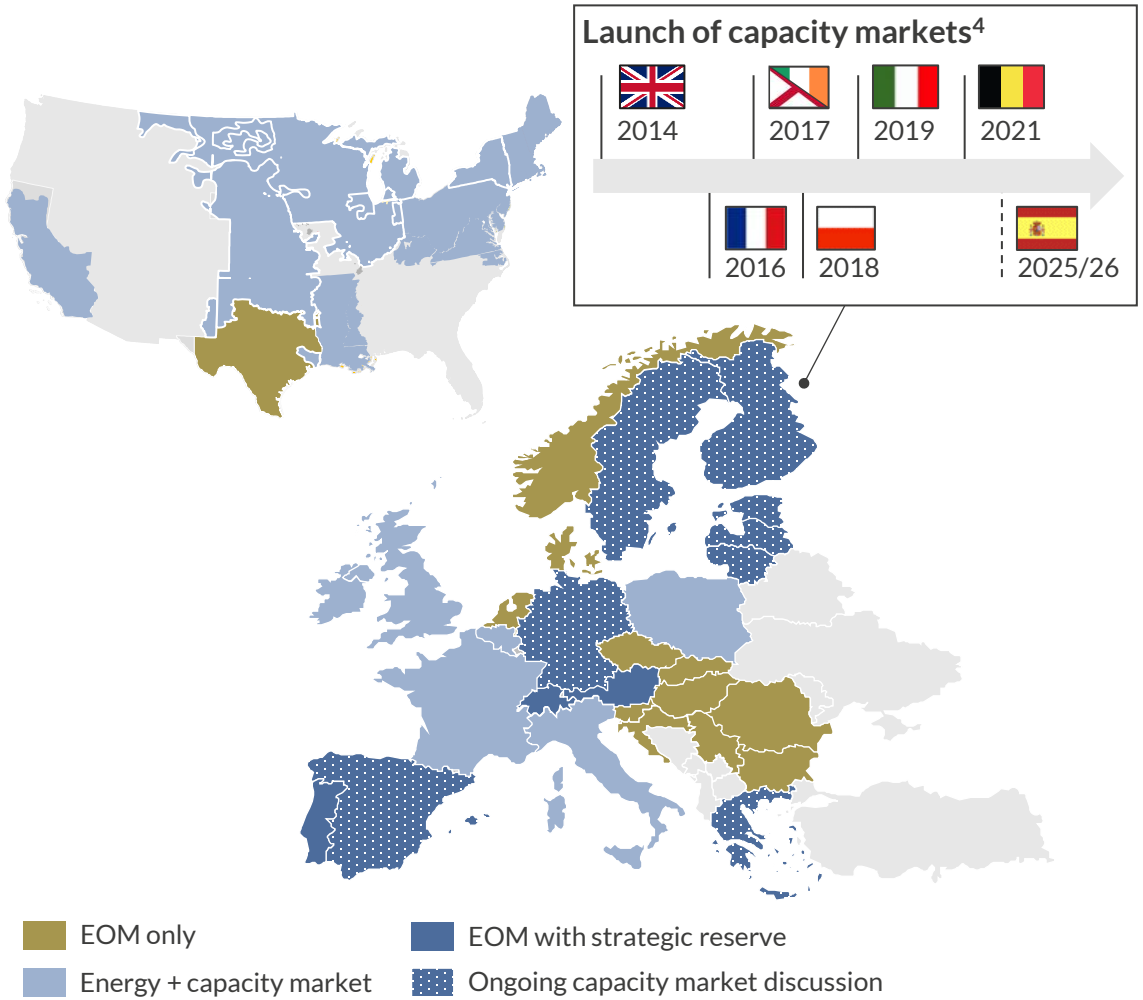
- An increasing number of countries have set up CMs over the past decades:

In Europe, CMs have been implemented in six countries. Eight more countries, including Germany, are currently debating the introduction of a CM[2].

Capacity markets in the US have been in place for longer, most of them were established in the early 2000s and have undergone or are undergoing reforms[3].

Deep dive See next slide for a comparison of SRs and CMs

Examples of power market designs in the US and Europe



1) Energy-Only Market. 2) Spain is currently at an advanced stage and undergoing consultation of its proposed CM. 3) Due to capacity changes and extreme weather events causing supply issues, several of the US Capacity Markets are currently undergoing revisions of their capacity accreditation and procurement target. 4) Refers to year in which CMs became/are expected to become operational and hold auctions.

Source: Aurora Energy Research

Deep dive

In contrast to a strategic reserve, capacity markets allow for plants to participate in wholesale power markets

Can contracted plants participate simultaneously in the capacity mechanism and in the wholesale or other ancillary markets?

No → **Strategic reserve**

Reserve / **Wholesale market**

- So far mostly used to extend lifetime of existing plants, but reserve capacity can in principle also be provided by new-build plants.[3]

Yes → **Capacity market**

Who sets the capacity target?

Central authority[2] → **Central capacity market**

- It is ensured that security margins are met for the region

UK | Italy | Poland | Belgium

Each supplier → **Decentral capacity market**

- Power suppliers and large consumers must secure capacity certificates issued by generators and DSR.
- Capacity certificates are then traded on market or bilaterally.

France

Legend:

Reserve plant only receiving capacity payment

Plant only receiving wholesale market[1] revenue

Plant receiving wholesale[1] and capacity mechanism revenue

1) Wholesale market mentioned as this is usually the biggest revenue stream. Other markets like ancillary services or balancing markets are also applicable. 2) In most cases, the TSO is the central authority. 3) One example of a reserve that was created through the buildout of new power plants is the grid reliability reserve (*besondere Netztechnische Betriebsmittel*) in Germany.

Sources: Aurora Energy Research

To comply with climate targets, CRMs should incentivise the buildout of carbon-free flexibility and contain emission thresholds

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! For CRMs to be compatible with climate targets, 2 general principles should be followed:
Realising the potential of clean flexibility options and setting emissions criteria for fossil power plants

Principles	Capacity market	Strategic reserve
Openness to clean flexibility options	▪ Currently, it is harder for smaller, decentral assets like demand-side flexibility to access CMs compared to large thermal assets. – For instance, there is a risk that clean energy solutions like storage, demand-side flexibility and other 'non-standard assets' are derated too strongly, impeding their competitiveness compared to fossil assets. ▪ Barriers to access for clean technologies should be removed to make it easier for these assets to access CMs, alongside other policy measures to boost uptake. – Enabling the self-declaration of de-ratings for non-standard assets is one way of lowering the barrier to entry. This option is already used in the Belgian CM.	▪ As power plants in the reserve do not participate in the market, the combination of EOM + reserve generally favours investments in non-fossil flexibility, like demand response and batteries.
Emissions criteria for fossil assets	▪ While CMs are mainly a security of supply and not a decarbonisation measure, they should be designed in line with climate targets, with tightening emissions rules – pushing fossil fuels out of the power mix over time, and prioritising investment in clean, fossil-free sources of flexibility.	▪ In general, the emissions caused by fossil plants will be lower than in a CM because the plants are only dispatched during scarcity events. ▪ Still, emission limits can help support fossil-free solutions.

Additional incentives and policy support, alongside capacity markets, may also be appropriate to rapidly boost investment in carbon-free flexibility options such as demand flexibility, batteries, long duration energy storage and interconnectors. Additional policies will also be needed to support a managed phase-out of gas plants.

Source: Aurora Energy Research

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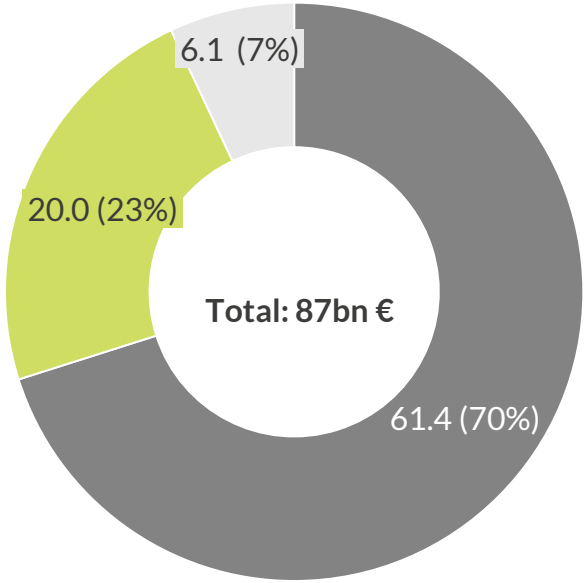
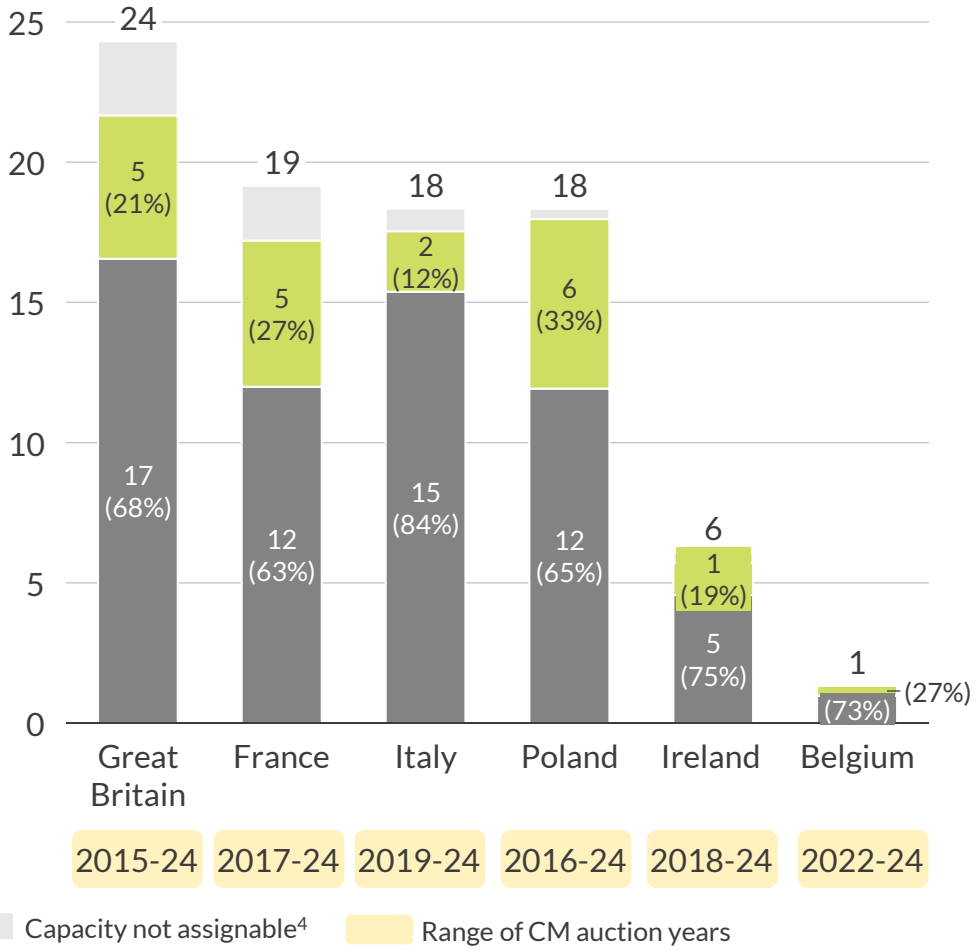
87bn € are estimated to be allocated in European capacity markets to date, more than two-thirds of which to thermal generators

Contracted payments under capacity markets in Europe[1]
Bn € (nominal)



Contracted payments by capacity market region[1]
Bn € (nominal)



Disclaimer

The figures shown were calculated using assumptions and estimations based on available public data. The information available does not always allow a clear allocation of capacity market capacities and payments (see Appendix)

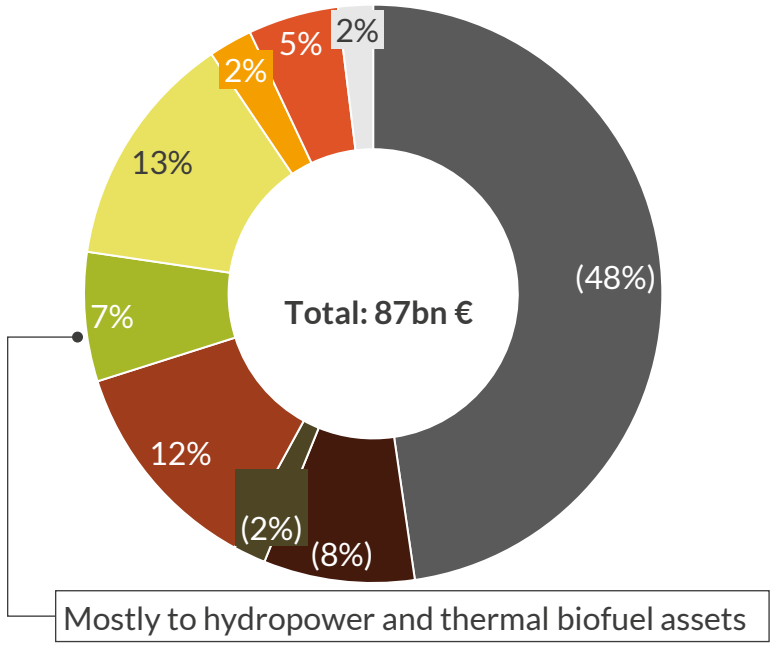
Thermal generation capacity[2] | Renewable & Flexible capacity[3] | Capacity not assignable[4] | Range of CM auction years

- Based on an analysis of capacity market auction results, close to 90bn € in capacity payments have been contracted in Europe.
  - We calculate payments by combining data on awarded de-rated capacities with auction strike prices.[5]
- Thermal generators have so far been the main beneficiaries of capacity payments and make up for at least 70% of contracted payments.
- Renewable and flexible assets account for 23% of contracted payments.
- The distribution of payments by capacity category is similar across regions with thermal generators accounting for nearly two-thirds or more in all 6 regions.

1) Not accounting for Strategic reserves. Includes payments secured for the provision of capacity in the future, i.e. payments that have not yet been made. 2) Includes Gas, Coal, and Nuclear. 3) Includes storage, renewables and demand-side response. 4) Technology category not inferable from source data. . 5) See slide 17 in the Appendix for a detailed explanation of the approach.
Sources: Aurora Energy Research, Regional system operators (Terna, RTE, SEM-O, NESO, PSE, Elia)

Gas-fired assets have thus far been the main recipients, accounting for almost half of all contracted payments

Contracted payments under capacity markets in Europe[1]
Bn € (nominal)



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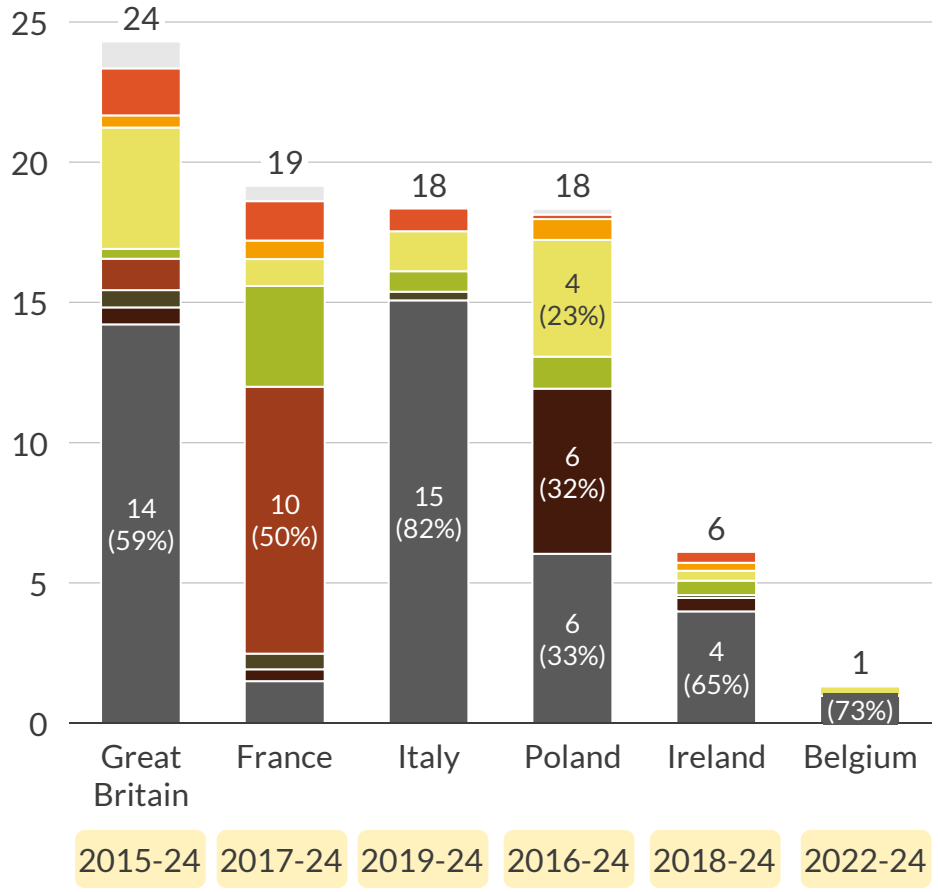
Bn € (nominal)



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1) Contracted payments include payments secured for delivery of capacity in the future, i.e. payments that have not yet been made. 2) E.g. oil-fired and waste incineration plants 3) Includes Hydropower, Biogas and Biomass. 4) Demand-side response 5) Capacities procured from neighbouring regions via interconnectors. 6) Technology not inferable from source data.
Sources: Aurora Energy Research, Regional system operators (Terna, RTE, SEM-O, NESO, PSE, Elia)

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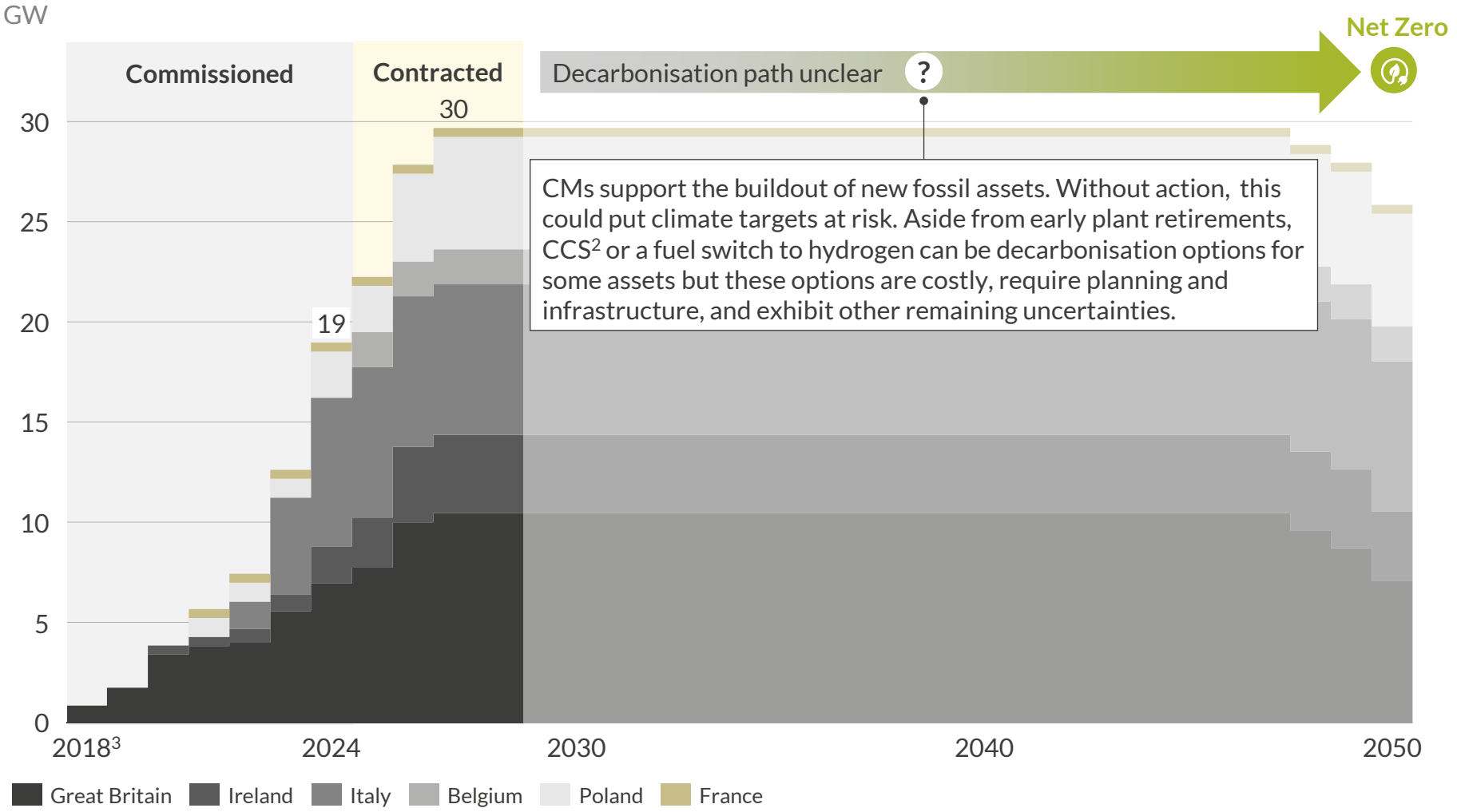
- Gas-fired power plants have been the main recipients of capacity market payments in Europe to date, accounting for roughly half of all contracted payments.
- Except for France, gas-fired generation makes up the single largest technology group by payments contracted in all other regions with a capacity market in place.
  - The share of payments to fossil generators is the lowest in France due to its large fleet of nuclear power plants.
- The Polish CM accounts for both the largest shares of payments to coal-fired generators and storage assets. The latter is driven by the two most recent auctions in which batteries secured most of the capacity under long-term contracts.

CMs have supported ~ 30GW of new gas power plants, action must be taken such that climate goals can be achieved

Installed capacity of new-build gas power plants that have been awarded in capacity markets, by region[1]



1) Assuming an asset lifetime of 30 years. Assuming that all projects that have received a CRM contract for delivery in future years will be realised. 2) Carbon capture and storage 3) 2018 was the first year in which capacity was delivered under the capacity market in GB.

Sources: Aurora Energy Research, Regional system operators (Terna, RTE, SEM-O, NESO, PSE, Elia)

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- To date, around 19GW of new-build gas-fired power plants with capacity market contracts have been installed in Europe and a further 11GW of projects have been awarded a contract for delivery in the next 3 years.
  - This is a snapshot to date – the capacity could increase further in upcoming auction rounds of existing CMs and as more countries plan to introduce CMs.
- While CMs are a security of supply and not a decarbonisation measure, they should be designed in line with climate targets, with tightening emission rules.
- Investments in clean, fossil-free flexibility sources should be accelerated (both within and alongside CMs) to reduce the need for new fossil capacity.

The first capacity market in Europe was introduced in the Great Britain in 2015, France, Ireland, Poland, and Belgium have followed since

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Capacity market key facts

	Great Britain	Ireland	Italy	France	Poland	Belgium
Type of CM	Central	Central	Central	Decentral	Central	Central
Earliest – latest auction	2015 – 2024	2018-2024	2019-2024	2017 - 2024	2016-2024	2022 - 2024
Earliest – latest delivery year	2018-2027	2018-2027	2022-2026	2017-2026	2021-2029	2025-2028
Number of auctions	17	14	5	14	29	5
Total capacity procured across all auctions	492GW	68GW	210GW	919GW	94GW	10GW
Range of auction prices	885 – 86,206 €/MW	40,646 – 147,580 €/MW	56,160-75,000 €/MW	8,090 - 46,410 €/MW	31,628 – 85,691 €/MW	15,694 - 53,402 €/MW
Price building mechanism	Pay as clear	Pay as clear	Pay as clear, price cap for existing units	Pay as clear (EPEX Spot auctions)[1]	Pay as clear, price cap for existing units	Pay as clear, price cap for existing units
Total allocated payments	24.3bn €	6.1bn €	18.4bn €	19.2bn €	18.3bn €	1.3bn €
Share of payments to thermal vs. renewable & flexible capacity	68% vs. 21%	75% vs. 19%	84% vs. 12%	63% vs. 27%	65% vs. 33%	73% vs. 27%

Sources: Aurora Energy Research, Regional system operators (Terna, RTE, SEM-O, NESO, PSE, Elia)

As new builds receive long-term contracts in most capacity markets, some gas-fired power plants are subsidised until the 2040s

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Key information on the role of gas-fired power plants in European capacity markets

	Great Britain	Ireland	Italy	France	Poland	Belgium
Number of identified[1] plants with CM contracts	126	37	37	20	16	22
Gas-fired capacity procured across all auctions (% of total procured capacity)	293GW (60%)	44.7GW (66%)	136GW (81%)	62GW (7%)	8GW (9%)	9GW (90%)
Nameplate capacity of new builds (incl. plant projects) that have been procured in CMs	10.4GW	3.9GW	7.5GW	0.4GW	5.6GW	1.7GW
Payments allocated to gas plants (% of total allocated payments)	14.2bn € (59%)	4.0bn € (65%)	13.8bn € 84%)	1.5bn € (8%)	6.7bn € (65%)	1.9bn € (73%)
Maximum contract length for new-builds	15 years	10 years	15 years	N/A[2]	17 years	15 years
Range of years that contracts cover	2018 - 2042	2018-2037	2022-2039	2017-2026	2021-2043	2025-2042

1) This refers to the number of plants covered in the Excel database on gas-fired power plants with CM contracts. Due to lack of data availability, this database does not capture all existing CM contracts. See here for more information. The French 1-year capacity market does provide long-term contracts for new-build assets. Long-term tenders for the development of new capacities were held in 2019, but no gas-fired capacity was procured in these tenders.

Sources: Aurora Energy Research, Regional system operators (Terna, RTE, SEM-O, NESO, PSE, Elia)

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A complete matching of CM contracts at plant level is not possible in all regions due to limited data transparency

Region / data availability	Comments
Belgium	▪ Plant-level data available for procured capacities. ▪ Only the average and maximum bid prices are available per auction, thus payments at plant level can only be approximated based on average bid prices.
Germany	▪ Plant-level data available for procured capacities under the Strategic reserve (*Kapazitätsreserve*). ▪ The auctions for the Strategic reserve are pay-as-clear, allowing a for a precise calculation of payments at the plant level. ▪ For the grid reserve (*Netzreserve*) and special grid reserve (*Besondere netztechnische Betriebsmittel)*: Data available for procured capacities at plant level, but no data available on payments.
France	▪ Plant level data on certified capacities is only available for plants >100 MW. ▪ Payments at the plant-level cannot be derived at a reasonable level of accuracy because capacity guarantees can be traded in multiple auctions per year and over the counter. The registry tracking all transactions is only accessible to market participants.
Great Britain	▪ Plant-level data published for procured capacities. ▪ The auctions are pay-as-clear, allowing a for a precise calculation of payments at the plant level.
Ireland	▪ Plant-level data available for procured capacities. ▪ The auctions are pay-as-clear, allowing a for a precise calculation of payments at the plant level.
Italy	▪ Plant-level data on procured capacities is only available for new-builds plants. ▪ Only aggregated data is available for the capacities procured from existing plants, not allowing for an unambiguous identification of plants that received CM contracts. ▪ The auctions are pay-as-clear, allowing a for a precise calculation of payments allocated to new-build plants.
Poland	▪ Plant-level data on procured capacities is published, but without naming the respective technology or asset class, which makes it difficult to identify the assets. ▪ The auctions are pay-as-clear, allowing a for a precise calculation of payments allocated to new-build plants.

Decreasing data availability

Source: Aurora Energy Research

Due to the lack of data transparency, the robustness of the calculated payments varies from region to region.

Region / accuracy	Approach used to compute the aggregate capacity market payments	Limitations
Belgium	▪ (1) For each contract: Multiplication of the procured capacity with the capacity-weighted average bid price for each auction and the respective contract duration. (2) Sum over all auctions and split by technology group.	▪ As only the average price is known, the distribution of payments by technology cannot be calculated precisely. With regards to gas-fired plants, this leads to an underestimation of payments as they generally enter the auctions with higher bids than other technologies.
France	▪ For each year since the introduction of the capacity market: Multiplication of the certified capacities by technology group with the capacity-weighted average price of the EPEX Spot auctions for French capacity guarantees in that year.	▪ As it is not known which and how many of the certificates issued were sold and at what price, neither the total number of payments nor the breakdown by technology can be calculated precisely.
Great Britain, Ireland	▪ (1) For each contract: Multiplication of the procured capacity with the specific auction price and the respective contract duration. (2) Sum over all auctions and split by technology group.	▪ Only minor limitations due to unregistered cancellations of capacity contracts.
Italy	▪ For new-builds: Multiplication of the procured capacities by technology group with the capacity-weighted average bid price for each auction and the respective contract duration. ▪ For existing plants: Split the procured capacity into technology types, then multiplication by the respective auction price.	▪ The published auction results for existing power plants are only roughly broken down by asset type (renewable, flexible, other). The more granular breakdown by technology carried out for the analysis is inferred based on assumptions and own research, which can impact the accuracy of the payment shares by technology.
Poland	▪ Estimation based on a tracker of aggregated contracted capacities maintained by Aurora and auction prices published by the regulator.	▪ The published auction results do not provide information on the asset type. The technology split is inferred based on own research and assumptions, impacting the accuracy of the payment shares by technology.

Source: Aurora Energy Research

Because of the limited availability of plant-level data, the database of gas assets published alongside the report does not cover all payments

- As a separate deliverable to this report, Aurora compiled an Excel database of gas-fired power plants and plant projects in Europe for which capacity-based payments are or have been contracted under CRMs.
- To create this database, available primary and secondary data sources for CM auction results were matched with the existing BFF database of gas-fired power plants in Europe, using asset names, asset capacities, and operator names as identifiers.
- Due to the missing data at plant level in some countries and the large quantity of individual capacity market contracts overall, it was not possible to match all CM contracts to power plants in the BFF database.
- Therefore, the sum of the capacity payments compiled in the Excel database is lower than the figures shown for gas-fired power plants in this report.
- In total, the database covers 76% of the total estimated allocated payments to gas-fired power plants. The below table provides an overview of the level of completeness per country and the reasons for the shortfall of payments covered.

Country	Level of completeness	Reason for the shortfall of CM payments covered in the database
Great Britain	74% 	▪ Large quantity of small assets that could not all be identified and matched with (or added to) the BFF database within the scope of the project.
Ireland	97% 	▪ Large quantity of small assets that could not all be identified and matched with (or added to) the BFF database within the scope of the project.
France	55% 	▪ Only payments for plants with certified capacities of >100 MW can be matched due to limited data transparency.
Italy	43% 	▪ Only CM contracts of new-build plants can be matched due to limited data transparency for existing assets.
Poland	100% 	
Belgium	100% 	

Source: Aurora Energy Research

Details and disclaimer

Public Report
Capacity remuneration mechanisms in Europe

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