AURORA ENERGY RESEARCH

REDACTED VERSION

European Offshore Wind Markets Attractiveness Report

June 2023

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This is a redacted sample of the European Offshore Wind Markets Attractiveness Report.
If you are interested in the full report, contact Alex Hutcheson, (alex.hutcheson@auroraer.com).

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- Judge your **market entry** perfectly and only develop the best sites
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This report assesses the attractiveness of investing in offshore wind across 21 European markets, based on eight metrics

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The overall market attractiveness score for each European offshore wind market covers three categories and nine metrics, which are set out in detail in this report.

Categories and metrics	Weighting	Rationale	Source of data
Market size, composition & outlook	[redacted]%		
1 Offshore wind deployment to 2030	[redacted]%	Indicates expected future market size in the medium term	Aurora fundamental modelling*
2 Offshore wind buildout in 2022	[redacted]%	Reflects recent trends and market activity	Aurora analysis*
Policy environment	[redacted]%		
4 Announced offshore wind targets in 2030	[redacted]%	Demonstrates policy ambition for RES deployment over the medium term	Aurora analysis*
5 Historical auctioned capacity	[redacted]%	Indicates track record of government support for RES build-out (and market size for refinancing)	Aurora analysis*
6 Planned auctioned offshore wind capacity until 2030	[redacted]%	Indicates expected government support for RES build-out	Aurora analysis*
7 Policy risks - support schemes, permitting, grid connection	[redacted]%	Reflects effect of key policy and regulatory risks on project development	Aurora analysis*
Project economics	[redacted]%		
8 Indicative fully merchant net IRR for project starting in 2030	[redacted]%	Captures the commercial viability of new build fully merchant projects for final investment decisions in 2030 to capture cannibalisation effects in different markets	Aurora fundamental modelling*

(*) Detailed country data available in Aurora's Power and Renewables Market subscriptions.

Source: Aurora Energy Research

The most attractive European market for Offshore Wind is xxxx [redacted], followed by [redacted] and [redacted]

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Installed capacity of offshore wind across Europe currently stands at 28 GW, making up 4.2% of total installed capacity. It is projected to grow by more than 3x to reach 114 GW by 2030, requiring EUR 197 billion CAPEX investment.

Rank	Region	Market attractiveness score
1		
2		
2		
3		
4		
4		
5		
6		
7		
8		

Market size, composition & outlook | Policy environment | Project economics

Top markets

[redacted]

Markets to watch

[redacted]

Source: Aurora Energy Research

If you are interested in the full report, contact Alex

Due to changes in policy and project economics [redacted], [redacted], [redacted] and [redacted], [redacted] and the [redacted] have improved in the ranking

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Region	Current rank (Apr-23)	Previous rank (Mar-22)	Highlights and key changes
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	10		

Source: Aurora Energy Research

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Decarbonisation efforts to date have driven strong growth in offshore wind capacity, rising to [redacted] GW over the last decade

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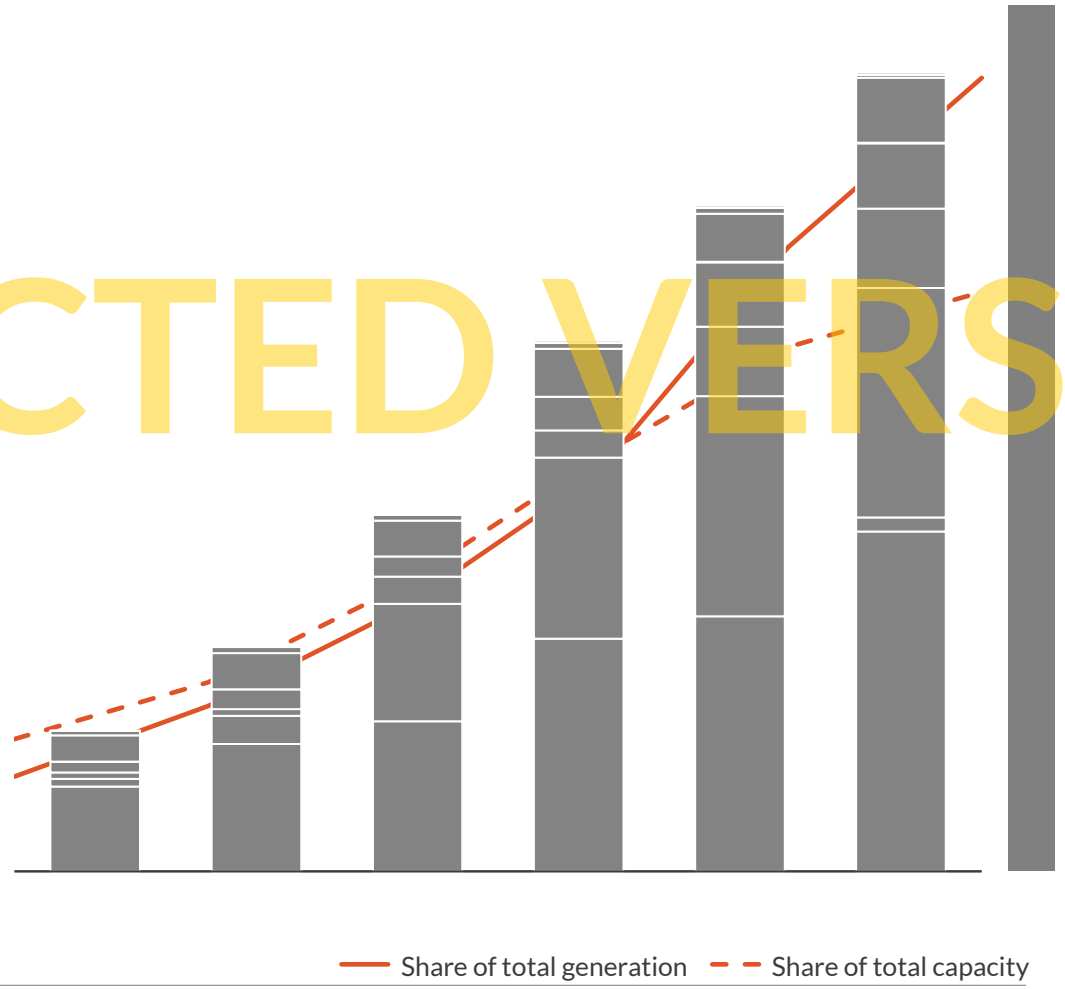
Key drivers of offshore wind deployment

1. Increasing power demand
[redacted]
2. Policy support
[redacted]
3. Rising commodity prices
[redacted]
4. Thermal phase out
[redacted]
5. Supply chains
[redacted]

Installed offshore wind capacity in Europe
GW

Share of total capacity/ generation
%



[redacted]

Sources: Aurora Energy Research, European Commission, IEA, IRENA

Renewable capacity buildout is driven by four key factors which cut across government policy and market forces

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1 Increasing power demand

+

+

–

[redacted]

2 Strong policy support and Government ambition

+

–

[redacted]

More in section IV of this report.

3 Rising fuel and carbon prices

+

+

–

[redacted]

4 Phase out of thermal capacity

+

–

[redacted]

Source: Aurora Energy Research

If you are interested in the full report, contact Alex

Power demand in Europe is expected [redacted]

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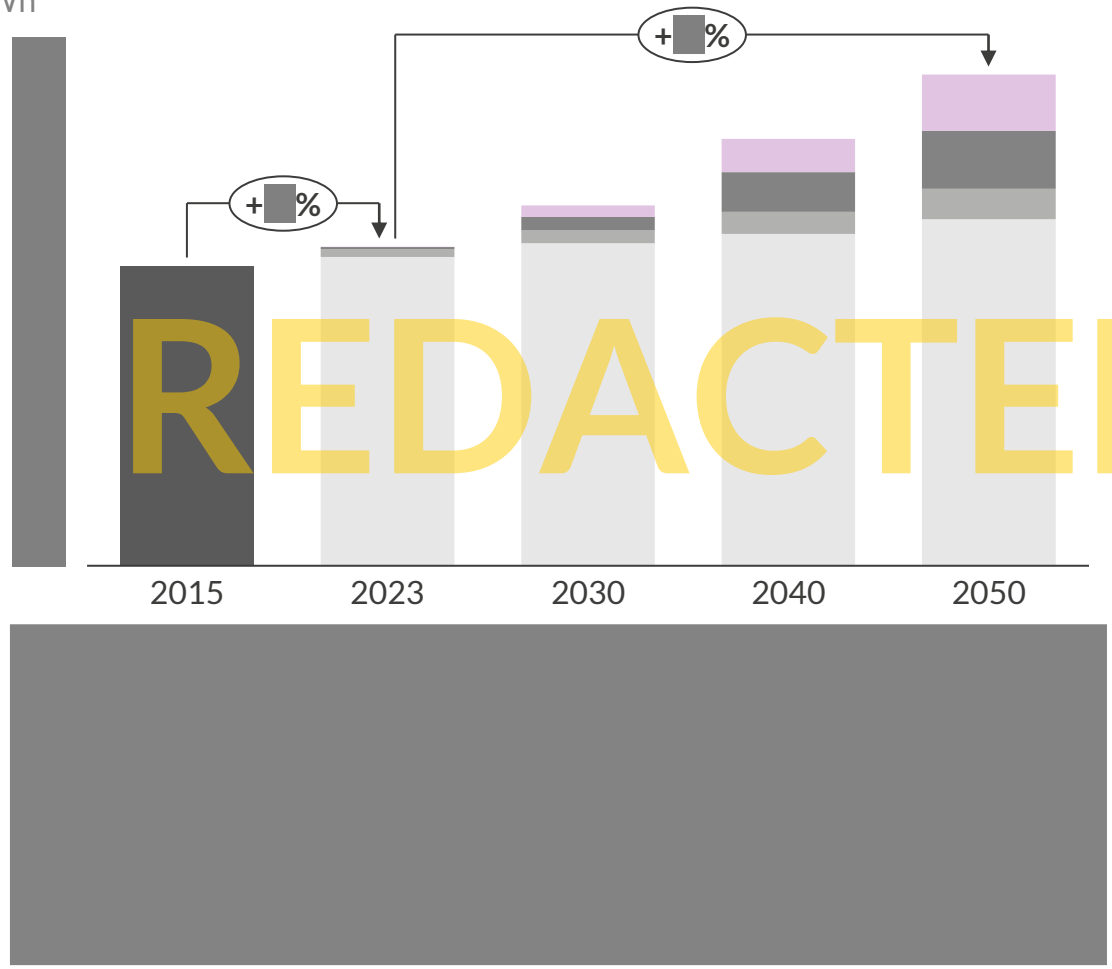
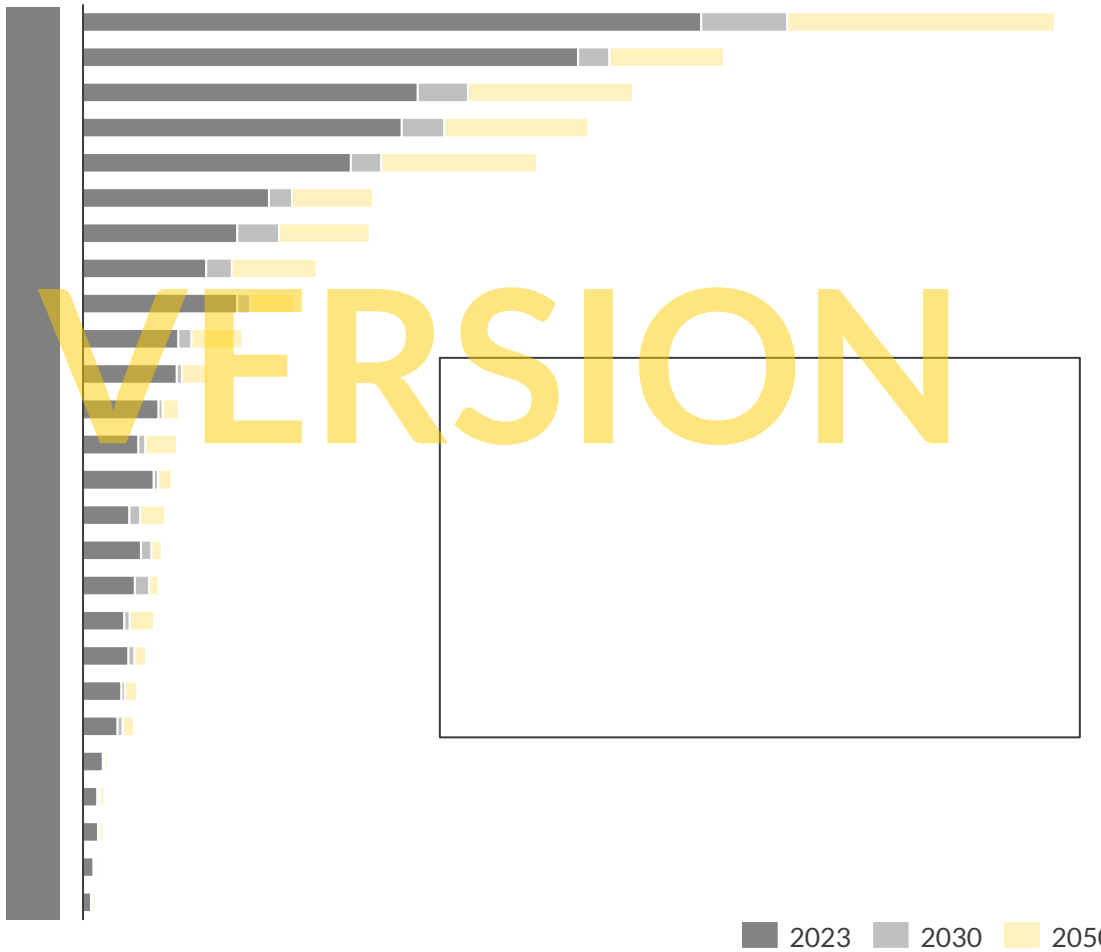
Annual power demand in Europe[1]

TWh



Annual country level power demand*

TWh



(*) Detailed country data available in Aurora's Power and Renewables Market subscriptions

Sources: Aurora Energy Research, Eurostat

If you are interested in the full report, contact Alex

The key objectives of EU's energy policy framework have long supported the buildout of renewables across the continent

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2 Strong policy support

Part of over-arching EU Green Deal framework

	2014	2019	2021	2022
	Climate & Energy Framework 2030	Clean Energy for all Europeans	'Fit for 55'	REPowerEU
Key objectives				
Emissions reduction				
Renewables deployment				
Energy efficiency				
Security of supply				

Sources: Aurora Energy Research, European Commission

The REPowerEU plan details key measures to reduce Russian reliance and fast forward the clean transition across five main pillars

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2 Strong policy support

[redacted]

1. Boost energy savings

[redacted]

2. Diversify energy imports

[redacted]

3. Reduce fossil fuel use

[redacted]

4. Smart investment

[redacted]

5. Reinforce preparedness

[redacted]

Sources: Aurora Energy Research, European Commission

Despite falling gas prices in the 2020s, rising carbon prices increase the costs of thermal assets, which [redacted]

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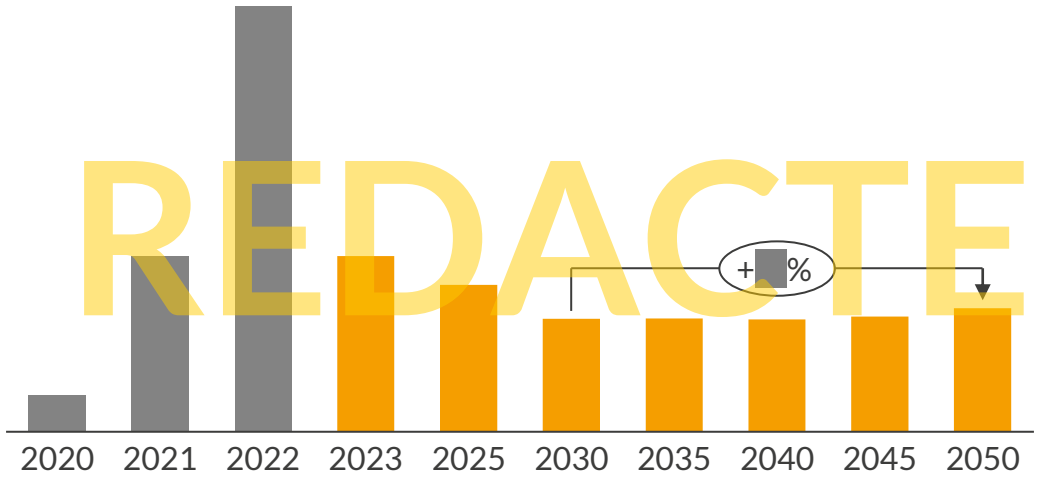
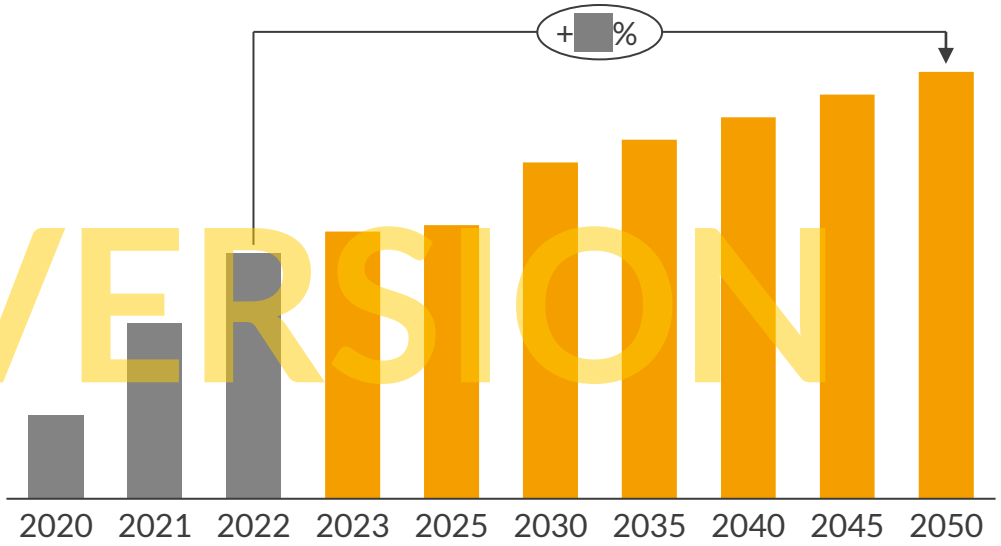
3 Rising fuel and carbon prices

Gas prices[1]
EUR/MWh (real 2022)



Carbon prices[1]
EUR/tCO_2 (real 2022)



[redacted]

Aurora April 2023 Central forecast[2] Historical

Source: Aurora Energy Research

Increasing buildout of low cost renewables will push thermal plants out of merit more often

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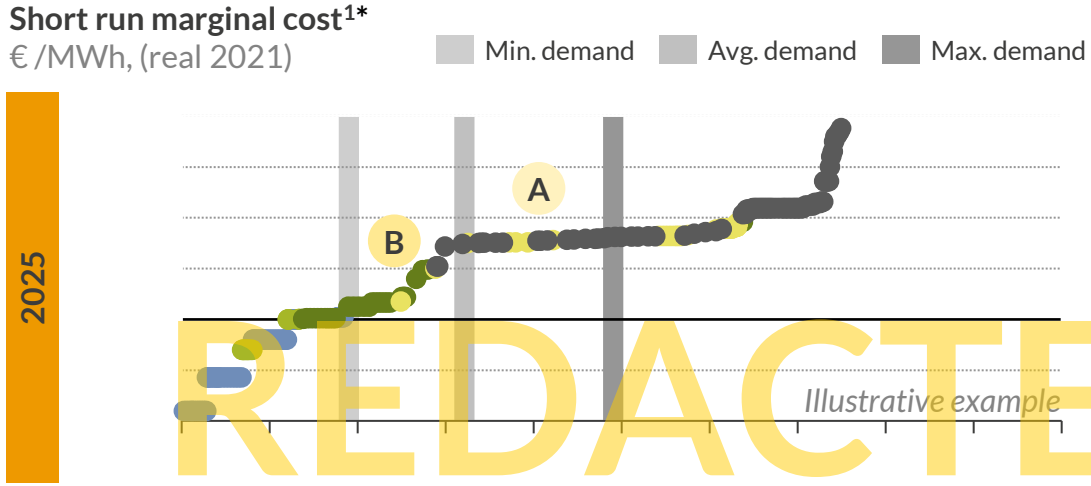
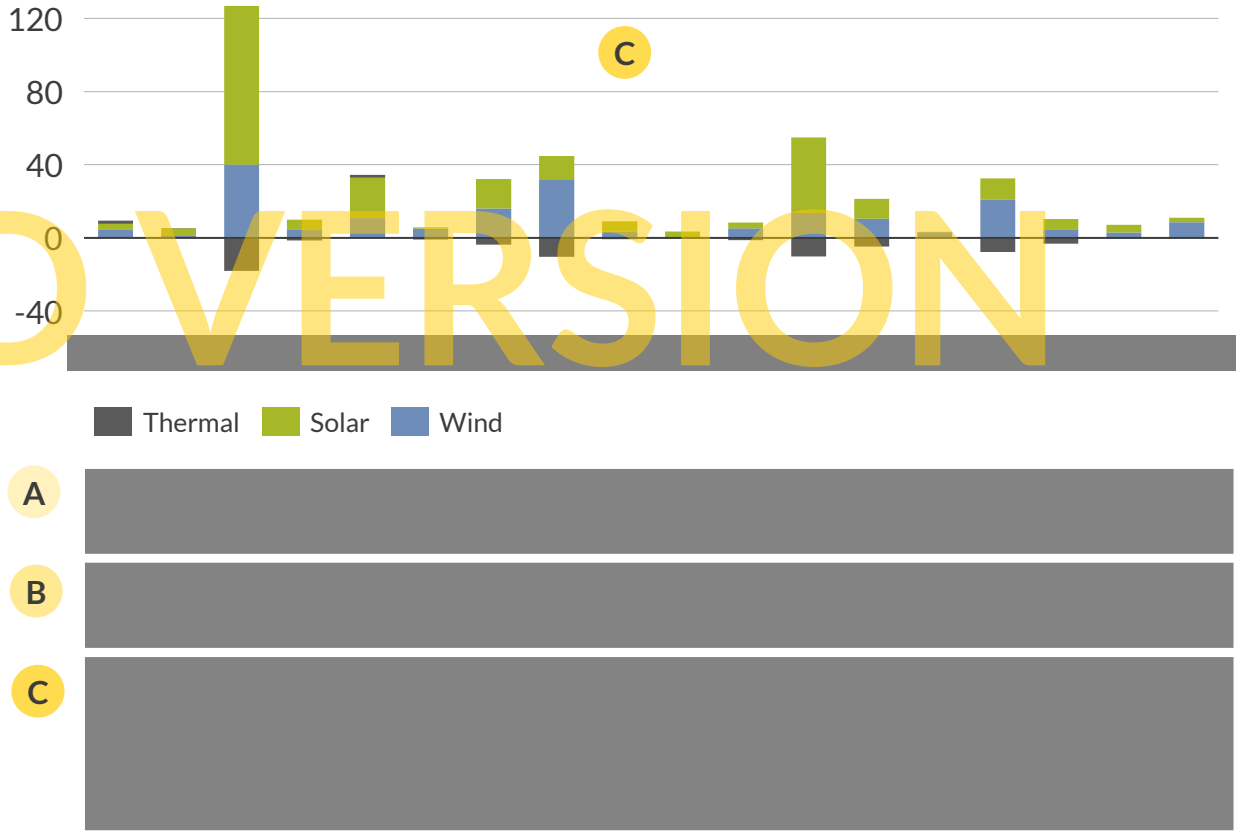
4 Phase out of thermal capacity

Short run marginal cost[1]*
€/MWh, (real 2021)



Capacity changes (2023 – 2030)*
GW



(*) Detailed country data available in Aurora's Power and Renewables Market subscriptions.

Source: Aurora Energy Research

…but even in a Net Zero scenario, dispatchable technologies exposed to commodity prices will set the price more than half of the time

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4 Phase out of thermal capacity (cont.)

Generation mix by 2050 in GB (illustrative example)
% of total generation

Sources: Aurora Energy Research, European Commission

Government support schemes are still the biggest driver of offshore wind build-out across most of Europe

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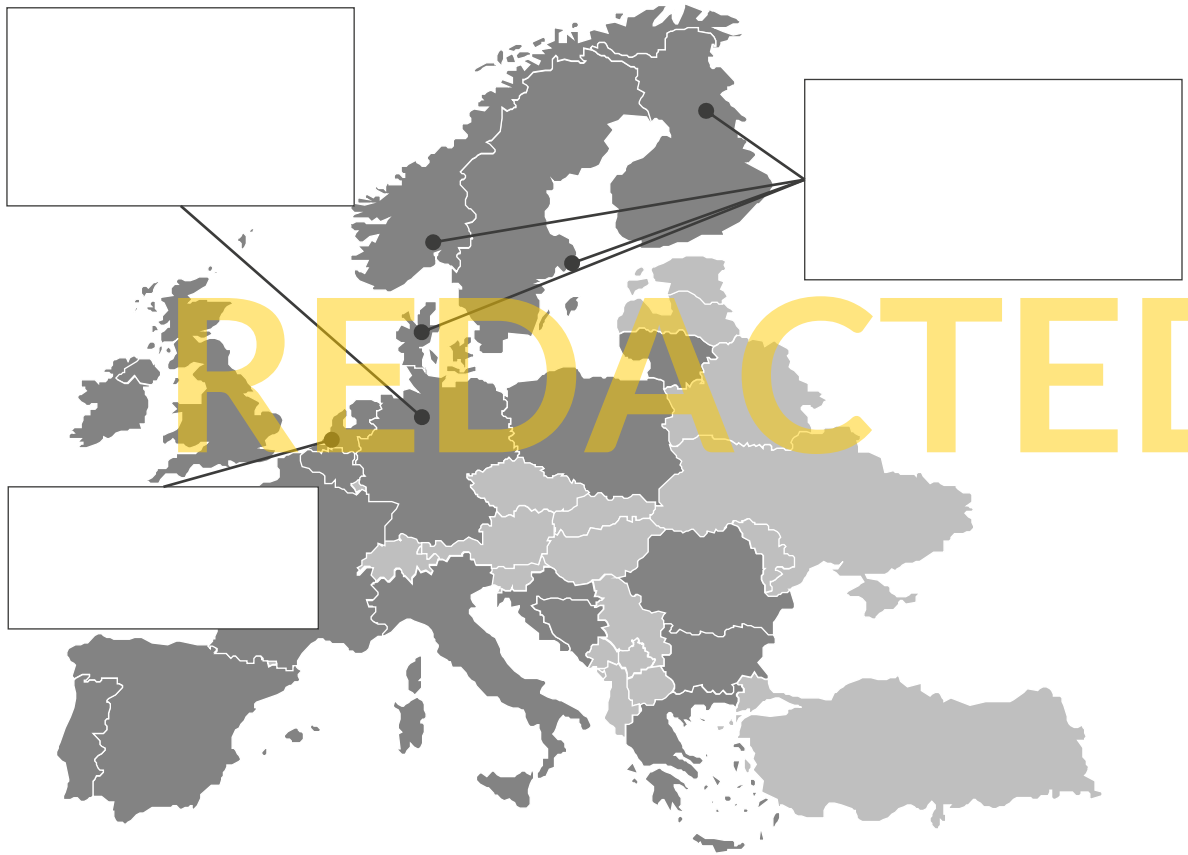
Existing and expected offshore wind support schemes



To be determined
One-sided scheme
Two-sided CfD[2]
No support

Impact of CfDs, PPAs and revenue cap on merchant business models

Sources: Aurora Energy Research

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The potential for offshore wind development in Europe depends on average wind speeds and sea depths, and is higher for floating wind

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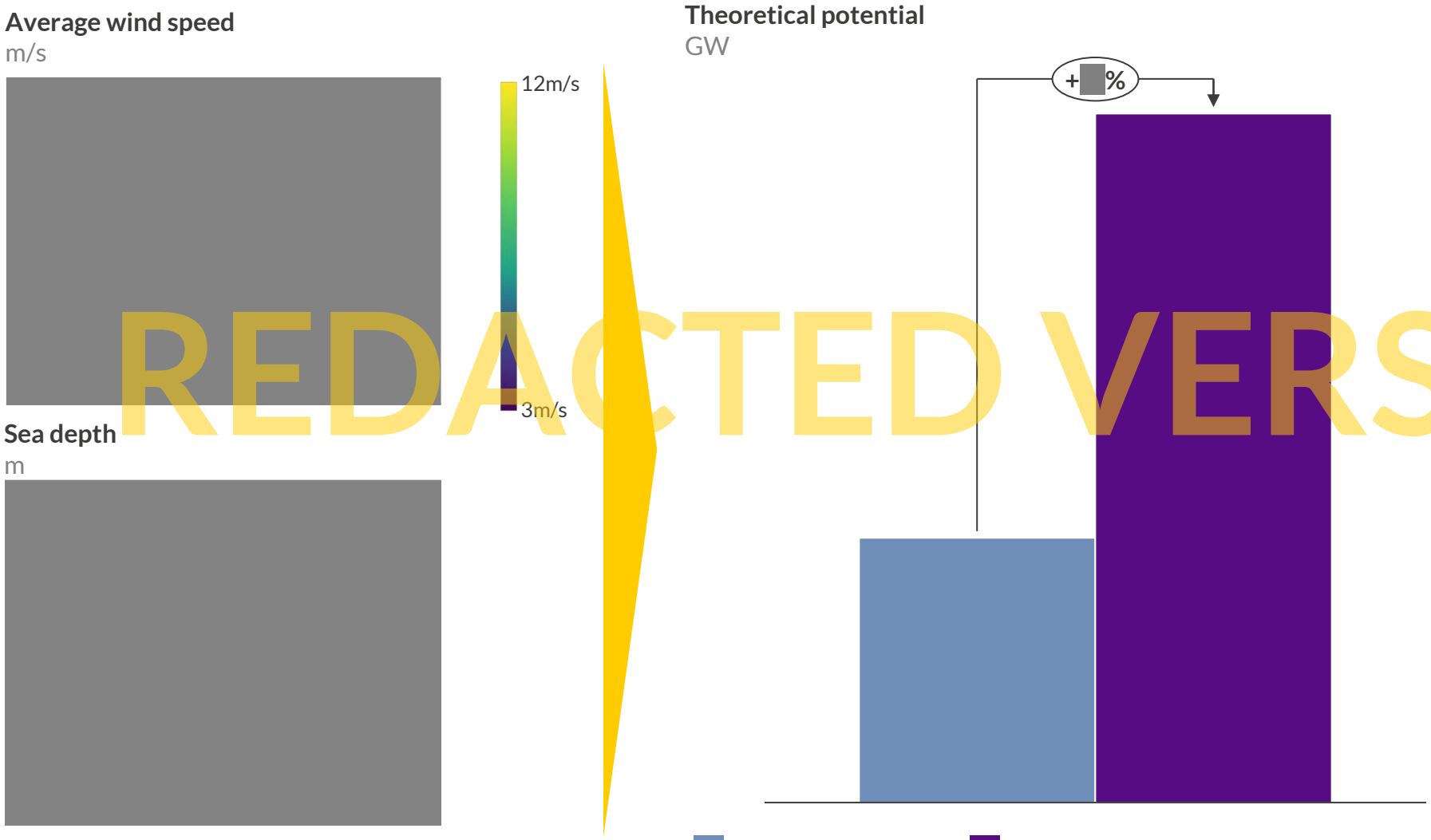

Sources: Aurora Energy Research, ECMWF, GEBCO

7,700 GW extractable offshore wind potential is available in Europe, most of which is concentrated in Great Britain and Norway

Fixed and floating offshore wind potential in Europe,
Only territorial waters with wind speed > 7m/s at 100m shown

[redacted]

Fixed and floating offshore wind technical energy potential in Europe by country[3]
GW

Fixed offshore potential[2] Floating offshore potential

Sources: Aurora Energy Research, IRENA, ESMAP

Floating offshore wind is gaining momentum across Europe and could unlock further deployment potential

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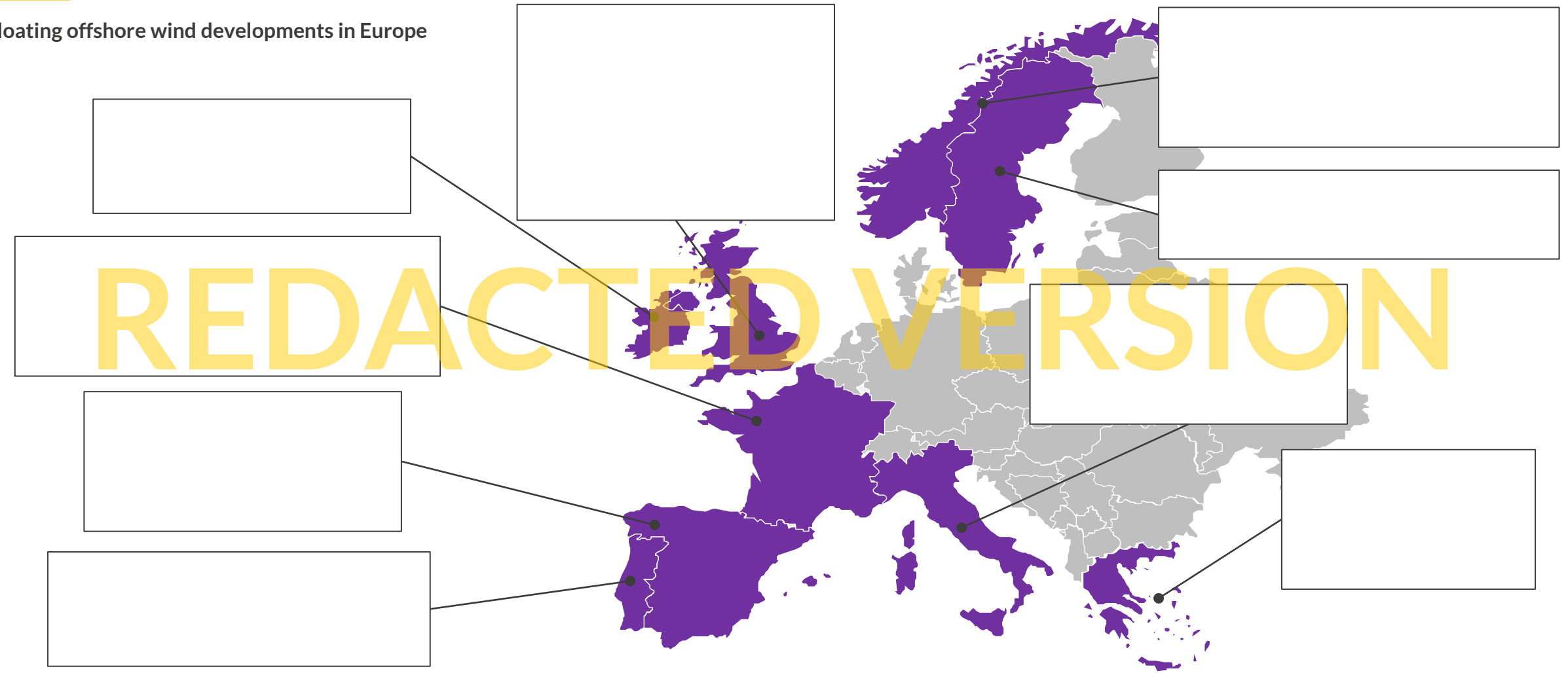
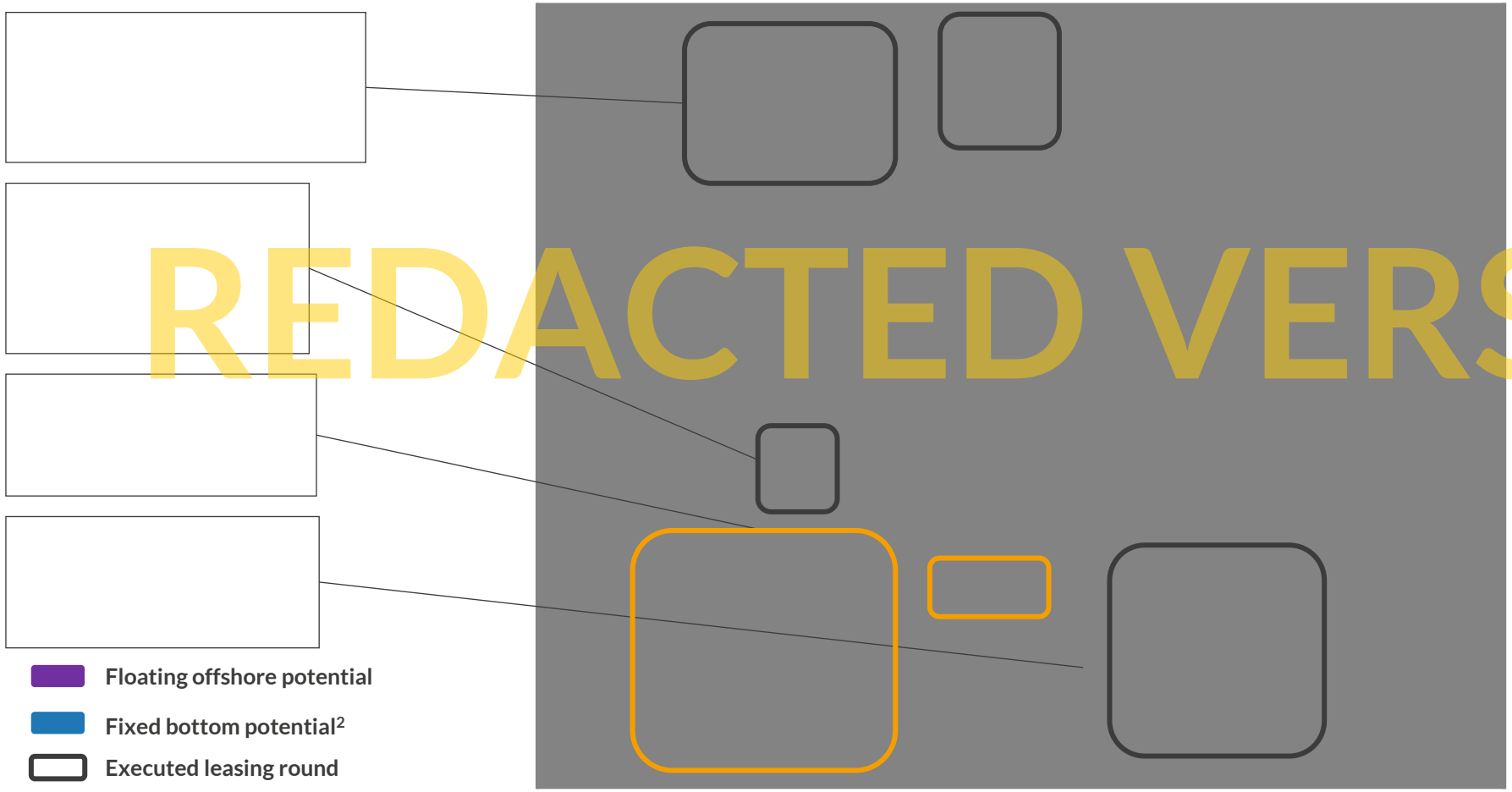
Floating offshore wind developments in Europe



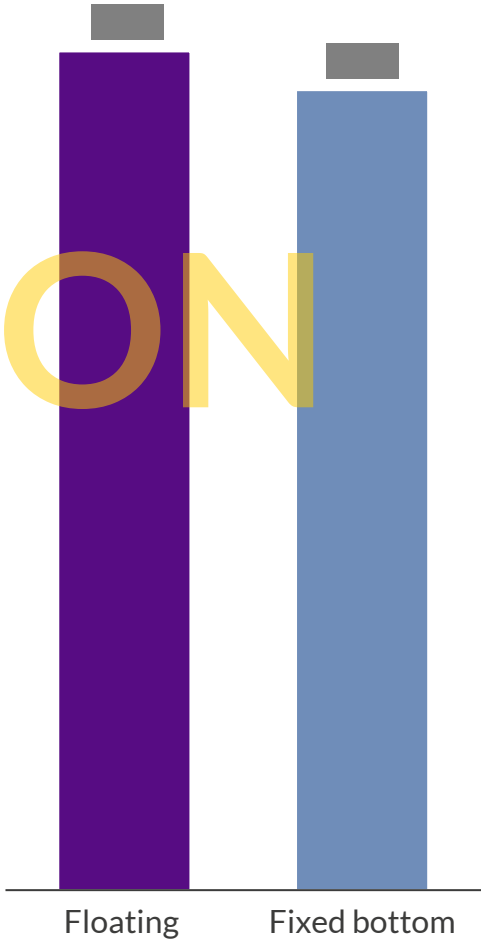
Source: Aurora Energy Research

The UK, Norway, France, and Italy all have executed planned floating offshore leasing rounds

Fixed and Floating offshore potential across Europe,
Only territorial waters with wind speed higher than 7m/s at 100m are shown



Average offshore wind speed[1]
m/s



Sources: Aurora Energy Research

Floating offshore wind can leverage existing wind turbine and flotation technologies to access greater water depths and wind speeds

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Fixed technology | Floating technology

Floating offshore wind can be developed under three main variations:

Substructure	Tension Leg Platform	Semi-submersible	Spar Buoy
Advantage			
Disadvantage			
Depth (m)			
Draft (m)			
Stability System			

Floating offshore wind offers several key advantages but at materially higher costs due to a lack of deployment

1 Greater deployment potential

2 ...enables access to higher and consistent wind speeds

3 ...with lower correlation

4 ...but at higher costs

Sources: Aurora Energy Research, IEA, ORE Catapult, Research Direct, Energy.gov

European countries have set ambitious renewables deployment targets, with the EU itself targeting [redacted] GW offshore wind by 2030

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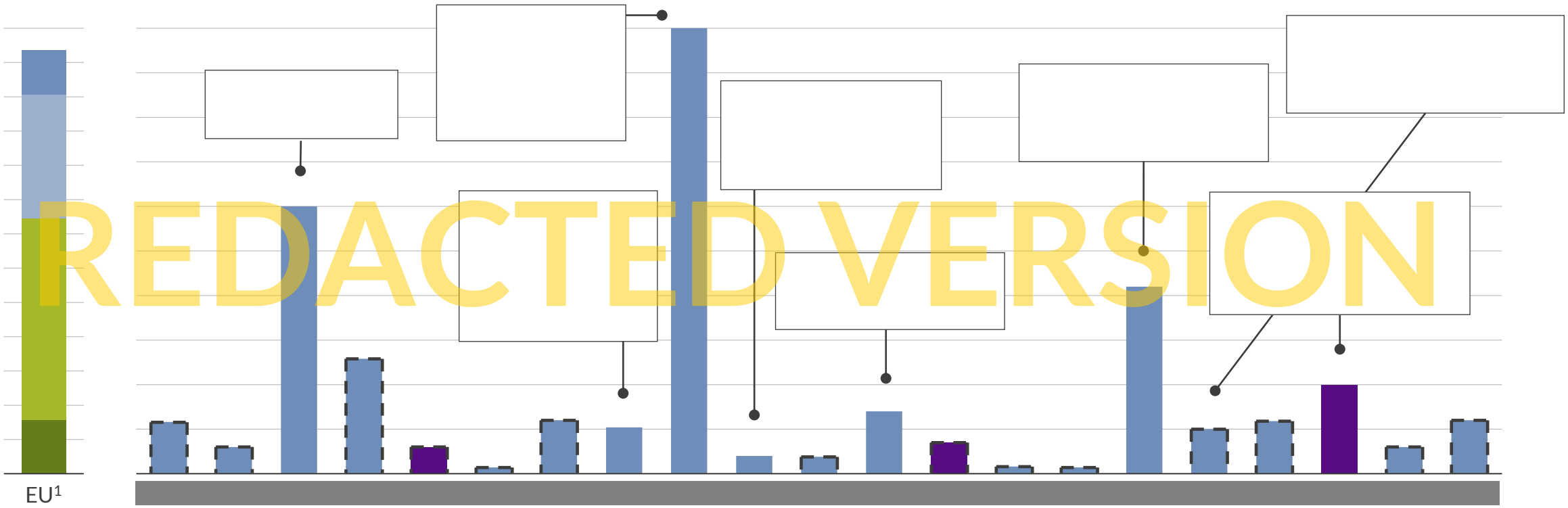
Installed renewables capacity by 2030 – country targets[1]
GW



Required capacity additions compared to currently installed offshore wind capacity
GW

Sources: Aurora Energy Research, European Commission, RTE, Nordic TSO, NECP, National energy strategies

Europe targets [redacted] GW offshore wind by 2030, requiring [redacted] GW or around x7 further capacity deployment

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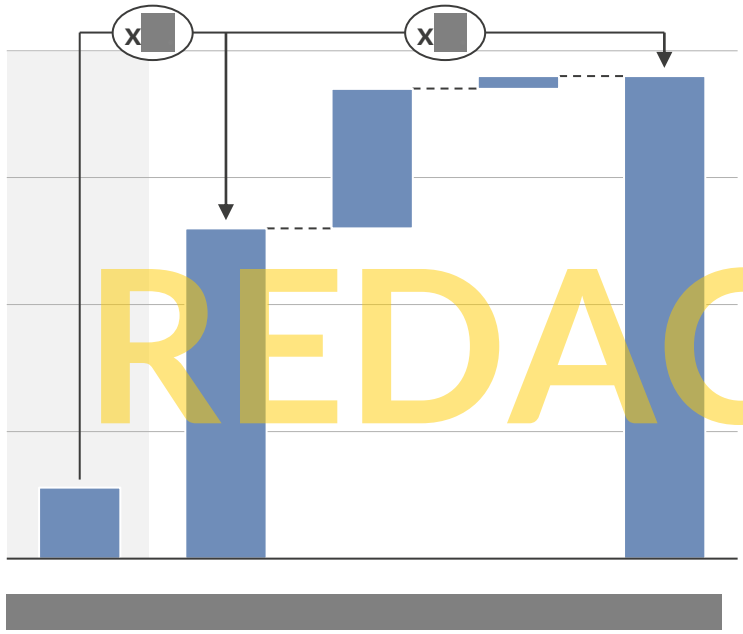
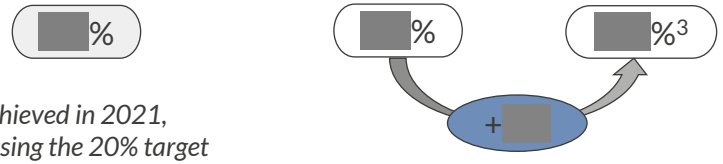
Target installed offshore wind by 2030

GW



2030 REPower EU target RES share of gross final energy consumption

%



Achieved in 2021, surpassing the 20% target

Installed offshore wind in Europe[3] – Aurora Central & Net Zero

GW

Net Zero Central

Source: Aurora Energy Research

Aurora's central case sees further growth of offshore wind driven by ambitious decarbonisation targets

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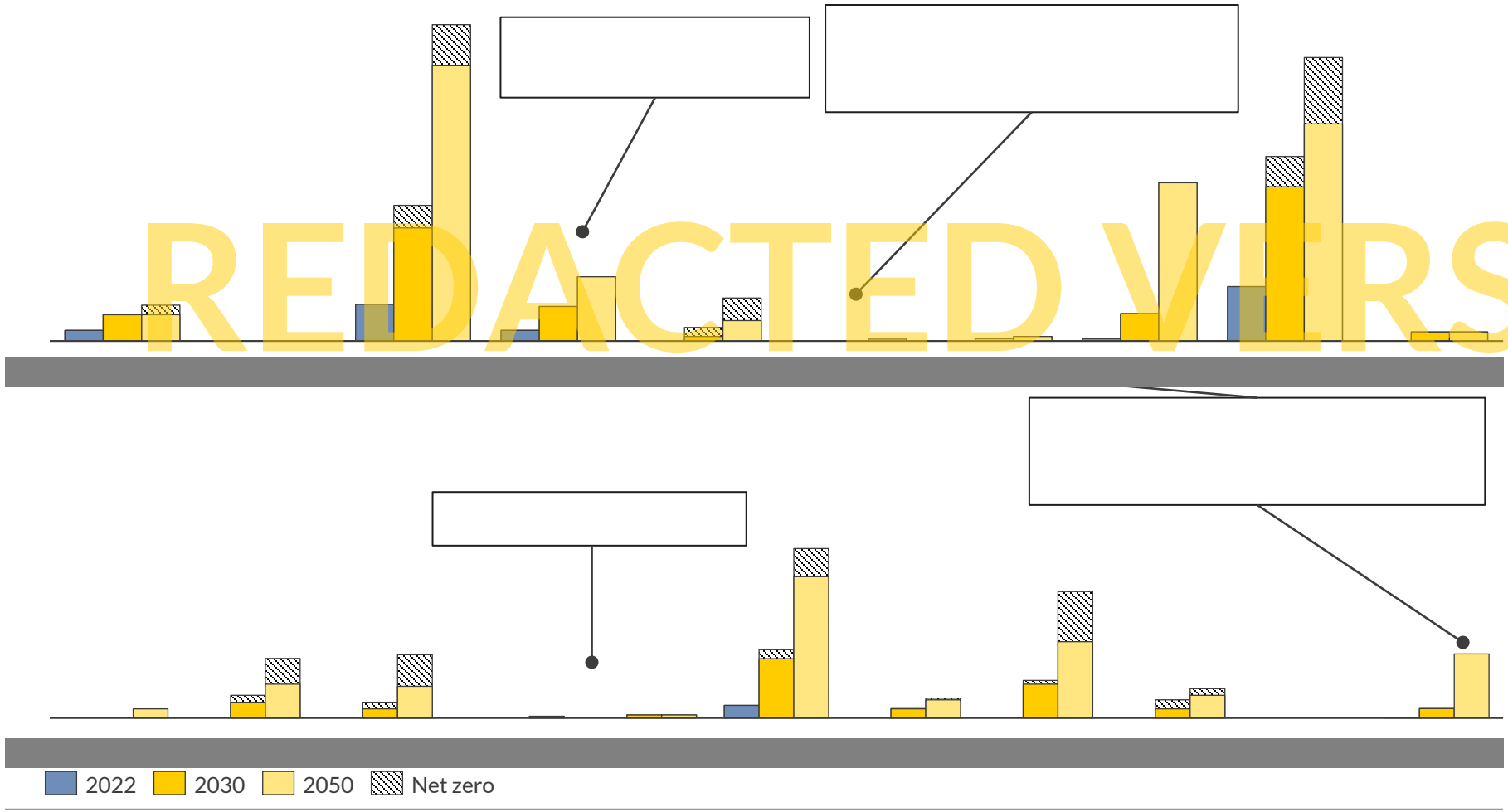
Installed offshore wind capacity 2022, 2030 and 2050 – Aurora Central & Net Zero scenarios
GW



Source: Aurora Energy Research

These new capacity additions represent a potential cumulative investment opportunity in Europe of up to [redacted] €bn between 2022-50

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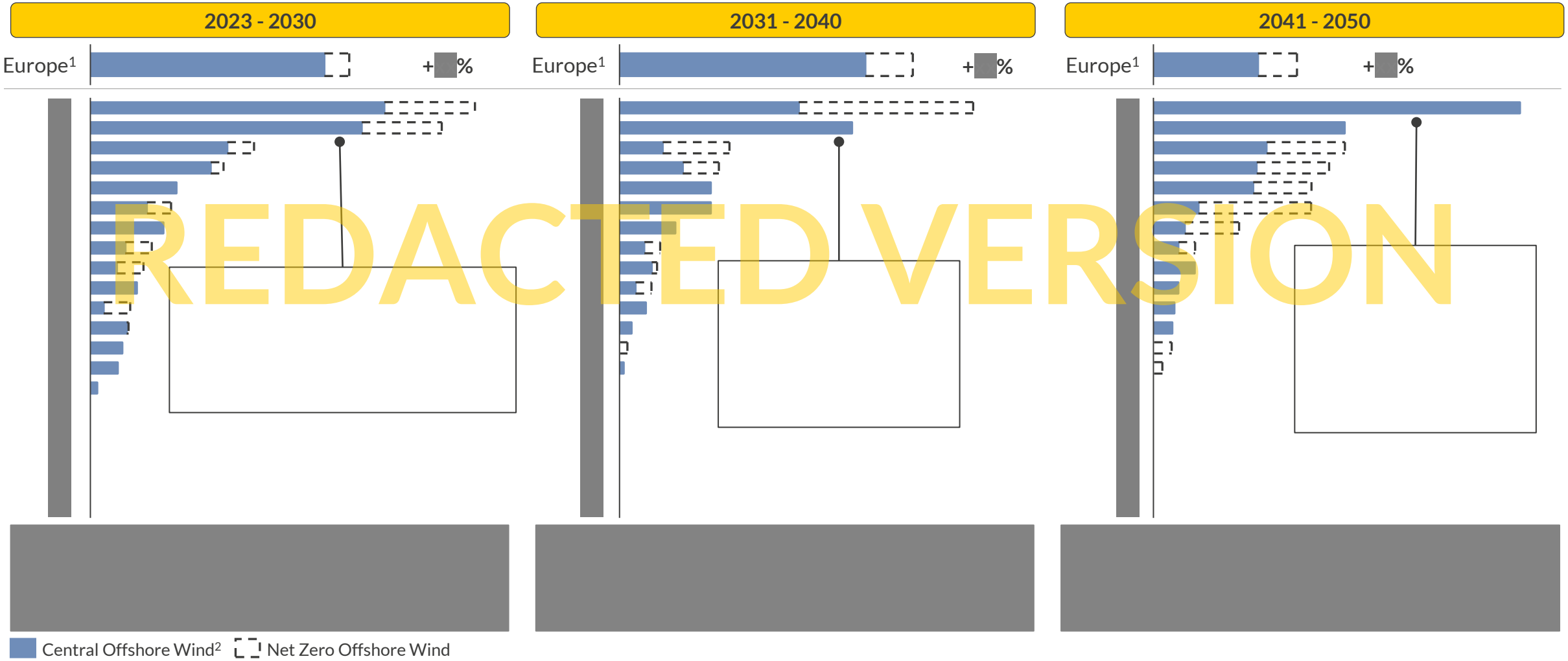
Total CAPEX spend on offshore wind
€bn (real 2022)



Source: Aurora Energy Research

A substantial pipeline exists across all countries within Europe, particularly [redacted] and [redacted], which have [redacted] GW and [redacted] GW, respectively

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1 A substantial pipeline exists across all countries within Europe, with projects at various stages of the development process

2 The scale of projects has increased over the last decade, with the largest projects in Europe ranging from [redacted] GW in [redacted] to [redacted] GW in [redacted]

Offshore wind project pipeline[1]

GW

Project name	Region	Development stage	Technology Type	Size

Announced | Development[2] | 2030 country targets[2]

Sources: Aurora Energy Research, Aurora Global Offshore Wind Database

Currently, [redacted] and [redacted] are the key players in the offshore wind market, with [redacted] and [redacted]% share of existing projects across Europe, respectively

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Developers (2012 – 2022)

Operational offshore wind capacity[7]
GW

Investors[8] (2012 – 2022)

Operational offshore wind capacity[7]
GW

BEL DEU DNK ESP FIN FRA GBR NLD NOR PRT SWE % Share of total offshore wind capacity[6]

Sources: Aurora Energy Research, Aurora Global Offshore Wind Database

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Offshore Wind projects require several policy and regulatory hurdles to be met through each stage of development process

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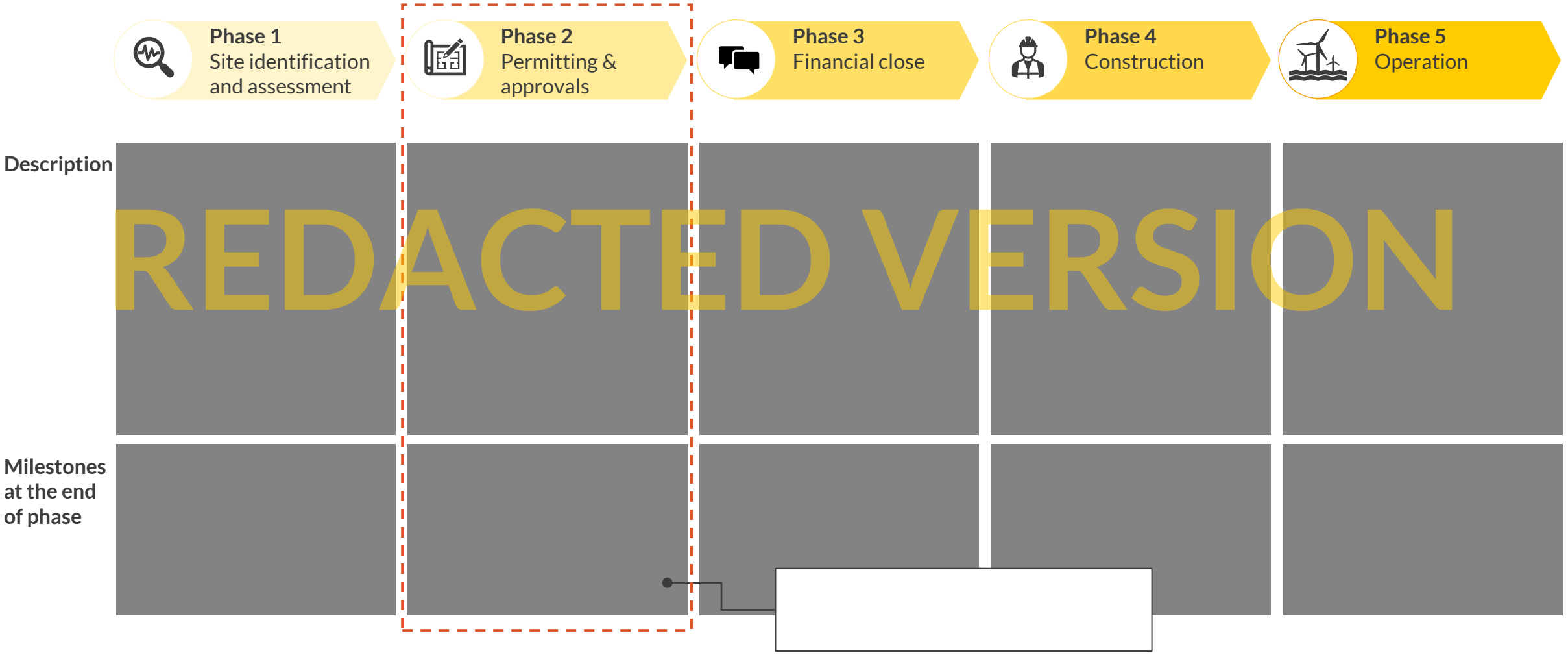
Deep dive in section IV



The permitting phase is characterised by [redacted]

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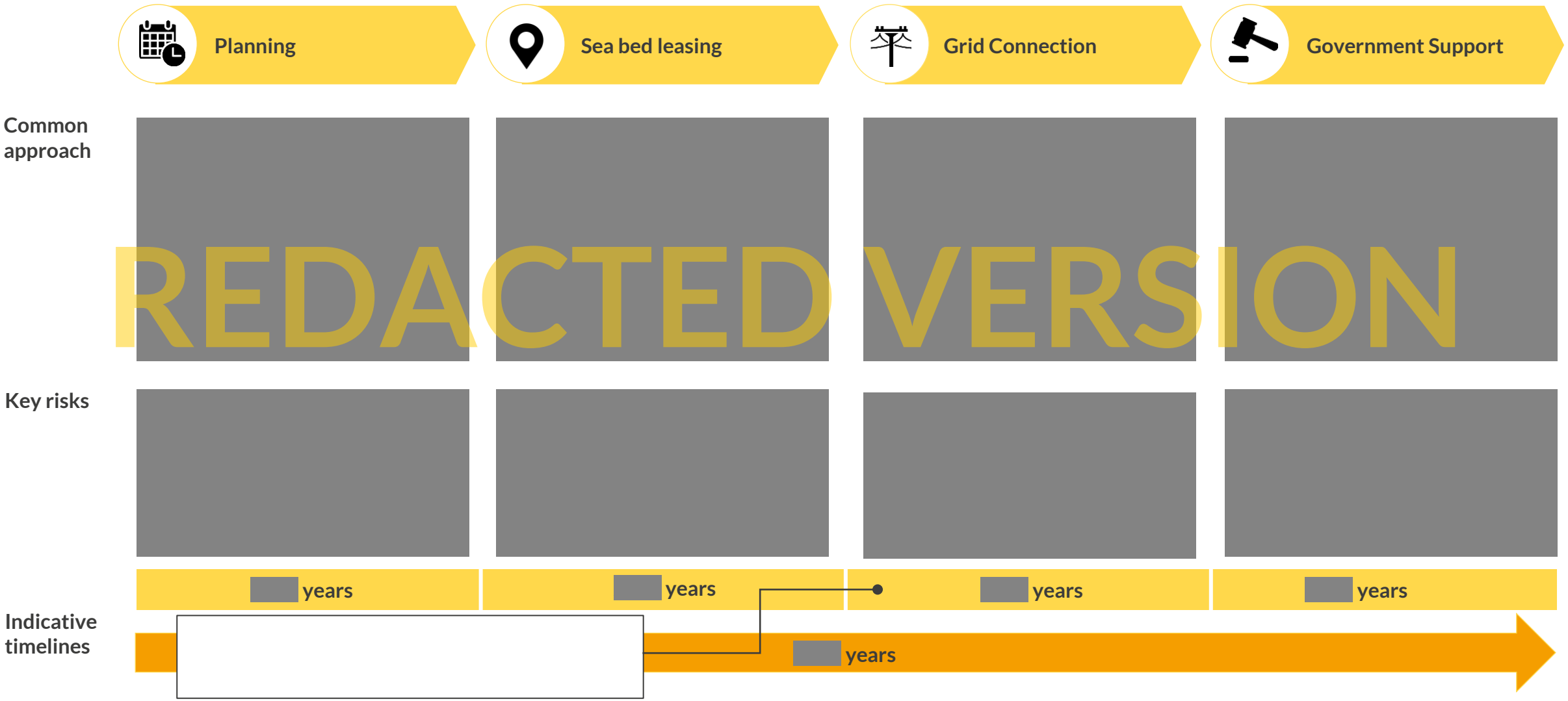

Sources: Aurora Energy Research

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With [redacted] km², [redacted] assigned the largest area to offshore wind development among the analysed countries

MSP[1]	Country	What is the relevant MSP	When was it adopted	When was it last updated	Area dedicated to offshore wind development	Undeveloped offshore capacity[3]

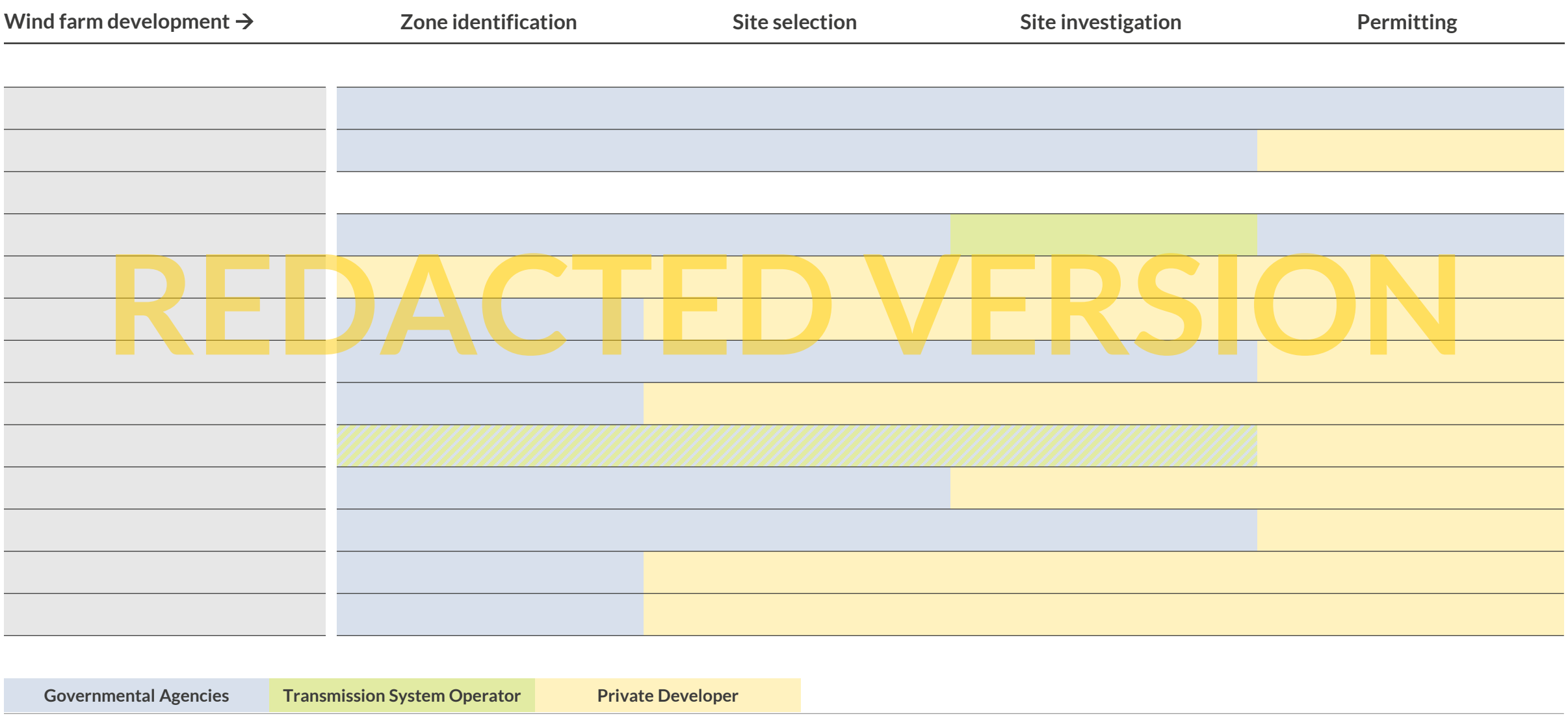
Sources: Aurora Energy Research, European Commission, Wind Europe

Both [redacted] and [redacted] dedicated around [redacted]% of their Exclusive Economic Zone to offshore wind development

MSP[1] Country	What is the relevant MSP	When was it adopted	When was it last updated	Area dedicated to offshore wind development	Undeveloped offshore capacity[3]

Sources: Aurora Energy Research, European Commission, Wind Europe

1. Planning: Many, but not all, countries offer an option to select sites outside the government-led framework



Sources: Aurora Energy Research

1. Planning: In most markets, projects can only be developed in zones identified by the government – exceptions are [redacted]

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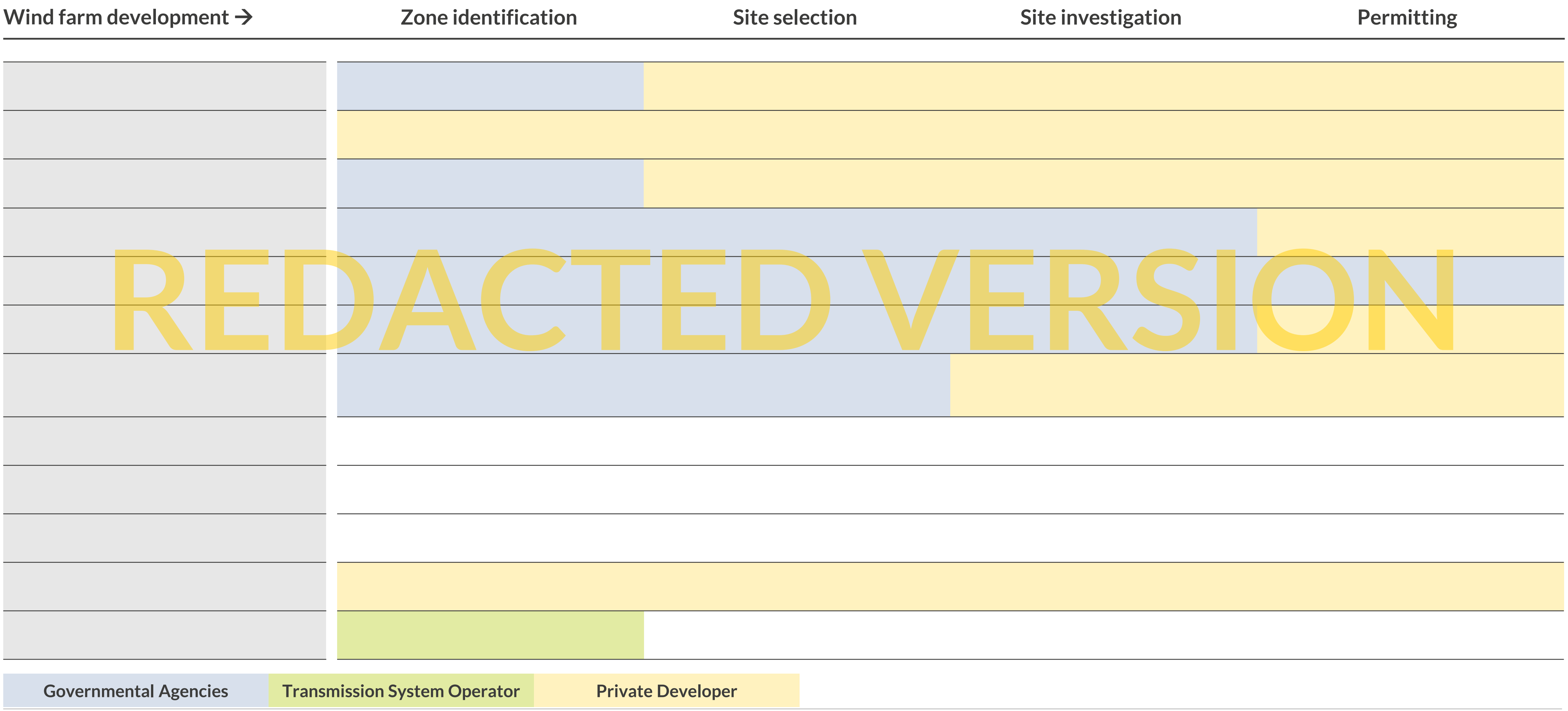

Sources: Aurora Energy Research

[redacted], [redacted] and [redacted] are each moving towards a centralised planning process

Region	Positives and nuances of the development process
	✓ ✗
	✓ ✗
	✗
	✗
	✗
	✓ ✗
	✓ ✗
	✓
	✓
	✗

Source: Aurora Energy Research

High uncertainty for development processes in [redacted] and [redacted], due to the lack of planning frameworks for offshore wind

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Region	Positives and nuances of the development process
	✓
	✗
	✓ ✗
	✓
	✓
	✓
	✗ ✗
	✗
	✗
	✗
	✗ ✗

Source: Aurora Energy Research

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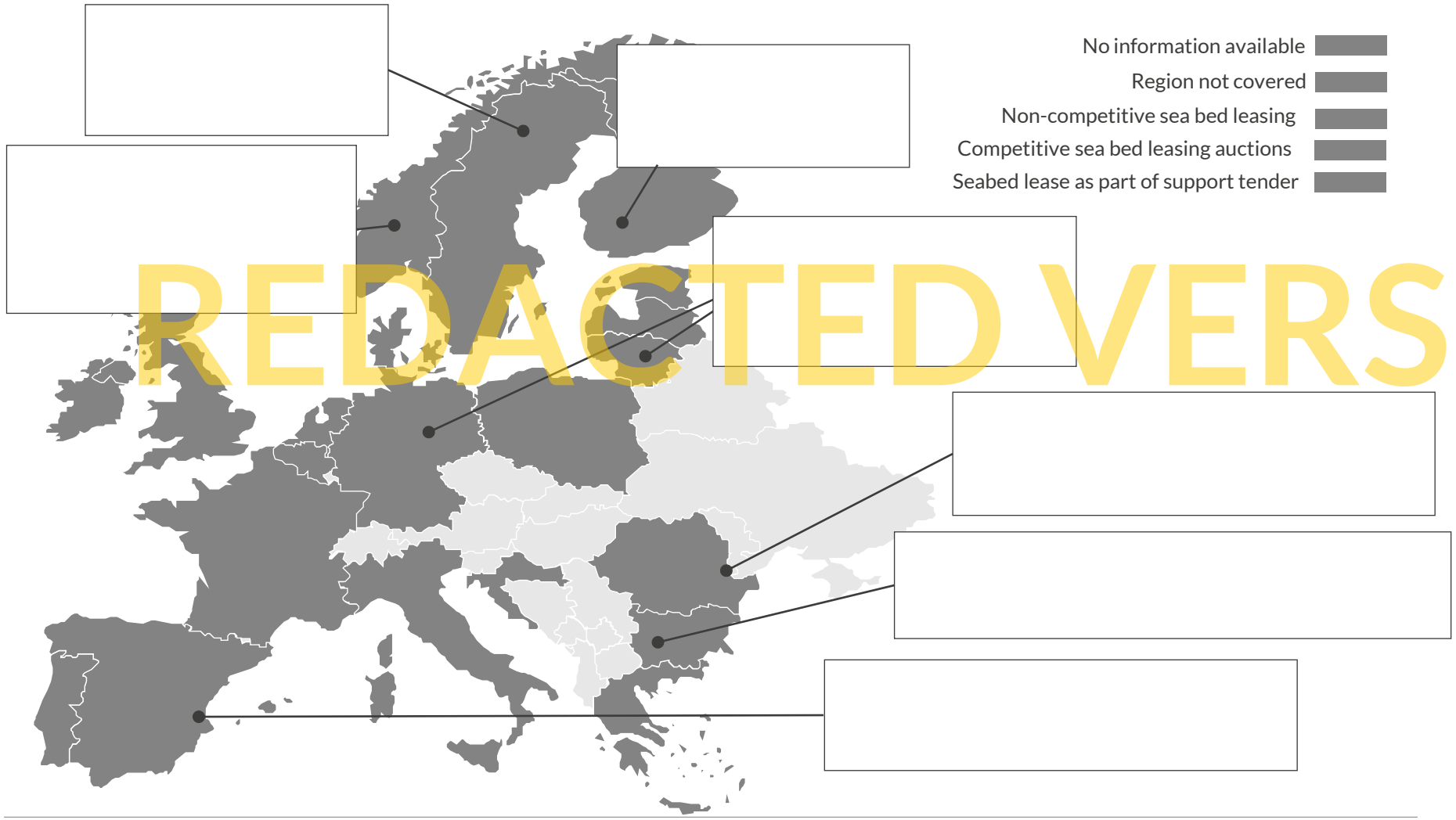
2. Sea bed leasing: Most countries tender sea bed leases – either combined with government support or subsidy-free

Sea bed lease award procedures in Europe



Sources: Aurora Energy Research

Great Britain: ScotWind winners comprised of an array of industry players, including [redacted]

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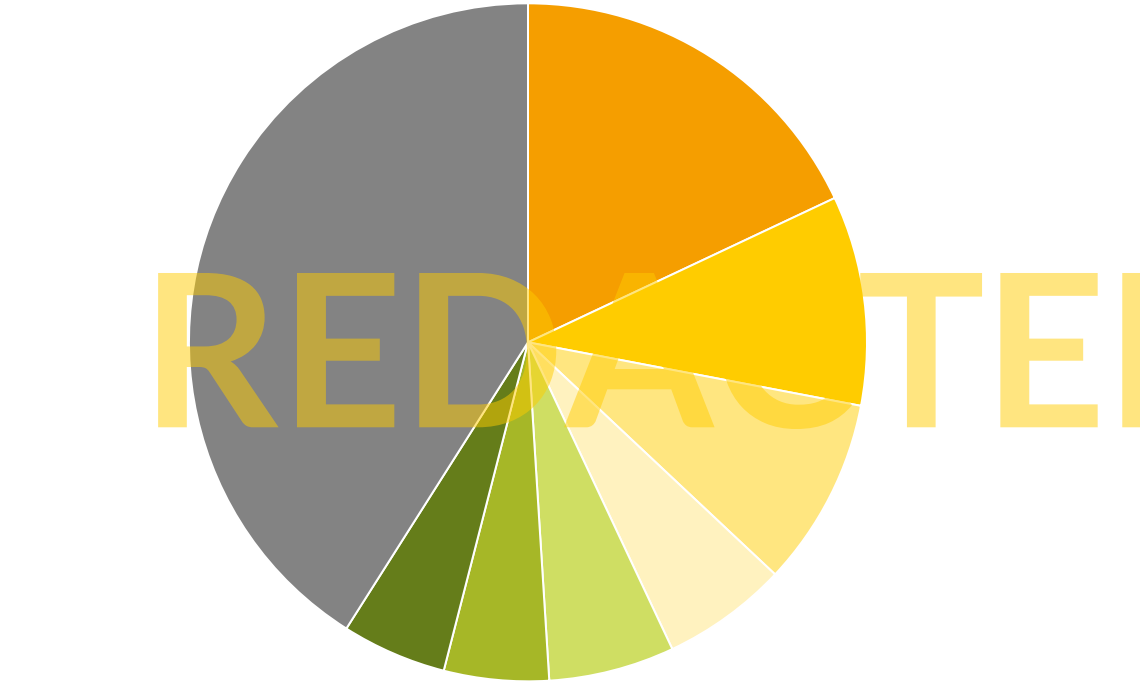
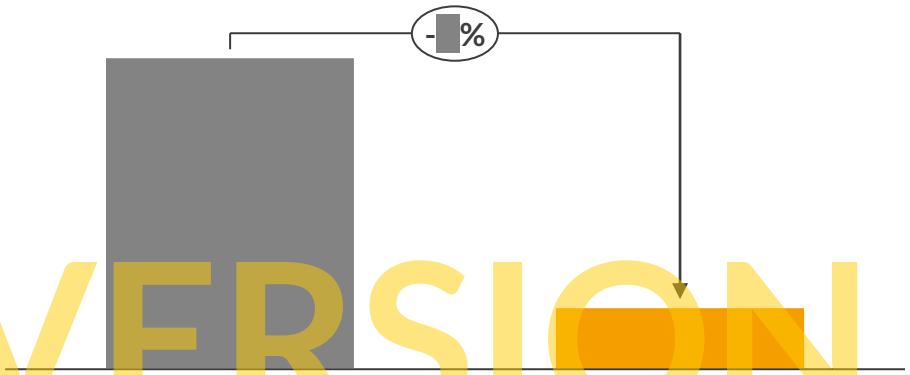
Net leasing right capacity secured in ScotWind as a % by company
%



[redacted]

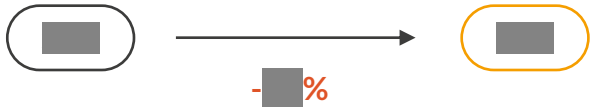
Comparing option fee payments Between TCE Round 4 and CES ScotWind[1]
£million (nominal)



Capacity secured (GW)

Seabed leased (km^2)

Average option fee[2] per kW^2 (£/kW)



Average option fee[2] per km^2 (£k/km^2)

Sources: Aurora Energy Research, Crown Estate Scotland, Company websites

Great Britain: The Crown Estate and Crown Estate Scotland could award up to [redacted] GW of floating offshore wind leasing rights by the end of 2023

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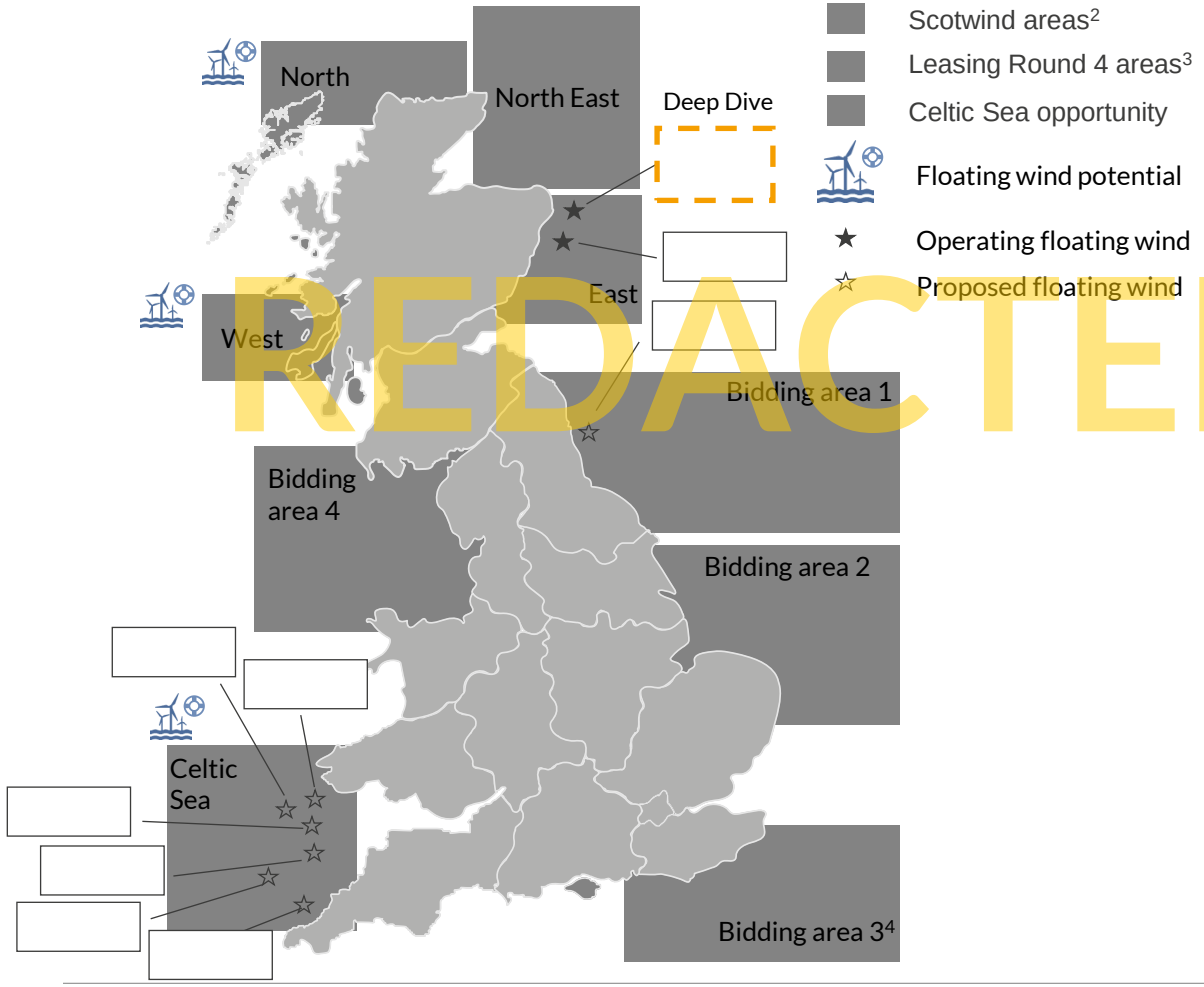
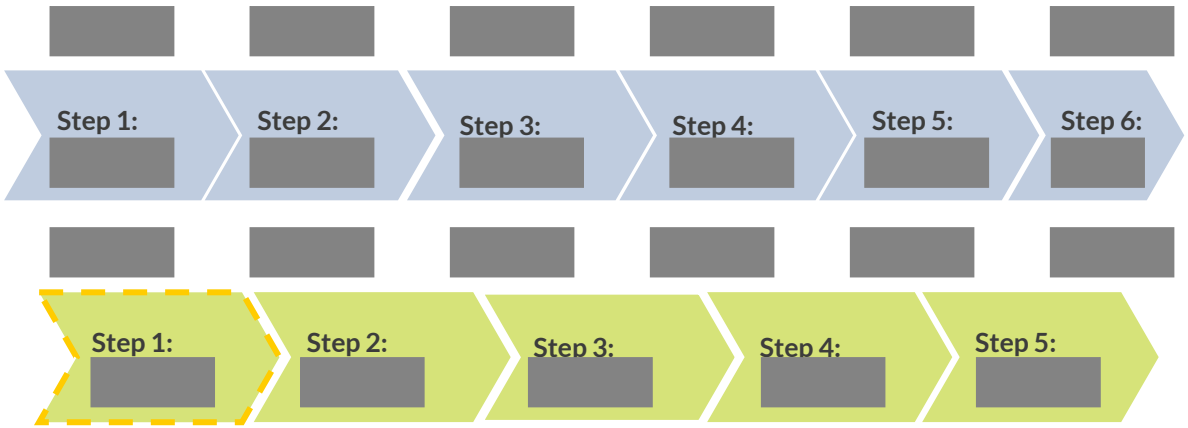
Map of the UK showing recent and ongoing offshore sea bed leasing areas and floating wind locations[1]



There are now significant leasing rights focused on floating wind but [redacted]

[redacted]

Timelines for next stages of Scotwind and the Celtic Sea floating wind opportunity



Sources: Aurora Energy Research, The Crown Estate, Crown Estate Scotland, Celtic Sea Cluster, Company websites

Great Britain: Crown Estate Scotland signed agreements with [redacted] GW offshore wind in its [redacted]

Following the success of the ScotWind leasing round, [redacted]

1 On 24th March 2023, CES announced that [redacted] MW of capacity was contracted [redacted]

2 Almost all the sites are in the East Scotland region, [redacted]

Capacity by lead applicant
MW

Innovation
Targeted Oil & Gas

Confirmed INTOG Applications
Area considered for future INTOG projects
Areas excluded from INTOG

Sources: Aurora Energy Research, Crown Estate Scotland, company websites

France: By 2031, [redacted] offshore wind projects are planned to be developed in four regions, with a combined capacity of [redacted] GW

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France has the [redacted] potential for offshore wind development in Europe (potential over [redacted] GW), behind the [redacted] and [redacted], and plans to deploy capacity over four regions; [redacted] – [redacted], [redacted] – [redacted], [redacted], [redacted]

2013-2018 offshore wind load factors average for a [redacted] MW turbine[1]

%

[redacted]

Sources: Aurora Energy Research, Ministère de la Transition Energétique

1. Seabed leasing: Countries are ranked according to their seabed lease frameworks and track record

Criteria	High Project Risk	Medium Project Risk	Low Project Risk	Not Applicable
Seabed leasing framework				
Track record				

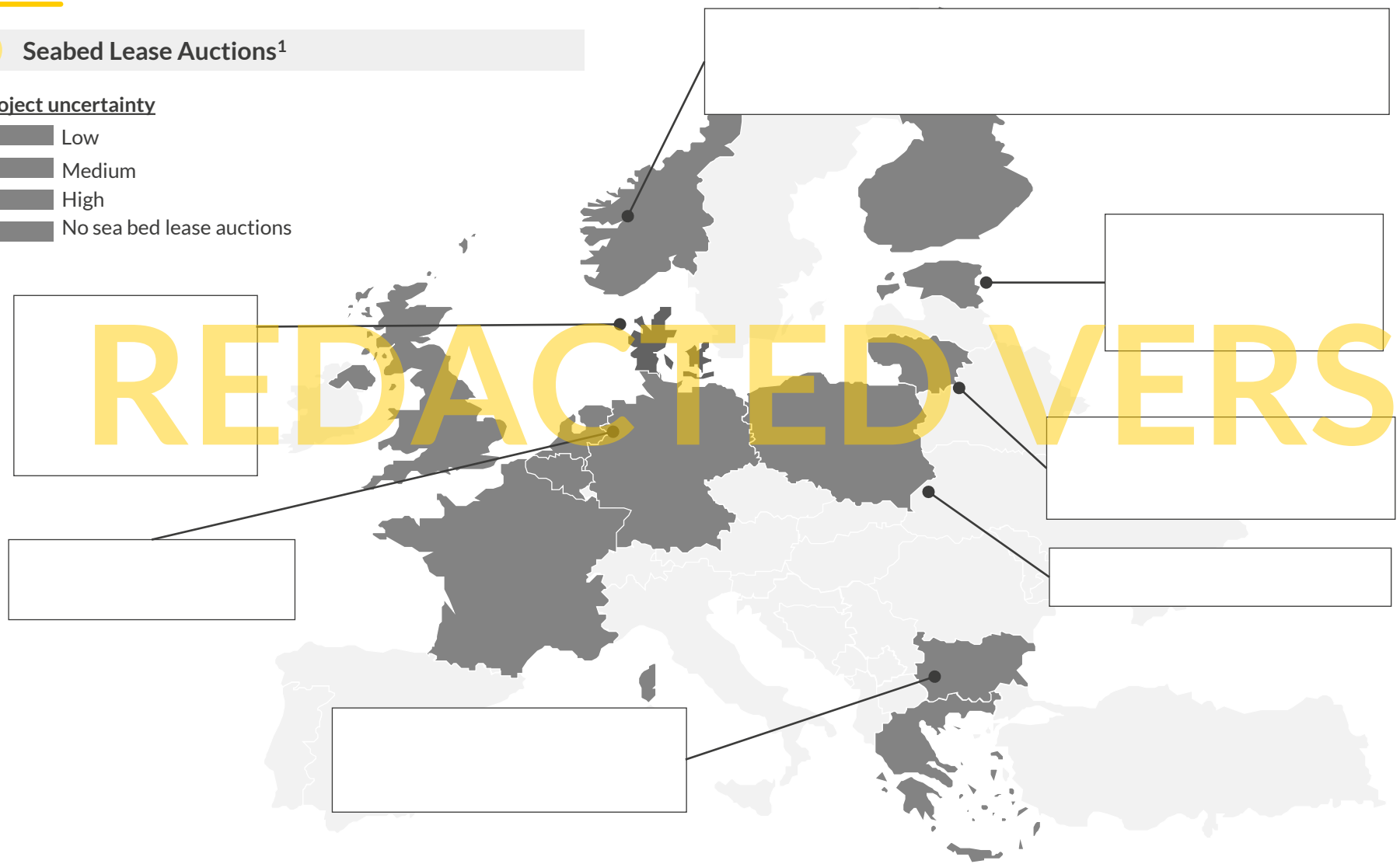
Sources: Aurora Energy Research

Sea bed lease procurement: [redacted] can increase project risk

1 Seabed Lease Auctions[1]

Project uncertainty

- Low
- Medium
- High
- No sea bed lease auctions



Source: Aurora Energy Research

Agenda

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I. Executive Summary

II. Renewables Market Drivers

III. Market Size, Composition and Outlook

IV. Policy & Regulatory Environment
   1. Planning
   2. Seabed Leasing
   3. Government Support Schemes
   4. Grid Connection

V. Financial Variable Inputs

VI. Government Support Auction Forecasts

VII. Project Economics

VIII. Investment Strategies

IX. Appendix

This is a redacted sample of the European Offshore Wind Markets Attractiveness Report.
If you are interested in the full report, contact Alex Hutcheson, (alex.hutcheson@auroraer.com).

Offshore wind in Europe has historically been brought to market by CfDs; some developers have shifted to merchant routes to market

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Direct support schemes

CfD Contracts for Difference

FiPT Feed-in/Premium tariff[1]

Additional support scheme

GC Green certificates

Other revenues

CM Capacity markets

Expectation based on official announcements

Region	Future auction support[1]	*Other support/revenues*

Source: Aurora Energy Research

For most countries in Europe, the final support scheme terms and conditions for offshore wind will be a two-way CfD

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Region	Past scheme	Future scheme[1]	*Neg. price risk*	*Indexation*	*Contract length*	*Comb. with GC[2]*	*Auction announced[3]*

CfD
Two-way contract-for-difference

FiPT
Feed-in premium

(dashed)
Expectation based on official announcements

At least [redacted] GW of offshore wind capacity is set to be procured through committed auctions to 2030

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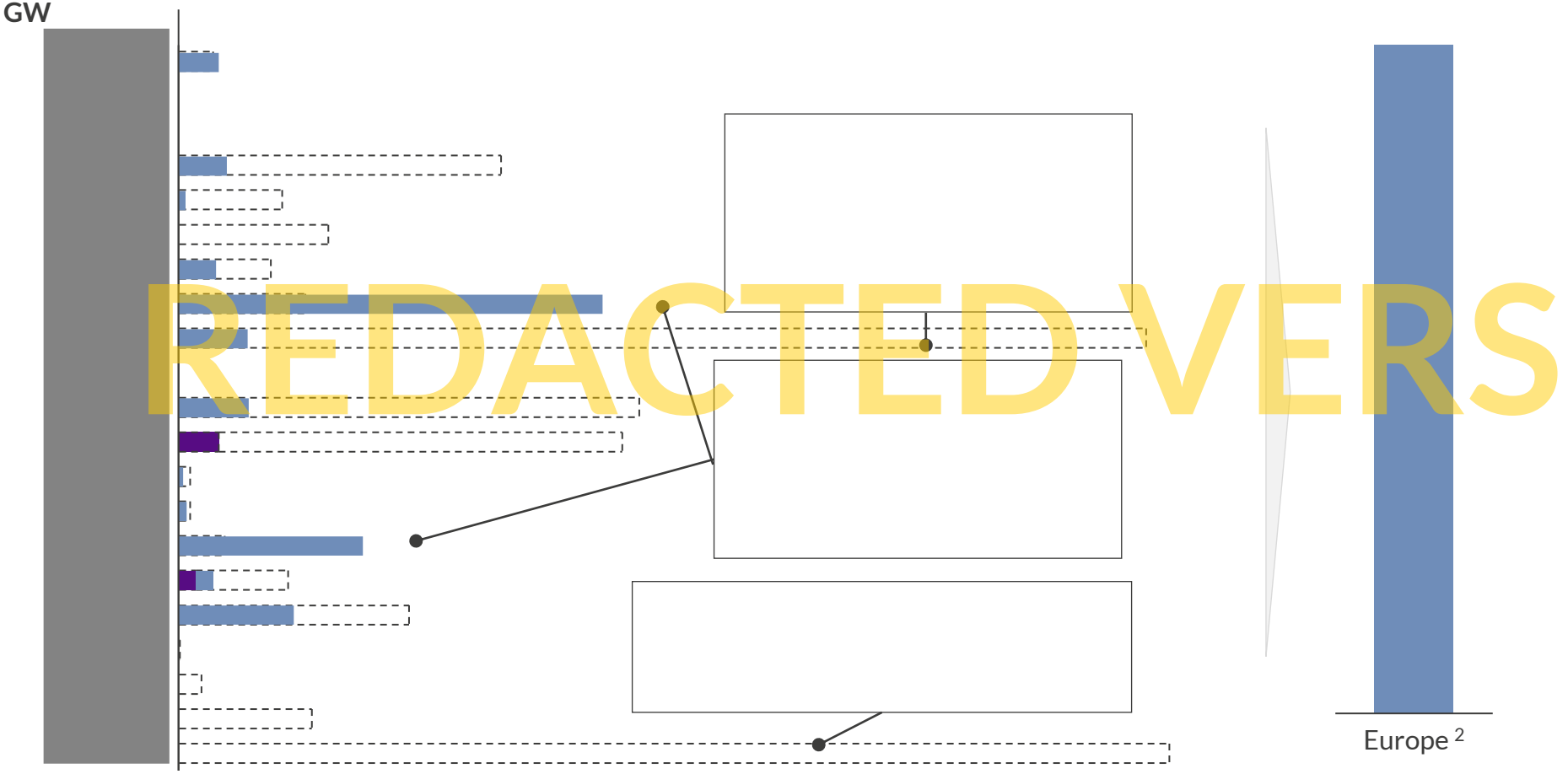
Planned capacity procurement through announced auctions to 2030 (both for support and Zero-bid auctions)



Volumes shown represent announced and confirmed auctions as of April 2022 and does not reflect all potential auctions in the period to 2030

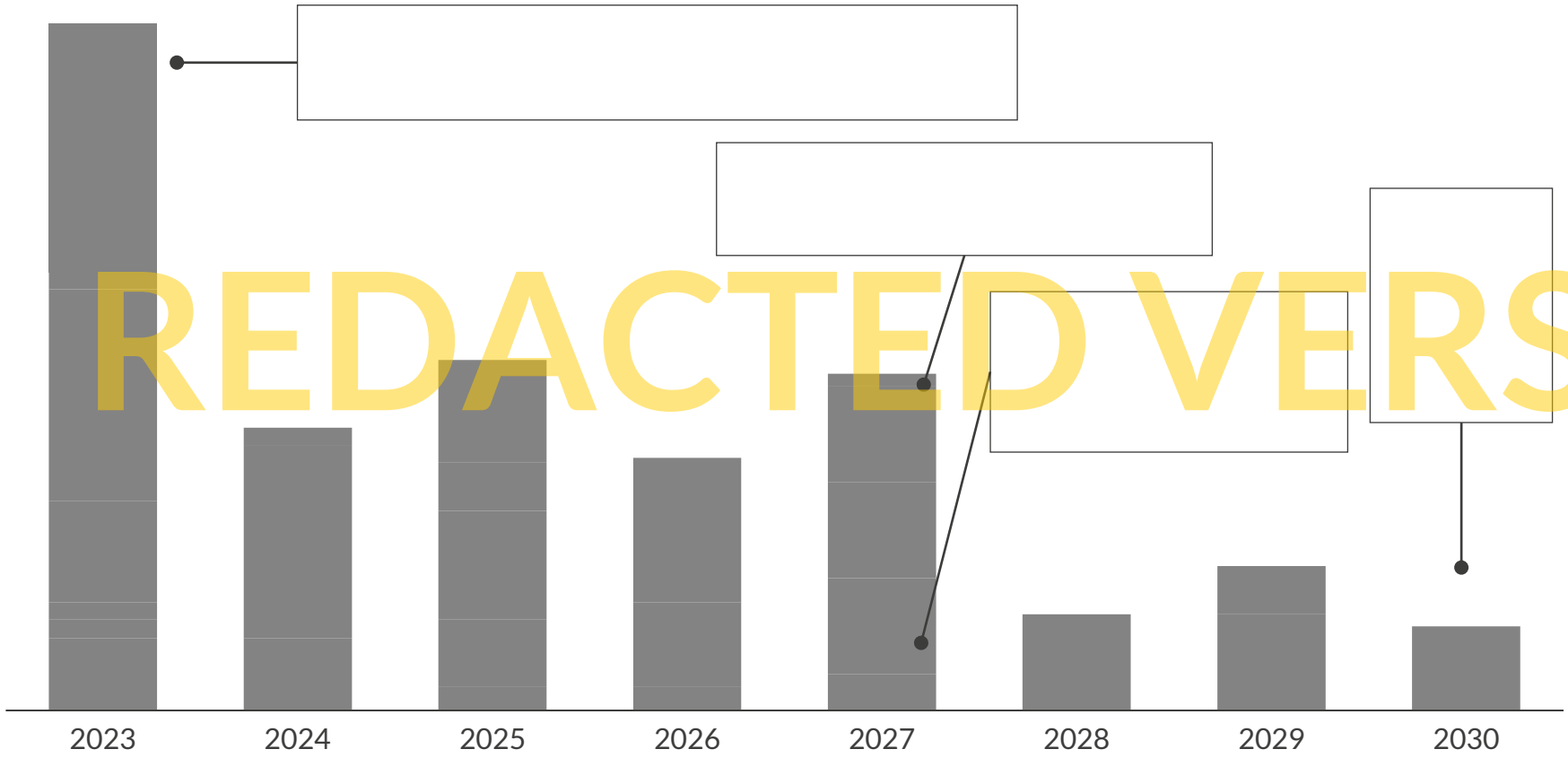
Announced floating offshore wind auction volumes | Announced fixed offshore wind auction volumes | Existing project pipeline

Source: Aurora Energy Research

[redacted], [redacted], [redacted] and [redacted] have a clear auction schedule for several years ahead to meet 2030 targets

Planned capacity procurement[1] through announced auctions until 2030 by auction year

GW



Comments

[redacted]

Sources: Aurora Energy Research

Recent offshore wind auctions across Europe have seen

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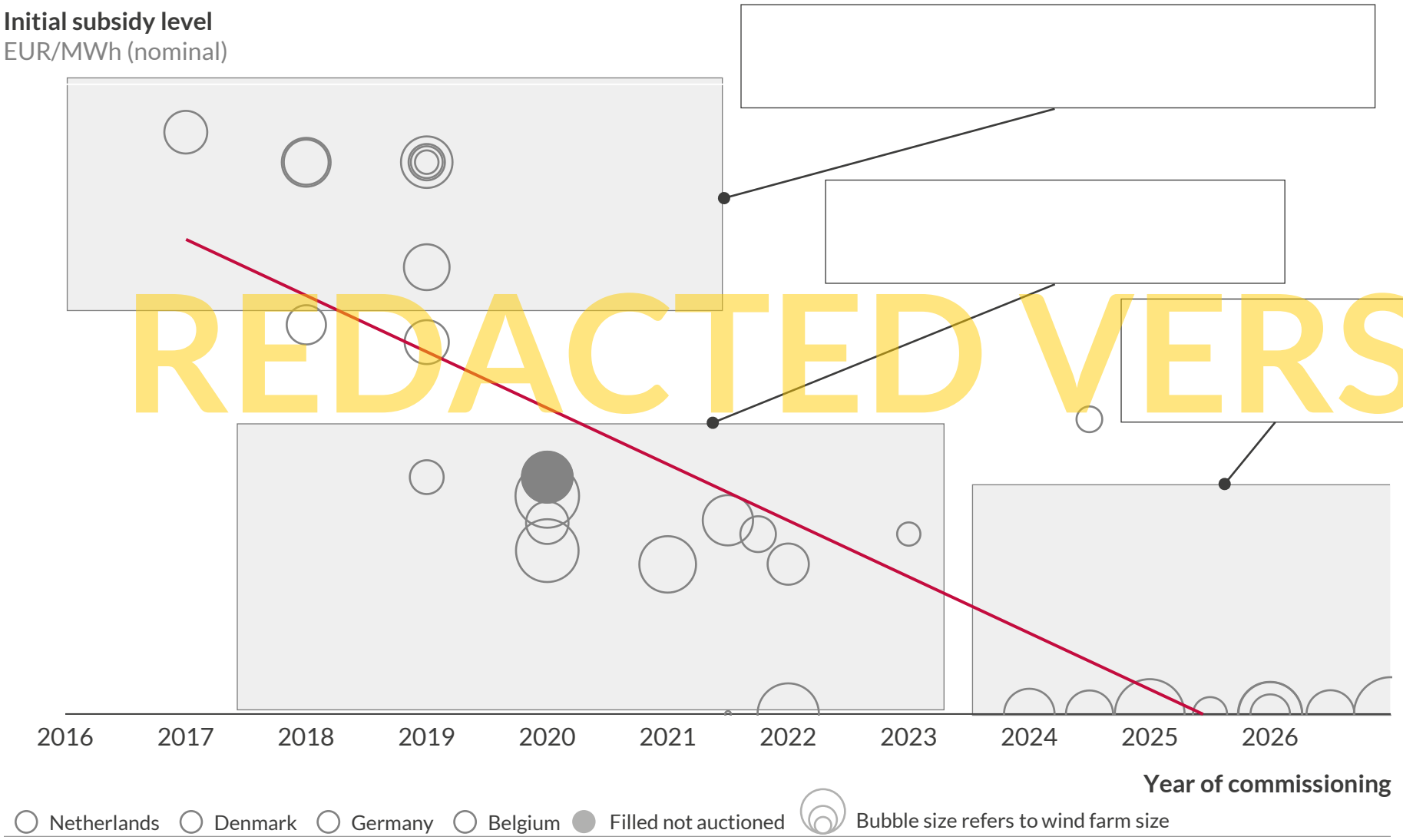
Initial subsidy level
EUR/MWh (nominal)



Comments

Sources: Aurora Energy Research, BMWi, NERA

Key nuances of the government support auctions across different countries in Europe (1/2)

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Region	Positives and nuances
Belgium	
Bulgaria	
Denmark	
Estonia	
Finland	
France	
Germany	
Great Britain	
Greece	

Source: Aurora Energy Research

Key nuances of the government support auctions across different countries in Europe (2/2)

AURORA

Region	Positives and nuances
Italy	
Latvia	
Lithuania	
Netherlands	
Norway	
Poland	
Portugal	
Romania	
Spain	
Sweden	

Source: Aurora Energy Research

We evaluate the project risk associated with support schemes based on auction and support characteristics

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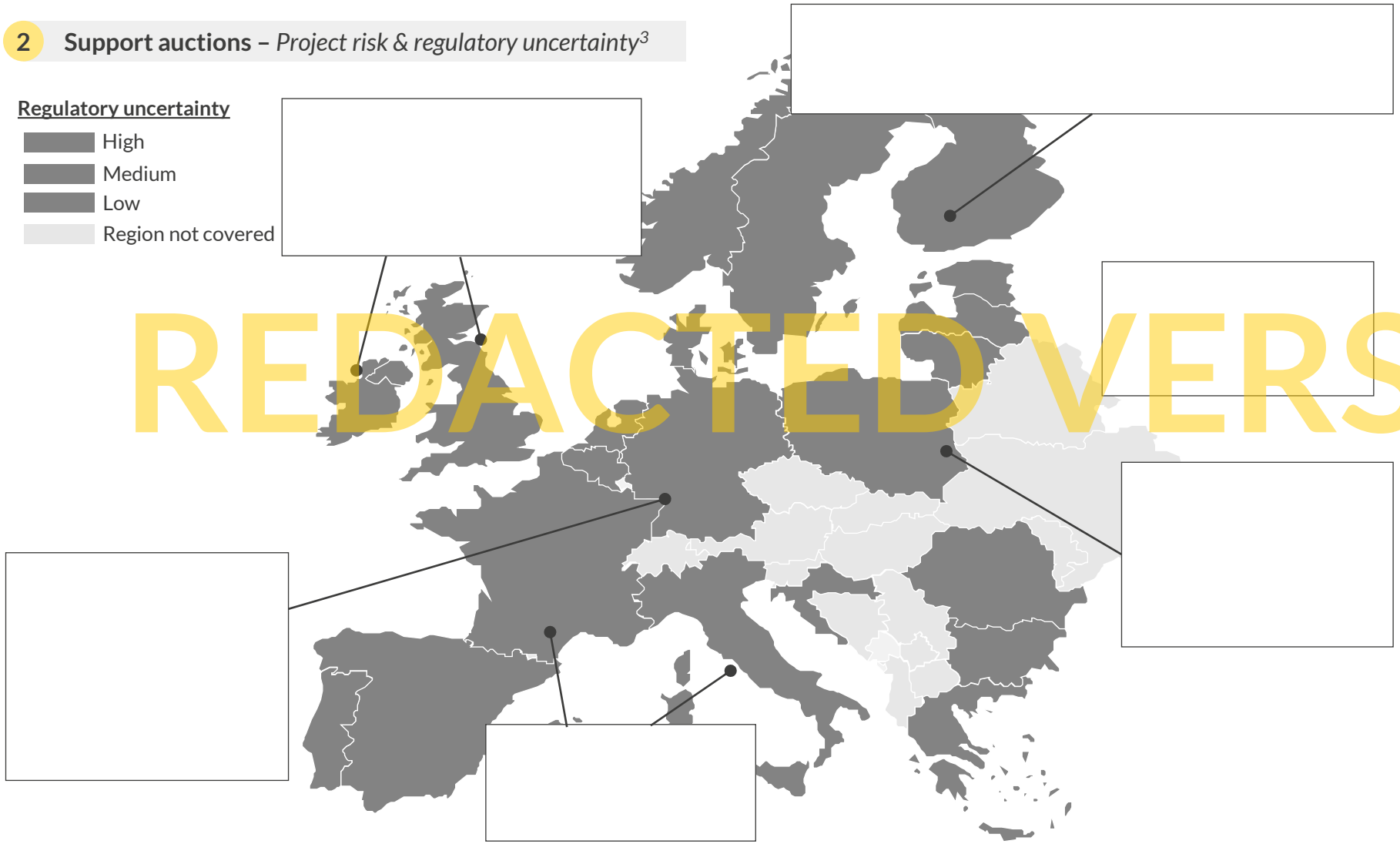
Criteria	High Project Risk	Medium Project Risk	Low Project Risk	Not Applicable
Auction volumes as market %				
Contract length				
Payment structure				
Indexation[1]				

Sources: Aurora Energy Research

In the [redacted], [redacted] and [redacted], offshore wind operators are likely exposed to the highest level of project and regulatory risk

2 Support auctions – *Project risk & regulatory uncertainty*[3]



Source: Aurora Energy Research

Comments

[redacted]

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Developers in [redacted], [redacted] and [redacted] are exposed to the highest risk with respect to the grid delivery model

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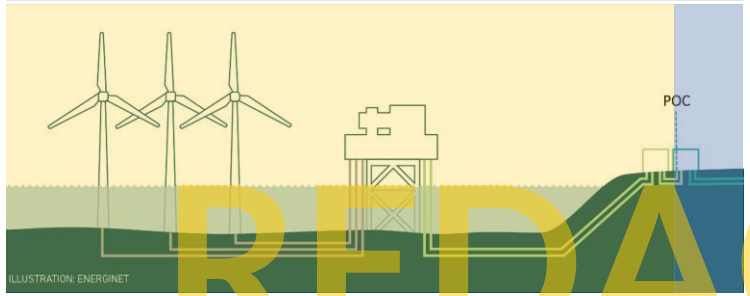
Grid delivery models

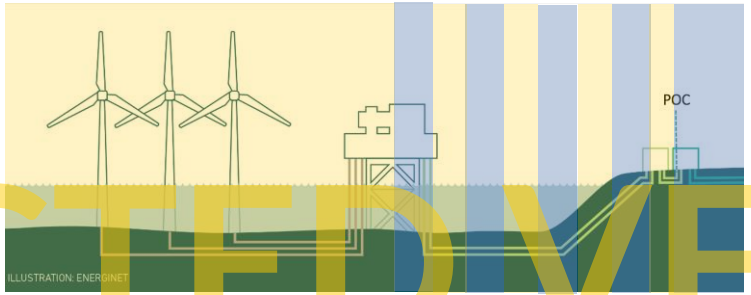
Developer led



- Developer is responsible to build, own and operate the transmission grid augmentation up to the onshore point of connection

Key risks

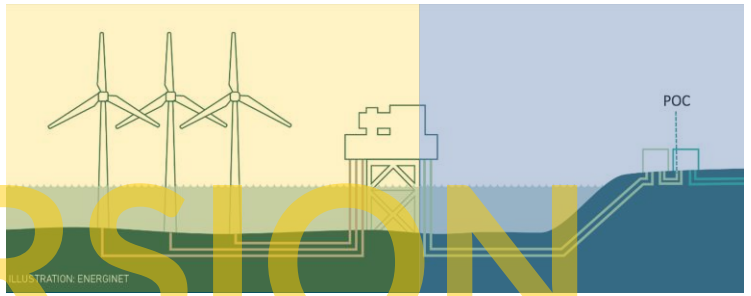
Developer/TSO



- Developer is responsible to build the offshore transmission grid augmentation
- Sells it to the TSO[1] afterwards, which is responsible for the operation

Key risks

TSO



- TSO builds, owns and operates transmission grid infrastructure, up to the offshore wind substation

Key risks

Developer
TSO

Sources: Aurora Energy Research, Energinet

3. Grid Connections: In most countries, the TSO is responsible for building the grid connection up to the substation

Grid development →	Responsibility	Details	Grid connection framework
	TSO		+
			−
			−
	Developer / TSO		+
			−
	Developer		−
	TSO		+
	TSO		+
	Developer / TSO		+
	TSO		+

Transmission System Operator | Private Developer

Comments

Sources: Aurora Energy Research, Government of Ireland DECC, Navigant

3. Grid Connections: There have been various grid delivery models adopted in north-western Europe, across the plan-/delivery-led spectrum

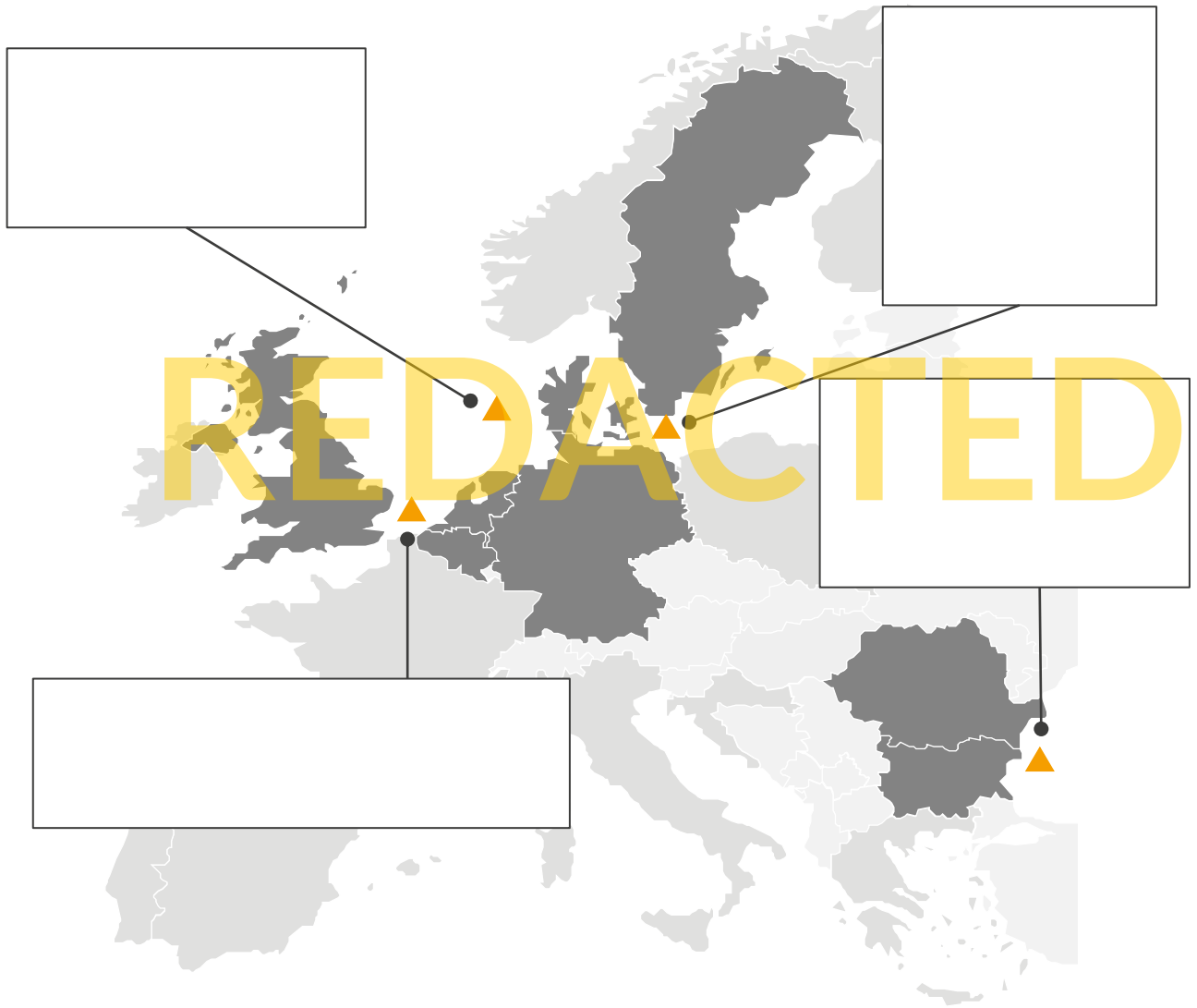
Grid development →	Responsibility	Details	Grid connection framework
	Developer / TSO		+
	Developer		+
			−
	Developer		+
	TSO		+
	TSO		+
	Developer / TSO		+
			−
			−
			−
	TSO		−

Transmission System Operator | Private Developer

Comments

Sources: Aurora Energy Research

Energy Islands propose a



Announced Energy Island Projects in Europe

Project	Developer Region	Capacity	COD	Technology	Regions to be connected

Source: Aurora Energy Research

Case Study: Danish energy islands

The North Sea Energy Island in the North Sea is [redacted]

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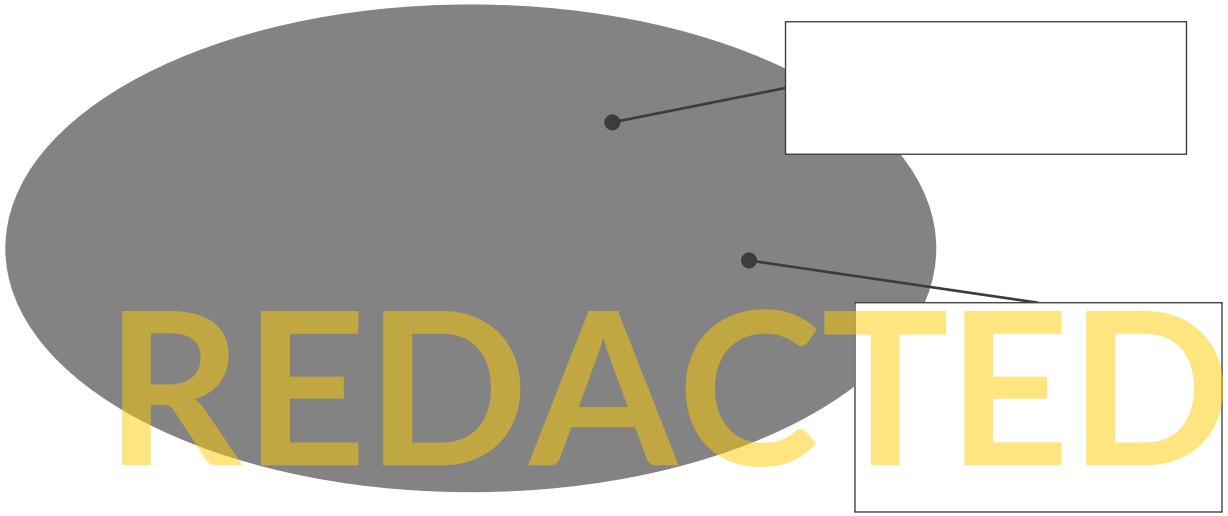
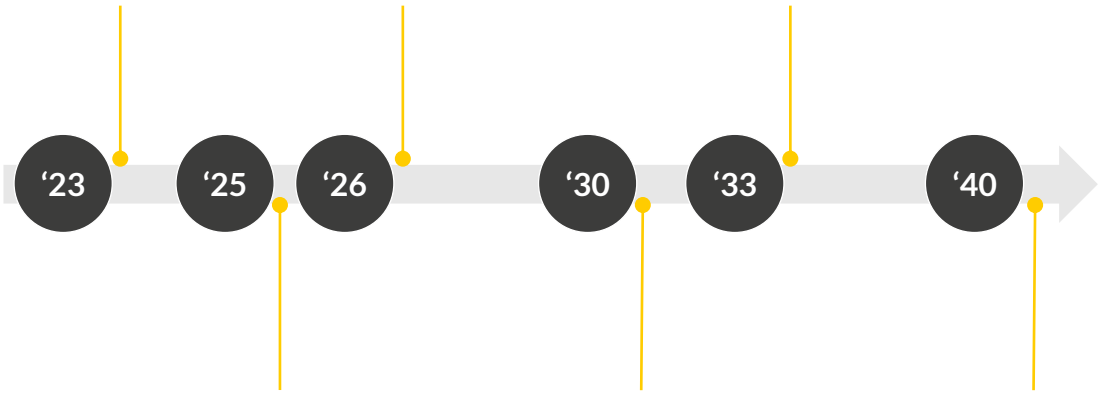
Planned set-up of the North Sea Energy Island



Timeline for the energy island in the North Sea



Planned process of the energy island in the North Sea

[redacted]

Sources: Aurora Energy Research, Danish Energy Agency

Key nuances of grid access across different countries in Europe (1/2)

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Countries	Positives and nuances
Belgium	
Croatia	
Denmark	
Estonia	
Finland	
France	
Germany	
Greece	
Great Britain	
Italy	

Source: Aurora Energy Research

Key nuances of grid access across different countries in Europe (2/2)

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Region	Positives and nuances
Ireland	
Latvia	
Lithuania	
Netherlands	
Norway	
Poland	
Portugal	
Romania	
Spain	
Sweden	

Source: Aurora Energy Research

3. Grid Access: Countries are ranked according to their grid delivery model and grid connection and congestion risks

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Criteria	High Project Risk	Medium Project Risk	Low Project Risk	Not Applicable
Grid delivery model				
Track record				
Grid congestion				

Sources: Aurora Energy Research

3. Grid Access: Scarcity and restrictions around grid connections further complicate offshore deployment particularly in [redacted]

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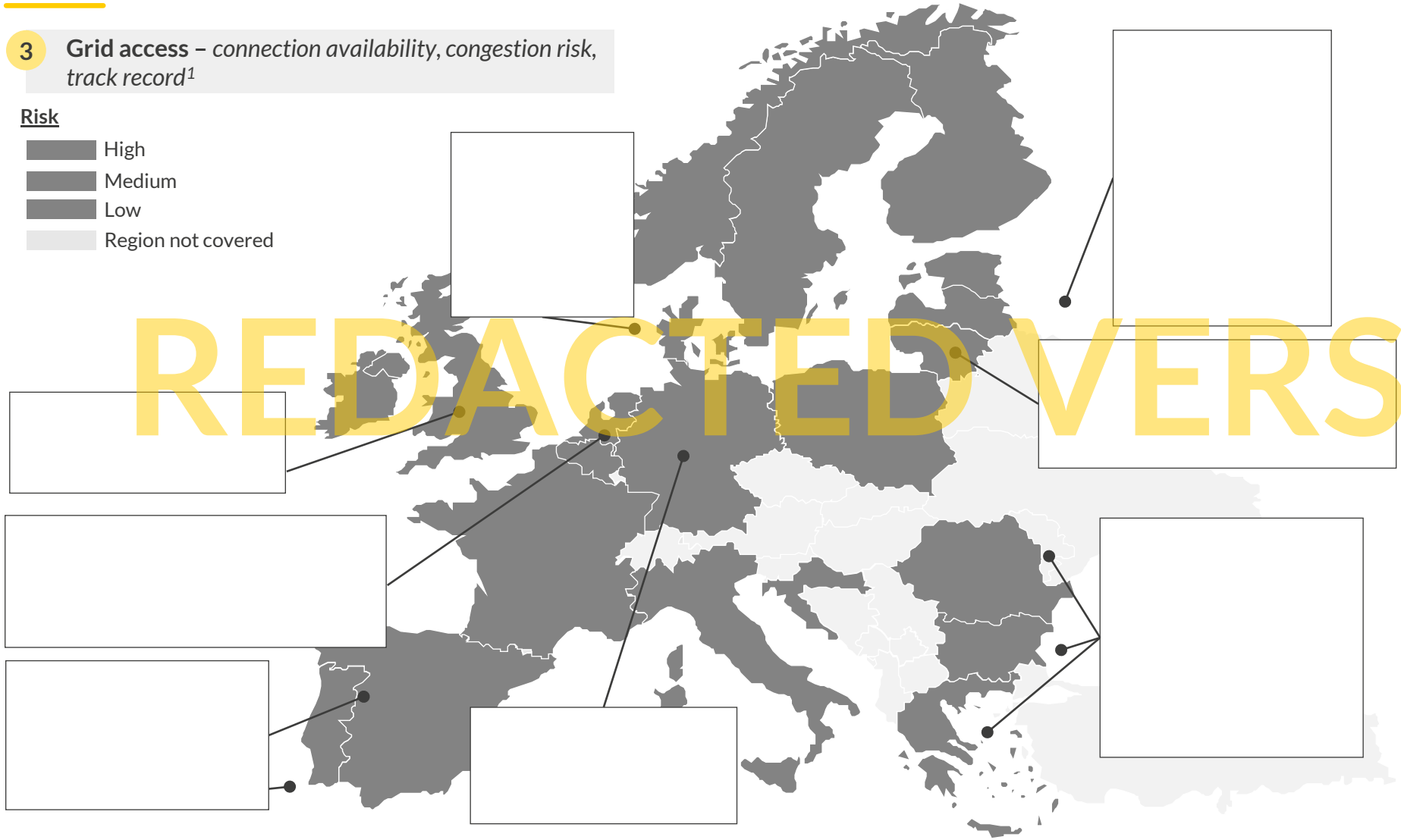
3 Grid access – *connection availability, congestion risk, track record*[1]

Risk

- High
- Medium
- Low
- Region not covered



Source: Aurora Energy Research

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A number of financial indicators can illustrate the financial performance of merchant offshore wind projects

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VARIABLES

Costs

Generation

Revenue

INDICATORS

LCOE

NPV

IRR

Example common errors in discussing the economics of renewable energy projects

-
-

Source: Aurora Energy Research

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Aurora creates an internal view of renewables cost trajectories based on modelling and client feedback

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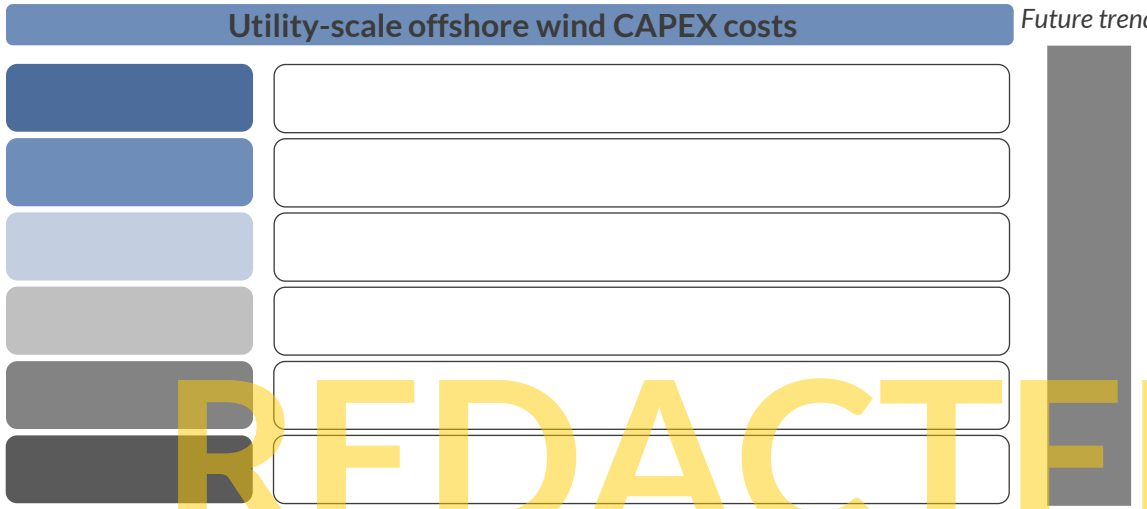
Between 2010 and 2020, the levelised costs of electricity generated has declined by more than [redacted]% for onshore wind, offshore wind, and solar PV. These developments have led renewables to the verge of market parity. However, the timing and the extent to which this occurs will largely depend on how cost declines and technological improvements continue.

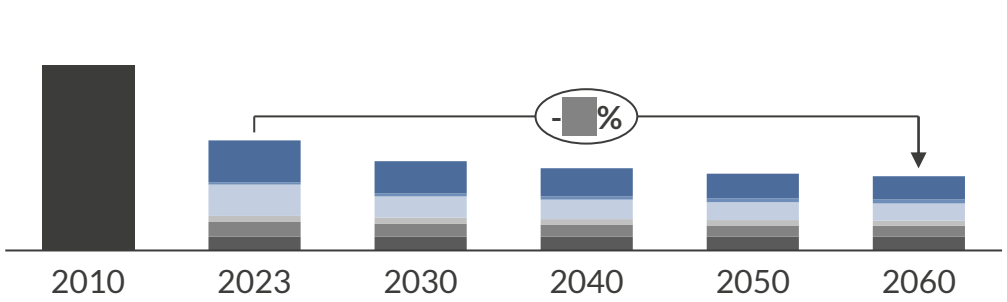
Source: Aurora Energy Research

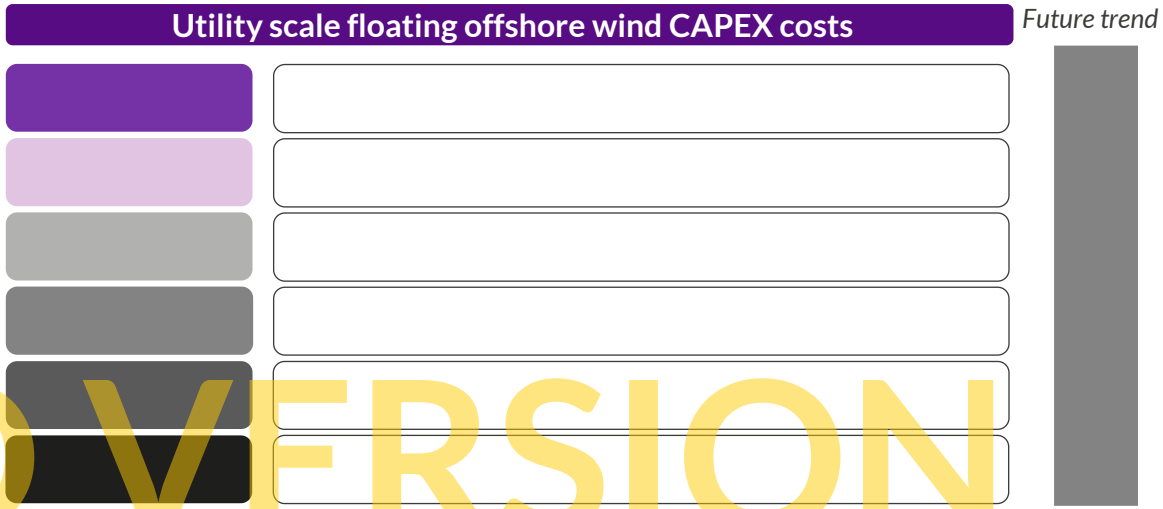
By 2060, total CAPEX for fixed offshore wind will decrease by [redacted]%, reaching [redacted]m €/MW whilst floating assets will reach [redacted]m €/MW

AURORA

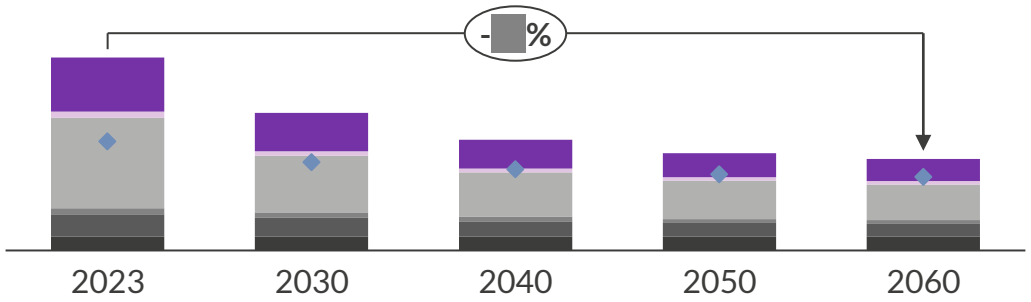


CAPEX-utility scale[1,2]
€m/MW (real 2022)





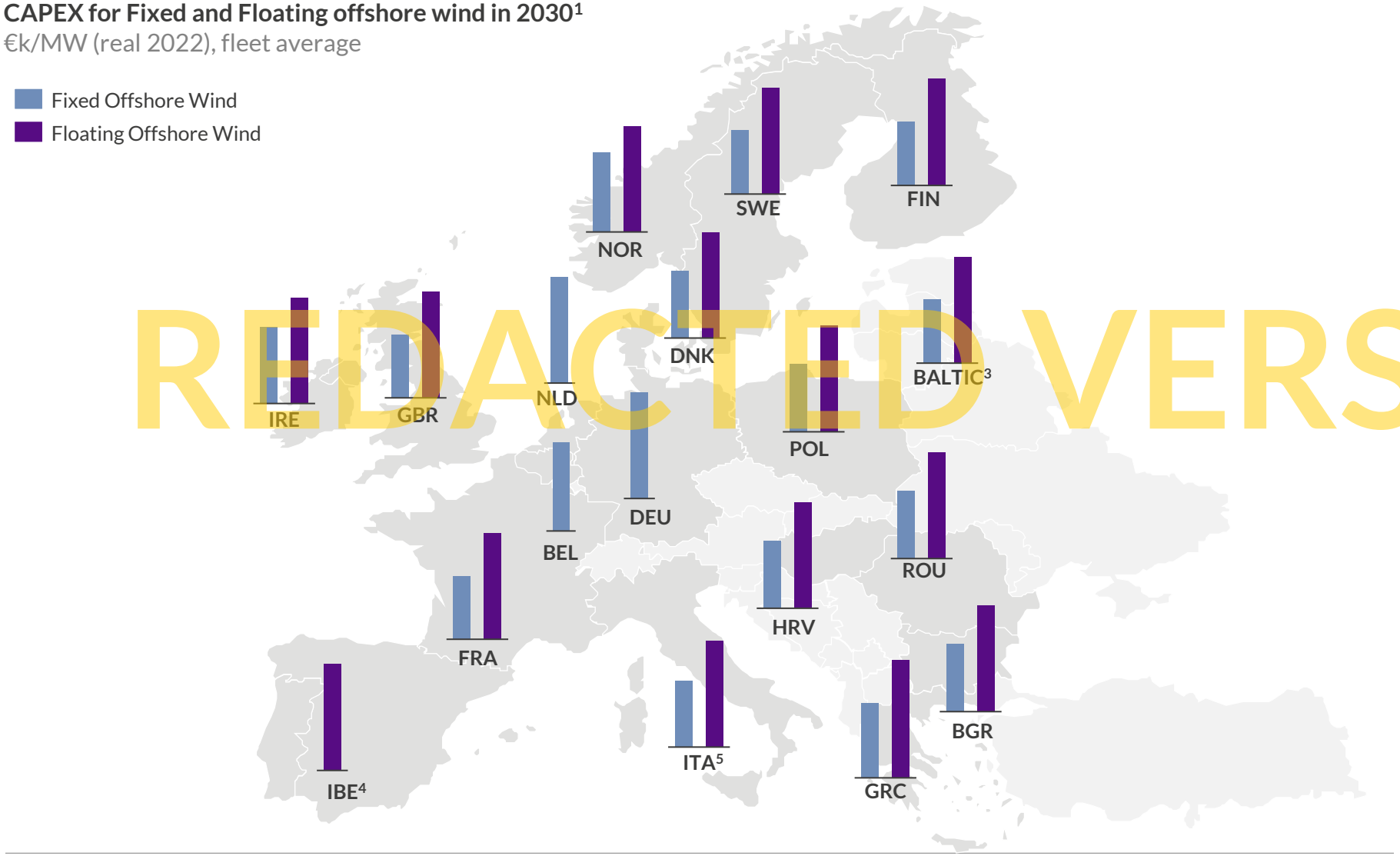
CAPEX utility scale[1,2]
€m/MW (real 2022)



Sources: Aurora Energy Research

CAPEX varies across Europe, primarily driven by differences in grid connection charges, as well as infrastructure & development costs

CAPEX for Fixed and Floating offshore wind in 2030[1]
€k/MW (real 2022), fleet average



Source: Aurora Energy Research

Currently, OPEX costs for floating offshore wind is [redacted]

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Fixed offshore wind OPEX costs | *Future trend*

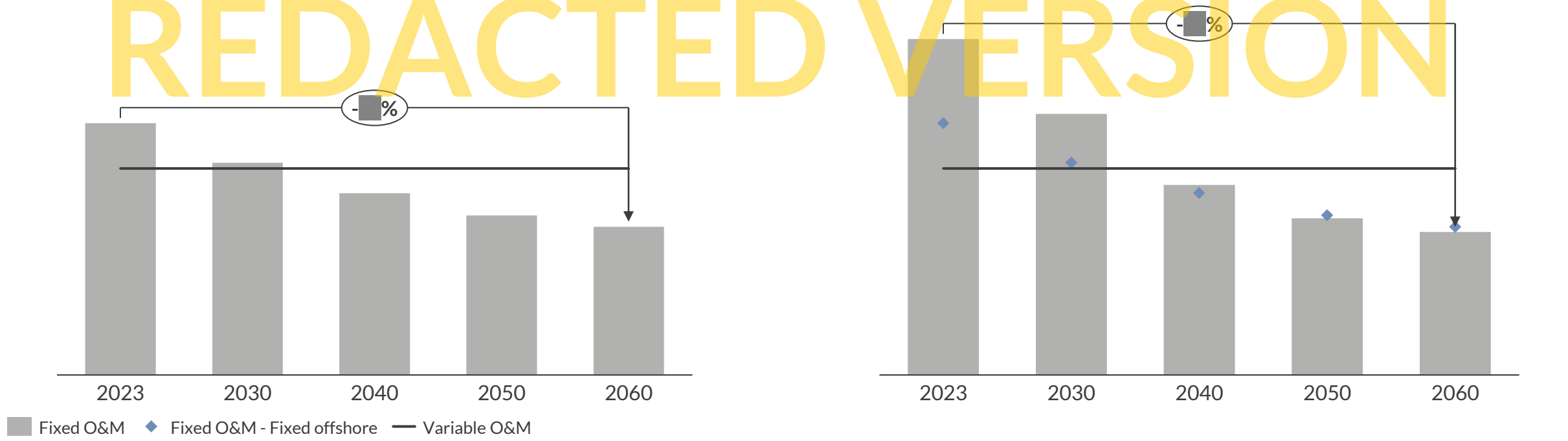
Floating offshore wind OPEX costs | *Future trend*

OPEX[1,2,3]
€k/MW/year (real 2022)

Variable O&M
€/MWh (real 2022)

OPEX[2,3]
€k/MW/year (real 2022)

Variable O&M
€/MWh (real 2022)



Sources: Aurora Energy Research

Imbalance costs vary across regions, with highest average costs in [redacted] at [redacted] €/MWh and the lowest costs in [redacted] at [redacted] €/MWh

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What are imbalance costs?

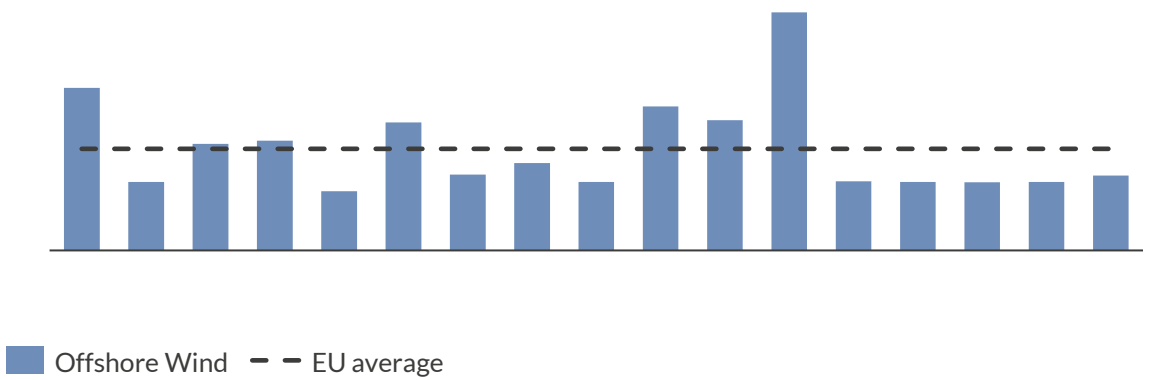
[redacted]

Main drivers for imbalance costs in different countries

Value driver	Description	Likelihood	Effect

Average imbalance cost by region and technology (average 2022-50)

€/MWh (real 2022)



Source: Aurora Energy Research

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Load factors are [redacted]

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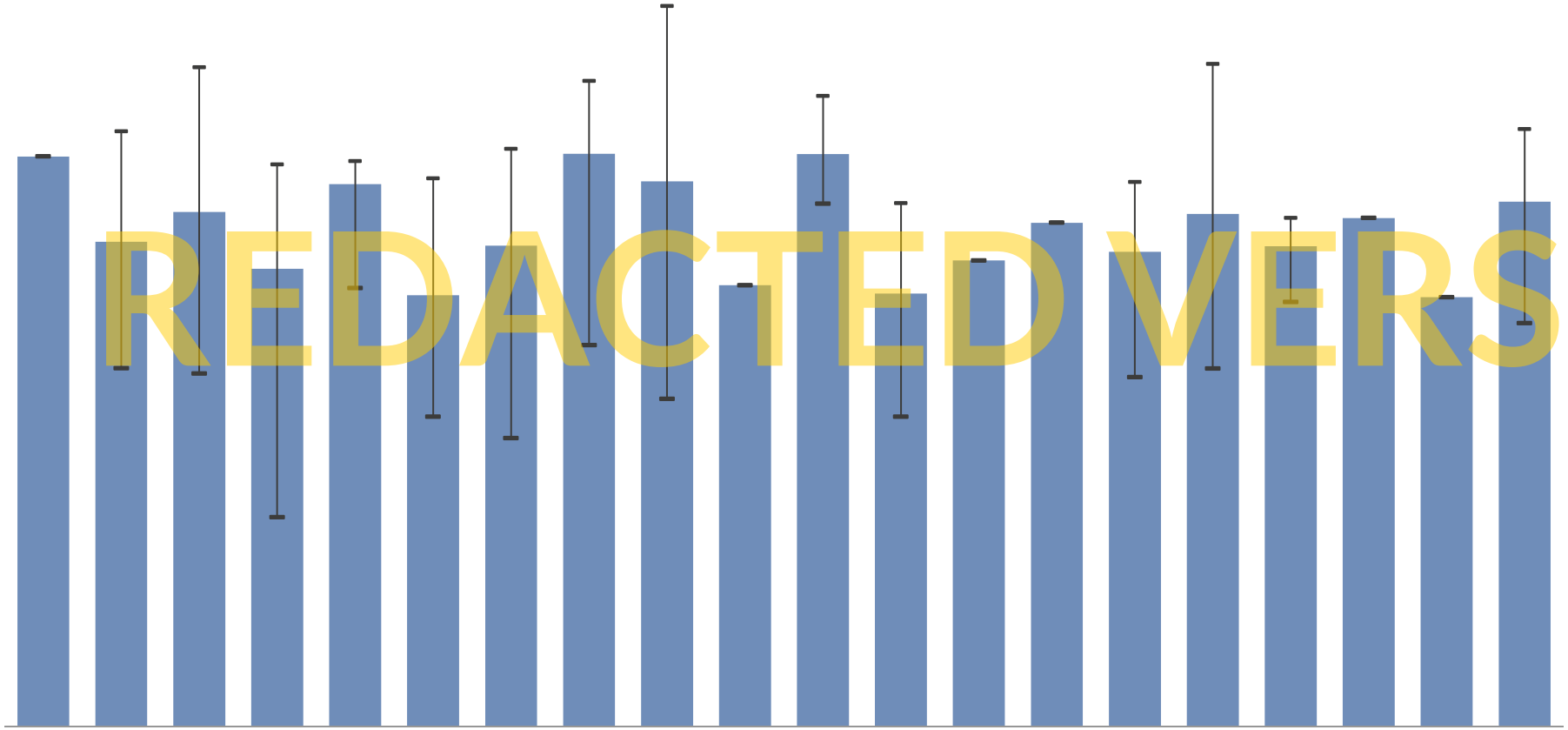
Average, min and max floating and fixed offshore wind load factors in 2030*
%

AMUN



[redacted]

Fleet wide average[1] Load factor range

(*) Detailed country wind data available in Amun.

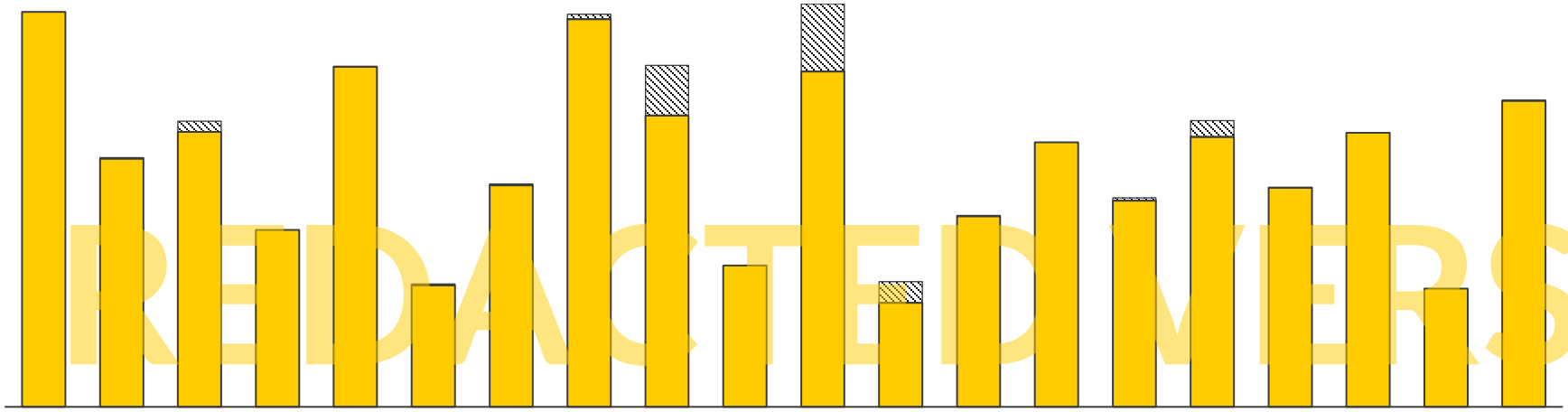
Source: Aurora Energy Research

Curtailment levels

AURORA

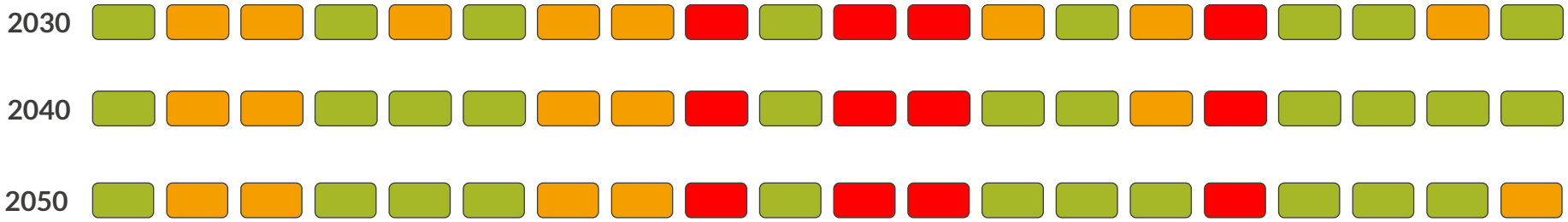
AMUN

Average generation[1] per project 2025-2040
GWh/year



Curtailed generation Actual generation

Curtailment[2]
%



Source: Aurora Energy Research

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Renewables capture price formation is based on marginal pricing and driven by several factors including demand and commodity prices

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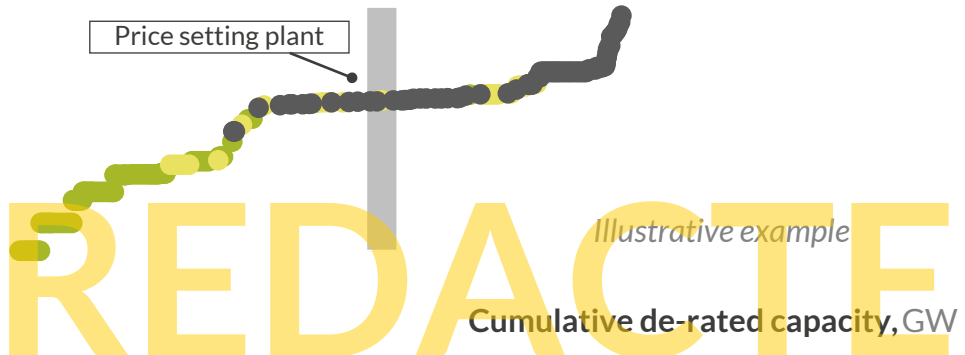
A **Baseload prices are set based on marginal pricing – the marginal plant that meets the final demand sets the power price**

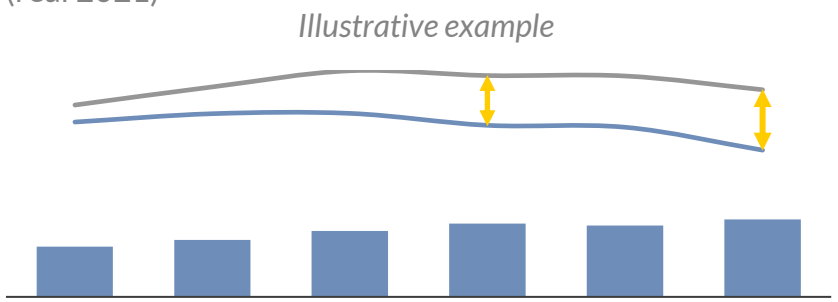
Short run marginal cost
EUR/MWh, (real 2021)



B **Renewables capture prices are set based on the baseload price and cannibalisation from renewables capacity buildout**

Electricity price
EUR/MWh (real 2021)

Offshore wind penetration[1]
%



What are the key factors that affect power prices?

1 **Demand**

2 **Fuel prices**:

3 **Carbon prices**:

4 **Capacity buildout**:

Source: Aurora Energy Research

The generation mix and load factors affect baseload market prices and capture price discounts across Europe

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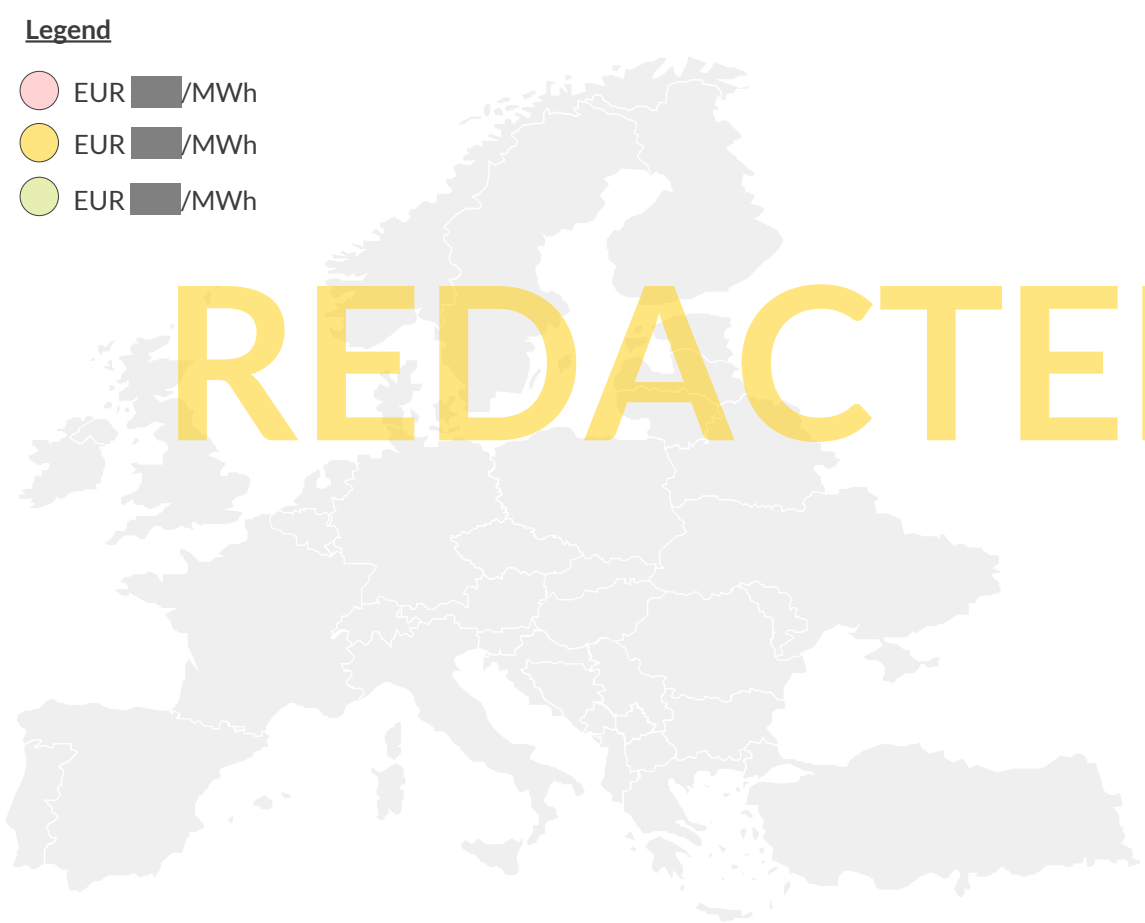
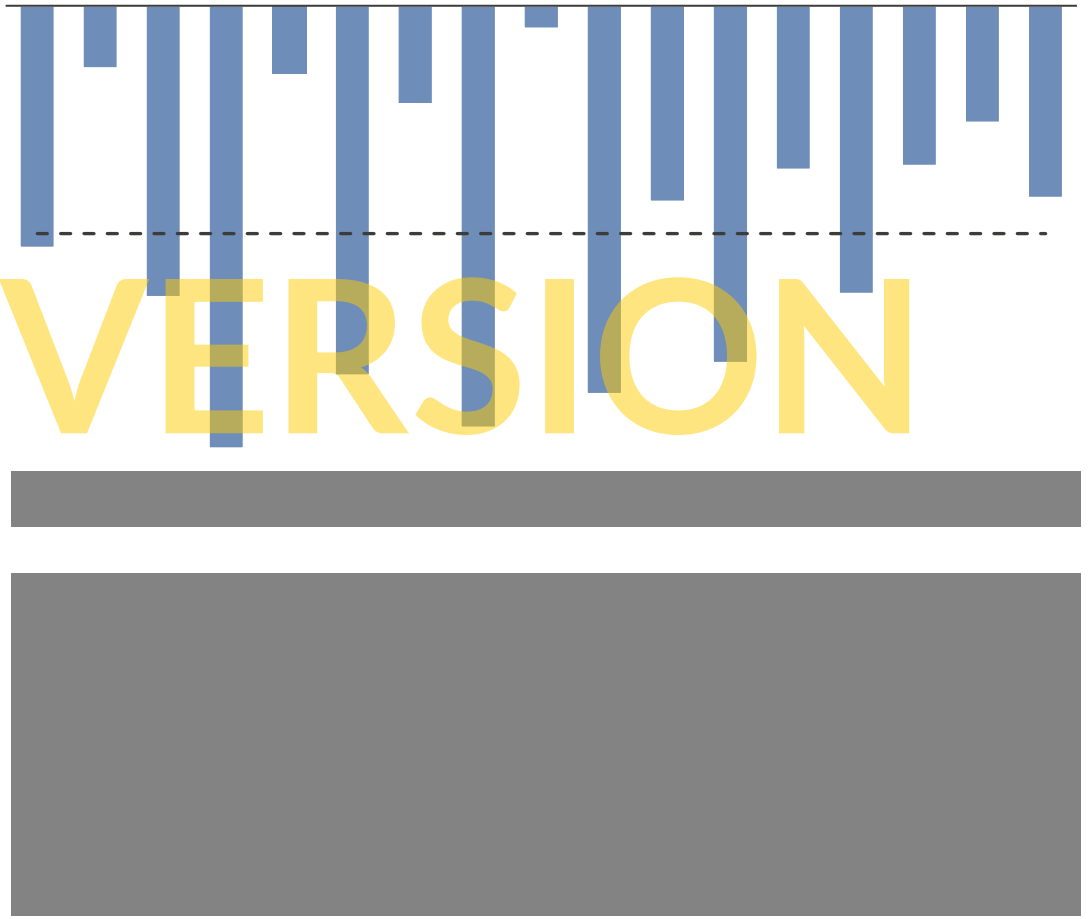
Average baseload price (2025 – 2040)
EUR/MWh (real 2021), Central scenario



Offshore wind capture price[1] discount to baseload price in 2030
%, Central scenario



Sources: Aurora Energy Research

Markets with a large pipeline of projects, such as [redacted] reflect a larger range of site-specific capture prices

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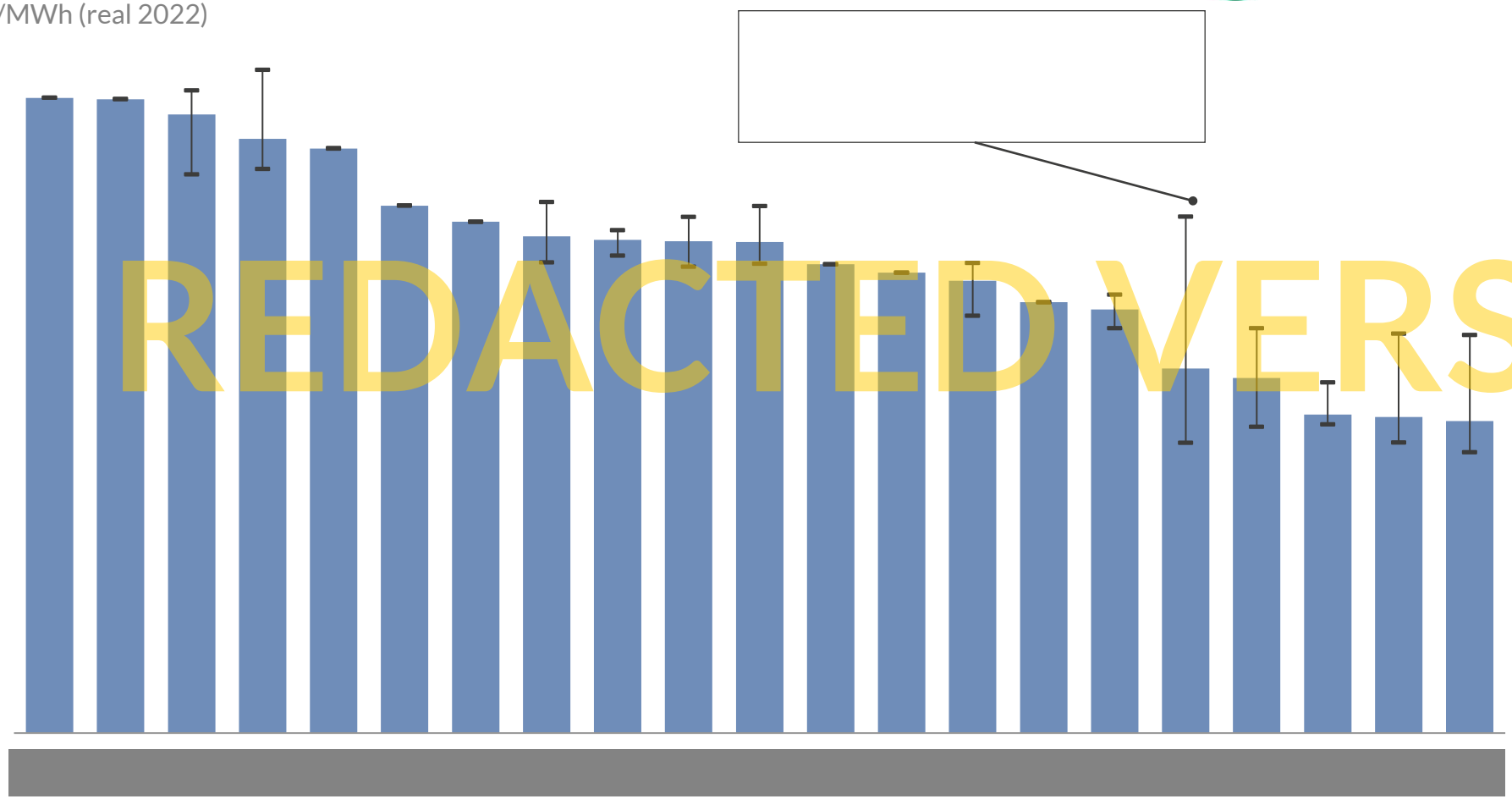
AMUN

Offshore wind site-specific average capture prices 2025-2050[2]
€/MWh (real 2022)



Sources: Aurora Energy Research

Other revenues: GO prices are expected to reach between [redacted] €/MWh and [redacted] €/MWh by 2040, depending on demand growth and willingness to pay

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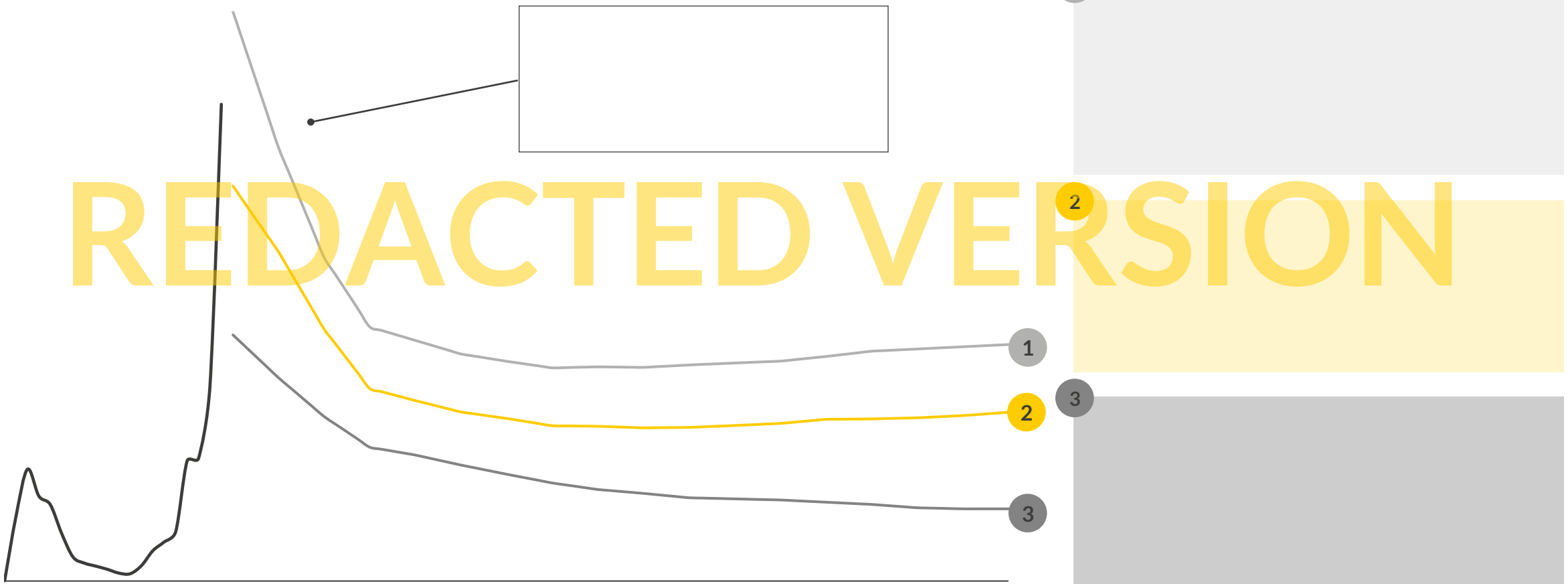
Forecast as of January 2023

Annual GO price[1]
€/MWh (real 2021)



Source: Aurora Energy Research

Agenda

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To simulate the outcome of two-way CfD auctions, we take into account plant-specific economics and the subsidy regulation to calculate minimum bids

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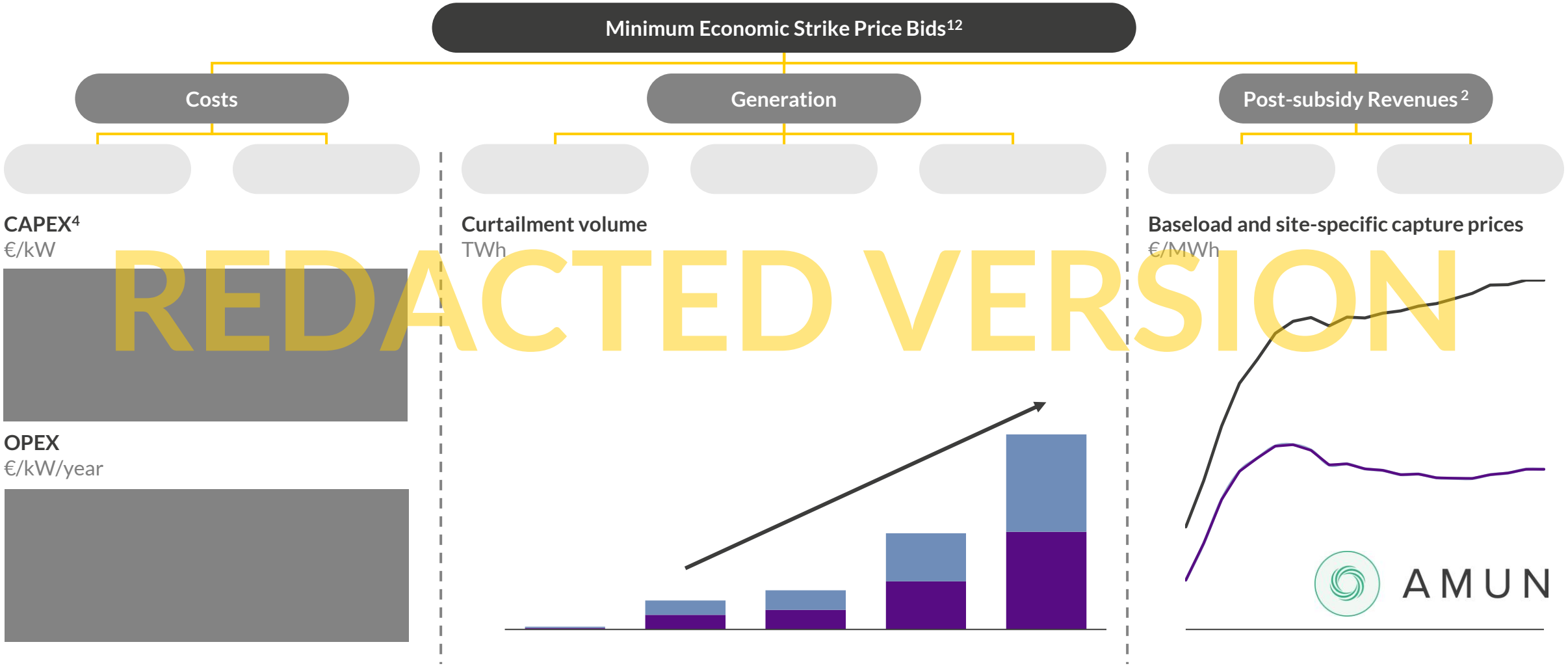

Source: Aurora Energy Research

We simulate auction prices for those markets in which there is an identifiable pipeline of projects, and announced auction volumes

Agenda

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Great Britain: If no constraints are breached, all qualified projects are awarded their Administrative Strike Price, otherwise, a competitive auction is triggered

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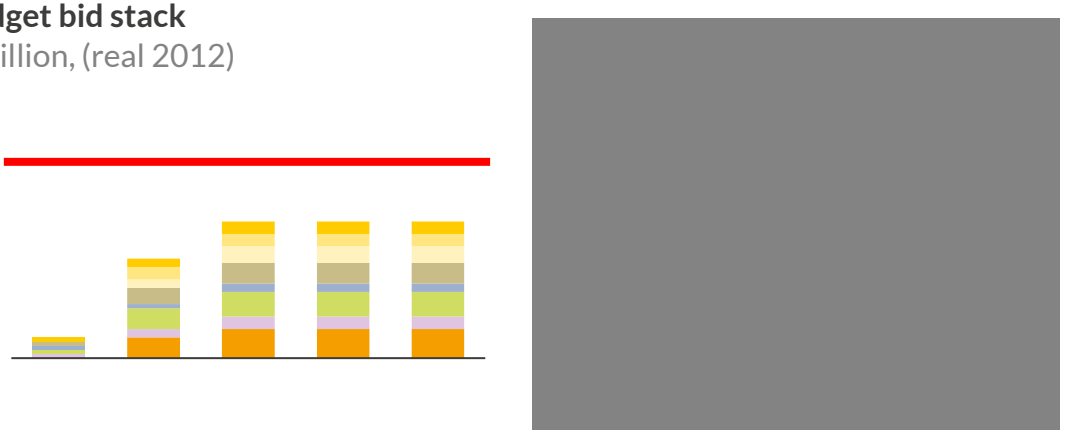
CfD AR5 Budget, in monetary terms

	Delivery and Valuation Years				
Budget (£ million, real 2012)	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**
Pot 1					
Pot 2	-				
- Maximum for Tidal Stream	-				

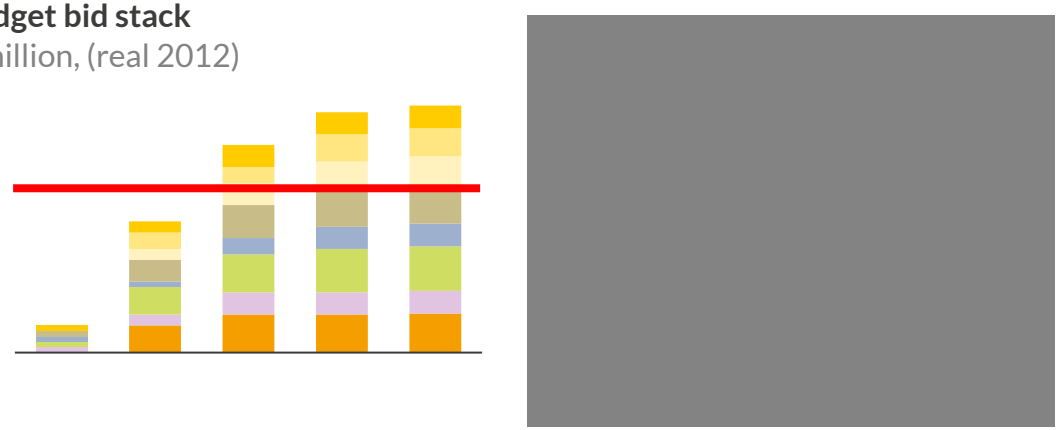
Unconstrained Allocation - Pot 1 example, no constraints breached

Budget bid stack
£ million, (real 2012)



Constrained Allocation - Pot 1 example, budget breached

Budget bid stack
£ million, (real 2012)



Delivery Year Valuation Year Budget/capacity cap

Sources: Aurora Energy Research, BEIS, NGESO

Great Britain's AR5 auction has £170m budget, with [redacted] GW of offshore wind capacity eligible to participate at average strike price bids of [redacted] £/MWh

AURORA

1 9 projects could be eligible to participate in the next AR5 round auction, with a total of [redacted] GW capacity across all projects

2 AR5 minimum strike price bids to range from [redacted] – [redacted] €/MWh, with an average price of [redacted] €/MWh across all eligible projects.

Offshore wind projects eligible for AR5
GW

Aurora 2023 estimated minimum economic strike price bids
€/MWh, real 2022

Average

English Channel & South Coast
East Scotland
North Sea
Irish Sea
Celtic Sea
Planning permission granted
Awaiting decision

Sources: Aurora Energy Research, EirGrid

Great Britain: If a competitive auction is triggered, strike price bids for offshore wind in AR6 are expected as low as [redacted] €/MWh

Pot 1 estimated fixed offshore wind 2024 minimum bid prices[1]
€/MWh, real 2022

[redacted]

Pot 2 estimated floating offshore wind 2024 minimum bid prices
€/MWh, real 2022

[redacted]

Estimated procurement[2]
GW

Capacity
MW

[redacted]

Auction year

Estimated marginal bid
€/MWh, real 2022

Capacity
MW

[redacted]

Lowest minimum economic bids by project

Fixed offshore

Rank[2]	Projects
1	
2	
3	
4	
5	

Floating offshore

Rank[2]	Projects
1	
2	
3	
4	
5	

[redacted]

Source: Aurora Energy Research

Great Britain: A low wind year sensitivity can lead to higher returns than Aurora Central for offshore wind, lowering min bids required to recover costs

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1 Wholesale prices tend to be negatively correlated with offshore wind output…

Wholesale price[1]
£/MWh (real 2022)

2 … therefore, a low wind year…

Load factor[2]
%

3 … is likely to be matched with higher capture prices…

Offshore wind uncurtailed capture price
£/MWh (real 2022)

4 …which actually leads to higher wholesale revenues

Offshore wind wholesale gross revenues[3]
£/kW (real 2022)

Source: Aurora Energy Research

Ireland's ORESS 1 auction awarded contracts to four offshore wind projects, with [redacted] GW procured and average strike price bids of [redacted] €/MWh

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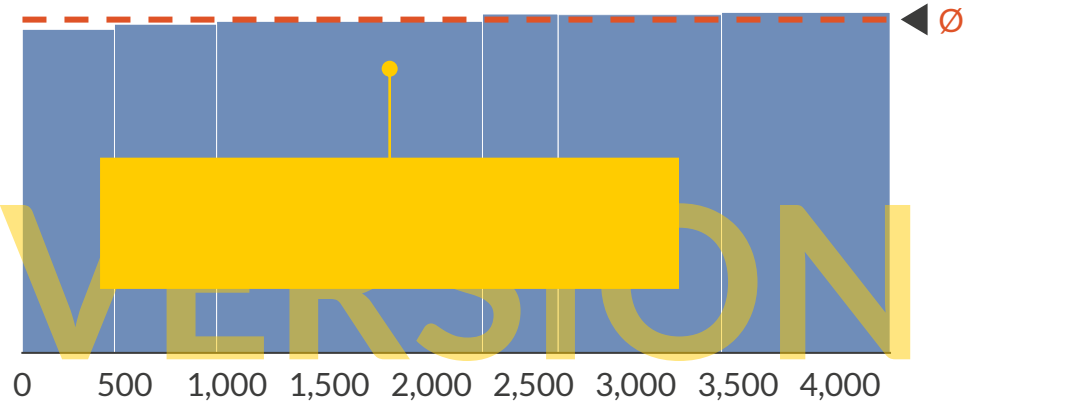
1 Six projects were eligible to participate in the first ORESS auction in Ireland, with [redacted] GW successful across four projects

Offshore wind projects eligible for ORESS 1
GW

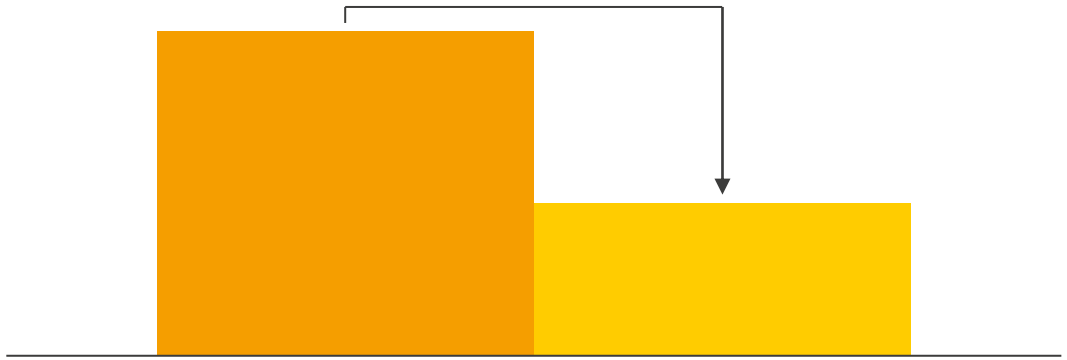
[redacted]

2 ORESS 1 auction cleared at an average strike price of [redacted] €/MWh, in line with Aurora's expectations (refer next slide)

Aurora 2023 estimated minimum economic strike price bids
€/MWh, real 2022



Average strike price bids
€/MWh, real 2022



Sources: Aurora Energy Research, EirGrid

Ireland has planned [redacted] GW worth of additional offshore wind capacity in auctions [redacted]

Estimated 2024 minimum bid prices[1]
€/MWh, real 2022

[redacted]

Capacity
MW

Estimated procurement
GW

Estimated marginal bid
€/MWh

[redacted]

Auction year

Lowest minimum economic bids by project	
Rank	**Projects**
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

[redacted]

Source: Aurora Energy Research

Poland's 2020 offshore wind policy has been

2025 estimated minimum bid prices[1]
€/MWh, real 2022

Capacity
MW

Estimated procurement
GW

Estimated marginal bid
€/MWh (real 2022)

Auction year

Lowest minimum economic bids by project	
Rank[2]	**Projects**
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Source: Aurora Energy Research

Under a two-way CfD, as proposed by the European Commission, bids in Germany would range from [redacted] to [redacted] €/MWh

2023 estimated minimum bid prices
€/MWh, real 2022

[redacted]

Capacity
MW

Estimated procurement
GW

Estimated marginal bid
€/MWh

[redacted]

Auction year

Lowest minimum economic bids by project

Rank[2]	Projects
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

[redacted]

Source: Aurora Energy Research

A new draft version of the Italian subsidy scheme FER2 was published in August, allocating [redacted] GW for floating offshore wind

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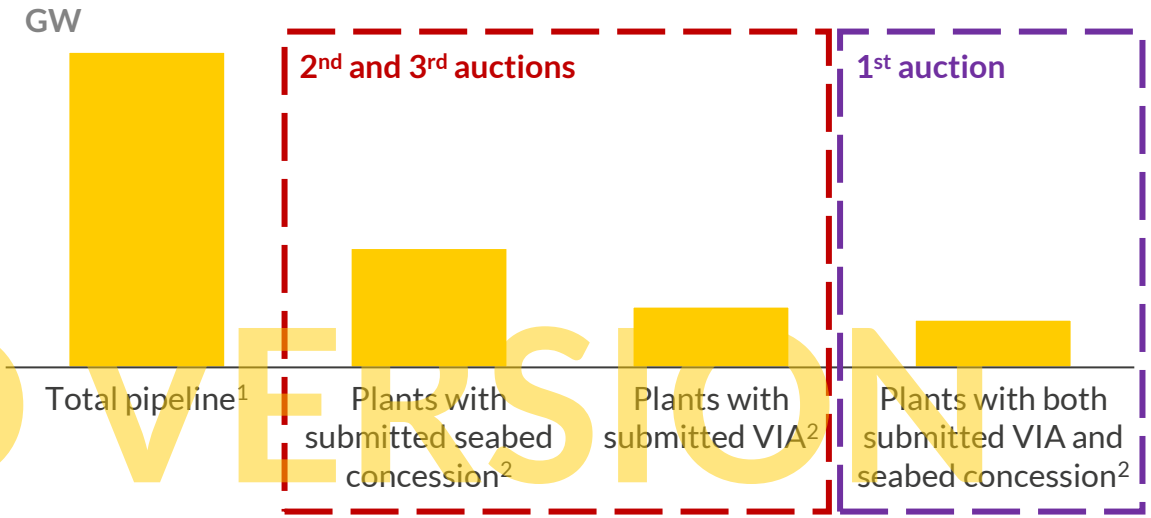
Italy FER2 draft highlights

[redacted]

Offshore capacity by authorisation status



[redacted]

Sources: Aurora Energy Research, MiTE

Italy auction bid prices are expected to be highest amongst European regions, due to lower load factors and higher costs

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2025 Italy minimum bid price stack

€/MWh

Capacity
MW

Lowest minimum economic bids by project

Rank[2]	Offshore Wind
1	
2	
3	
4	
5	

Italy

2025 Greece minimum bid price stack

€/MWh

Capacity
MW

Rank[2]	Offshore Wind
1	
2	
3	
4	
5	

Greece

Sources: Aurora Energy Research, DCCAE

Offshore wind projects in Spain and France to clear with competitive bids as low as [redacted] and [redacted] €/MWh, respectively

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2025 Spain minimum bid price stack

€/MWh

Capacity
MW

Lowest minimum economic bids by project

Rank[2]	Offshore Wind
1	
2	
3	
4	
5	

Spain[1]

2025 France minimum bid price stack

€/MWh

Capacity
MW

Rank[2]	Offshore Wind
1	
2	
3	
4	
5	

France

Sources: Aurora Energy Research, DCCAE

Despite no subsidy support schemes currently in place in Finland and Norway, minimum bid prices could reach as low as [redacted] - [redacted] €/MWh

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2025 Finland minimum bid price stack

€/MWh

Capacity
MW

Lowest minimum economic bids by project

Rank[2]	Offshore Wind
1	
2	
3	
4	
5	

Finland

2025 Norway minimum bid price stack[1]

€/MWh

Capacity
MW

Rank[2]	Offshore Wind
1	
2	
3	
4	
5	

Norway

Sources: Aurora Energy Research, DCCAE

Sweden has a large pipeline of projects with minimum bids between [redacted] and [redacted] €/MWh

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2025 Sweden minimum bid price stack

€/MWh

[redacted]

Capacity
MW

Lowest minimum economic bids by project

Rank[2]	Offshore Wind
1	
2	
3	
4	
5	

Sweden

[redacted]

2025 Denmark minimum bid price stack

€/MWh

[redacted]

Capacity
MW

Rank[2]	Offshore Wind
1	
2	
3	
4	
5	

Denmark

[redacted]

Sources: Aurora Energy Research, DCCAE

Estonia has a large pipeline of projects with auction bids between [redacted] - [redacted] €/MWh

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2025 Estonia minimum bid price stack

€/MWh

[redacted]

Capacity
MW

Lowest minimum economic bids by project

Rank[2]	Offshore Wind
1	
2	
3	
4	
5	

Estonia

[redacted]

Sources: Aurora Energy Research, DCCAE

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This is a redacted sample of the European Offshore Wind Markets Attractiveness Report.
If you are interested in the full report, contact Alex Hutcheson, (alex.hutcheson@auroraer.com).

Zero bids have been driven by auction design and project economics, however EU reforms may see regions forced to adopt 2-way CfD design moving forward

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	Drivers of zero bids	Countries[1]
Project-level	Location	
Project-level	Economies of scale	
Project-level	Lifetime	
Country-level	Grid connection costs	
Country-level	Auction design	

To evaluate projects in a zero-bidding world, European governments have developed point systems based on additional qualitative criteria

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Qualitative criteria in selected European offshore wind auctions

Market	Non-price criteria (%)	Description

[redacted]

Tenders for pre-examined [3] sites in Germany are now [redacted]

[redacted]

Sources: WindSeeG, Aurora Energy Research, WindEurope

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Aurora forecasts LCOEs based on total asset lifetime costs and projected energy output

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LCOE is an economic tool that allows comparison between generation projects which use different technologies and locations.

Levelised cost of electricity (LCOE) = *Total discounted lifetime costs* / *Total discounted lifetime energy output*

Lifetime in years (T)

$$LCOE = \frac{\sum_{t=0}^{t=T} \frac{CAPEX_n + OPEX_n}{(1+i)^t}}{\sum_{t=0}^{t=T} \frac{Capacity * Load\ factorn * \ 365 \ * 24}{(1+i)^t}}$$

Total cost in EUR

Total Energy in MWh

Discount Rate or WACC (i)

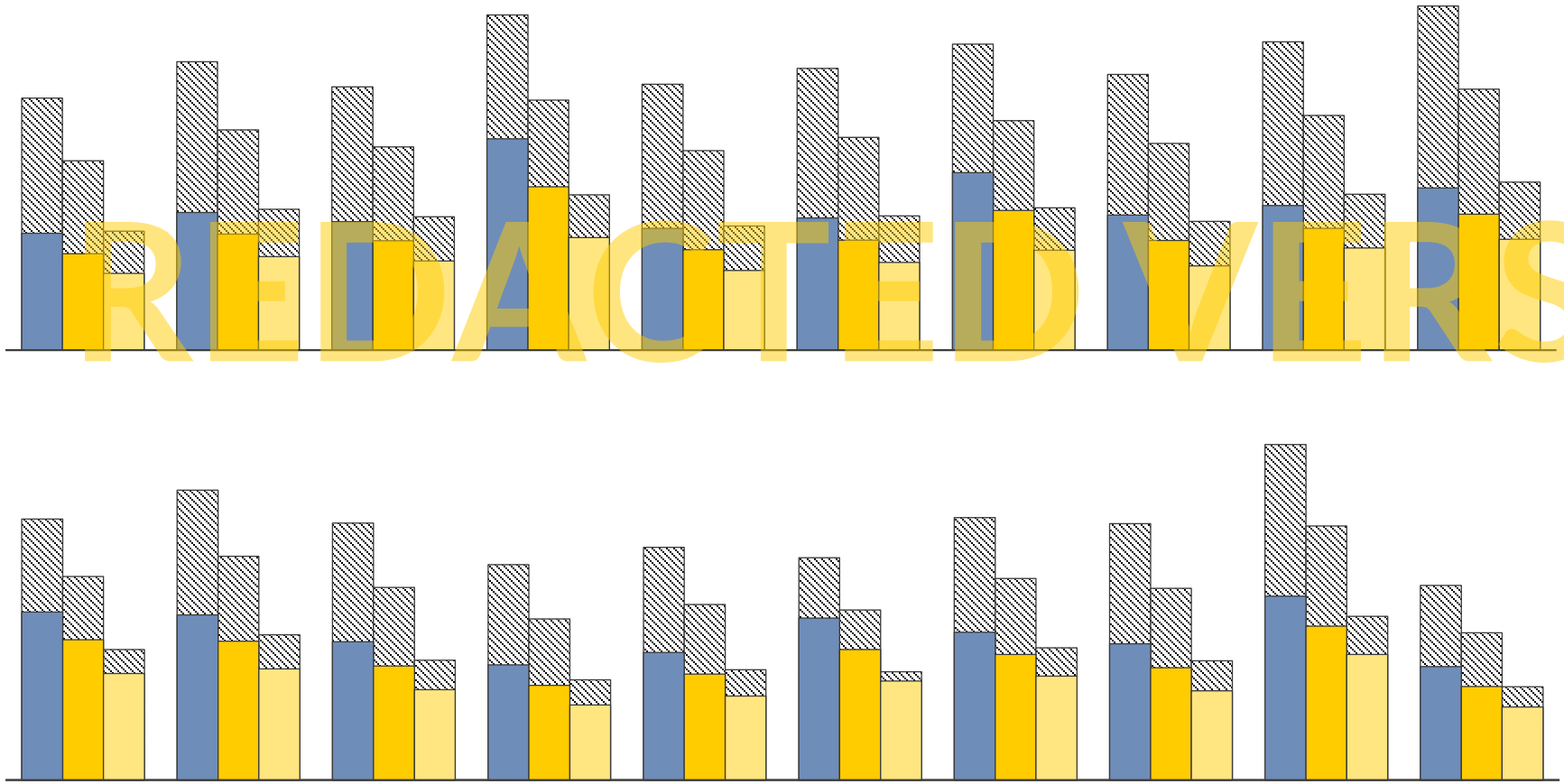
Key Drivers of LCOE

1. CAPEX
2. OPEX
3. Load Factor
4. Discount Rate or WACC
5. Lifetime

Source: Aurora Energy Research

LCOE expected to decrease over time for offshore wind across all regions for both fixed and floating assets

Fleet average LCOEs Fixed and Floating Offshore Wind 2025, 2030, and 2050
€/MWh (real 2022)



Source: Aurora Energy Research

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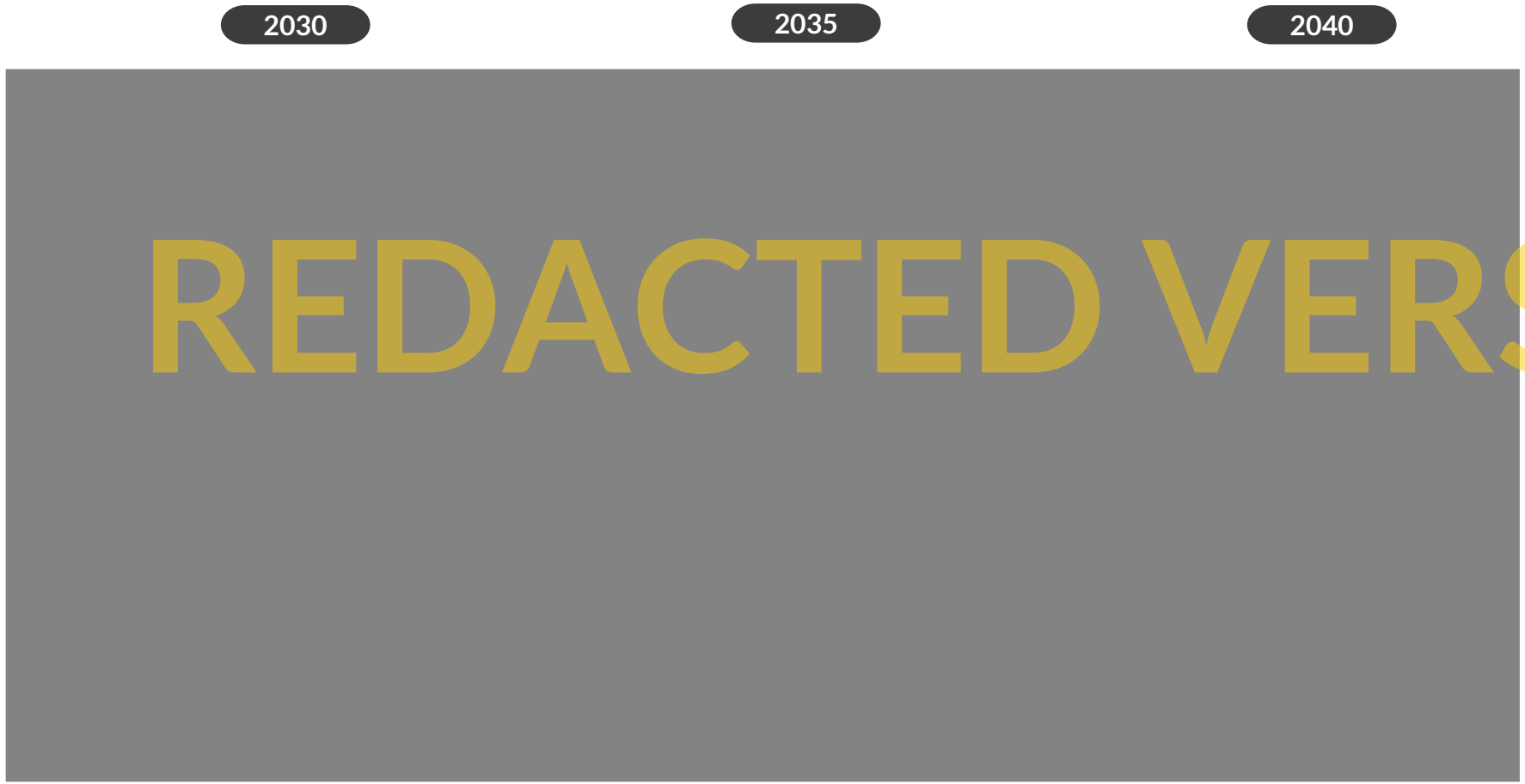
Due to decreasing capture prices and shorter lifetime of assets, the net present value of brownfield assets decreases across all markets

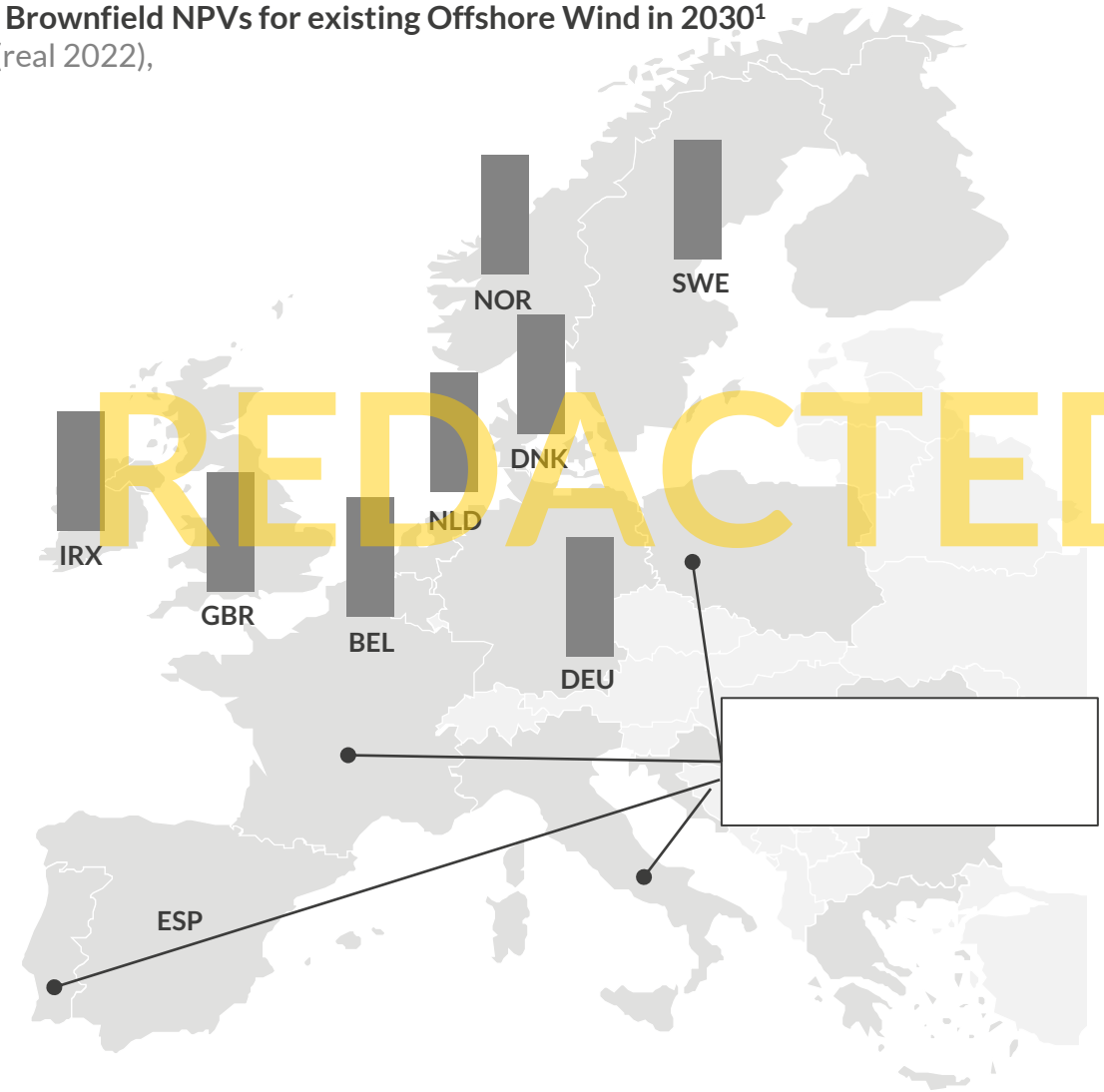
Net Present Value of brownfield projects for 2030, 2035 and 2040 per COD year
€mn/MW (real 2022)



Sources: Aurora Energy Research

Projects in [redacted] offer largest investment opportunity, due to [redacted]

Total Brownfield NPVs for existing Offshore Wind in 2030[1]
€mn (real 2022),



Ranking of country NPVs for Offshore Wind in 2030[1]

Rank[2]	Offshore wind[3]
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Source: Aurora Energy Research

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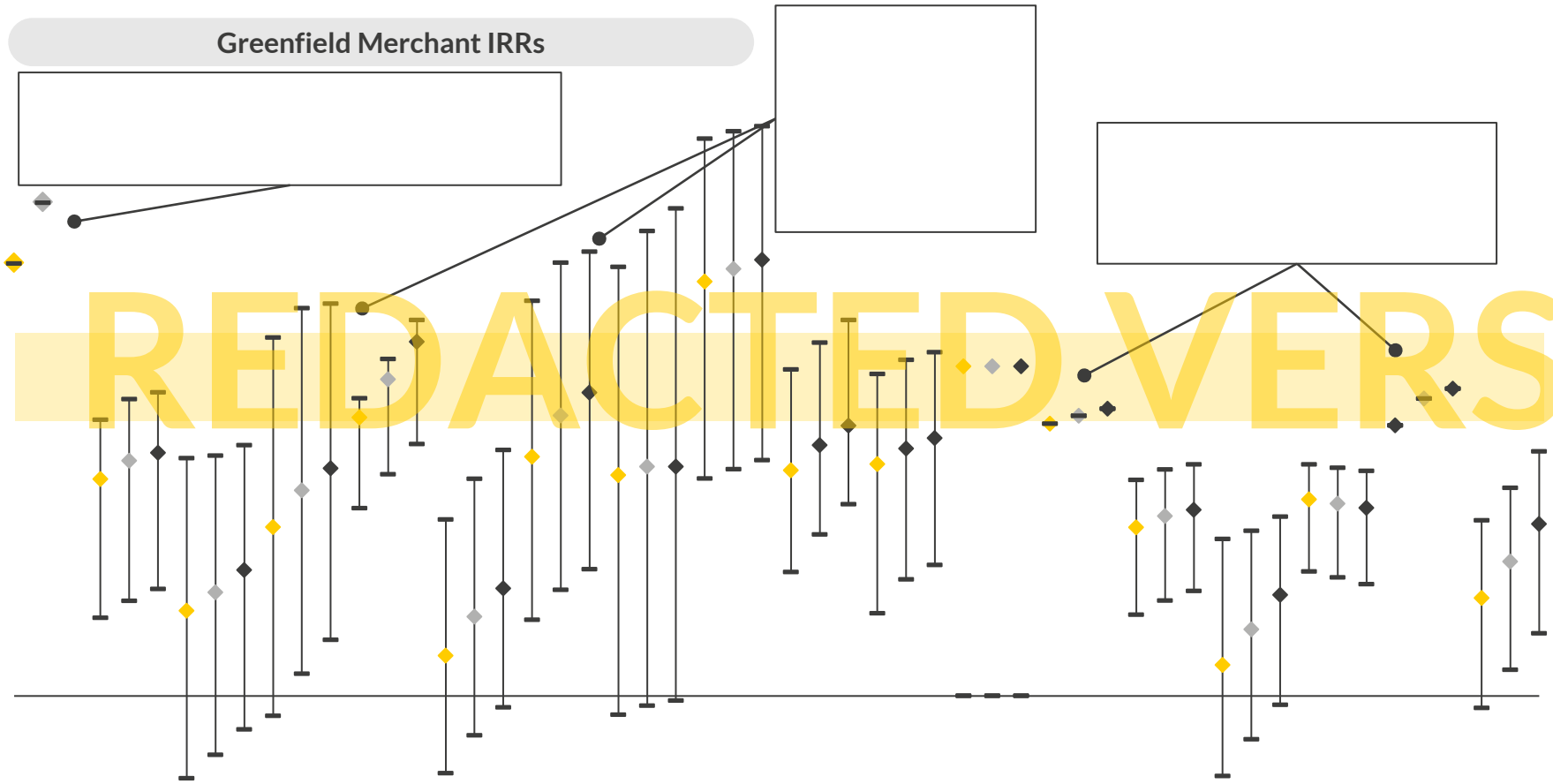
Range of Internal Rate of Returns per country for 2030, 2035 and 2040

%



Source: Aurora Energy Research

Fluctuations in key drivers such as [redacted] are enough to tip projects above or below the hurdle rate

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Merchant project IRR sensitivities (in 2030)
%, pre-tax (real 2022)

IRR, base case *(region)*	[redacted]% *(European average)*
Load factor *(+/- 10%)*	
Capture Price *(+/- 10%)*	
CAPEX *(+/- 10%)*	
OPEX[1] *(+/- 10%)*	
Lifetime *(+/- 3 years)*	
GoOs *(+/- 10%)*	
Imbalance costs *(+/- 10%)*	

[redacted]

Source: Aurora Energy Research

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An Energy Island can improve the business case by reducing curtailment and offering additional revenue streams

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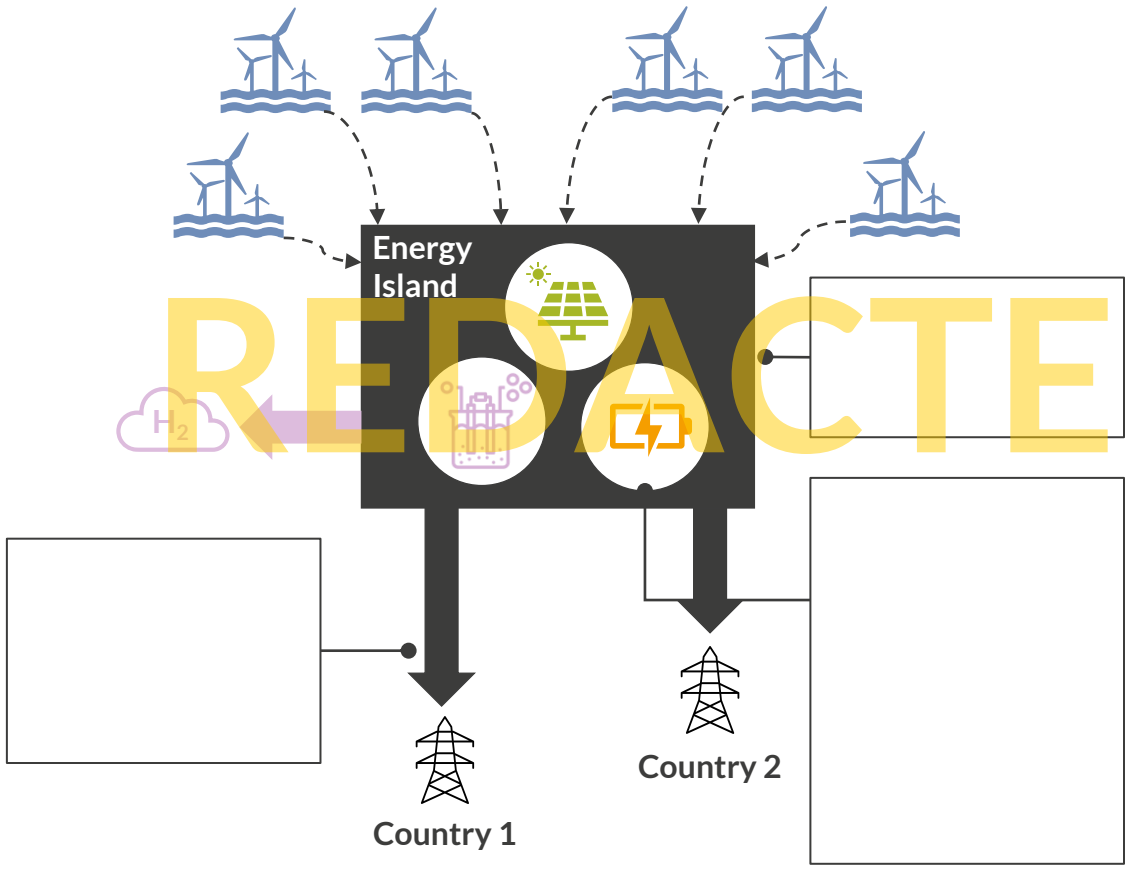
Illustration of a potential Energy Island set up



1. Co-location of offshore wind asset and battery
2. Co-location of offshore wind, solar and battery
3. Co-location of offshore wind with electrolyser

Sources: Aurora Energy Research

Moving to a co-location model involves trade-offs compared to a standalone asset, which differs by asset type and configuration

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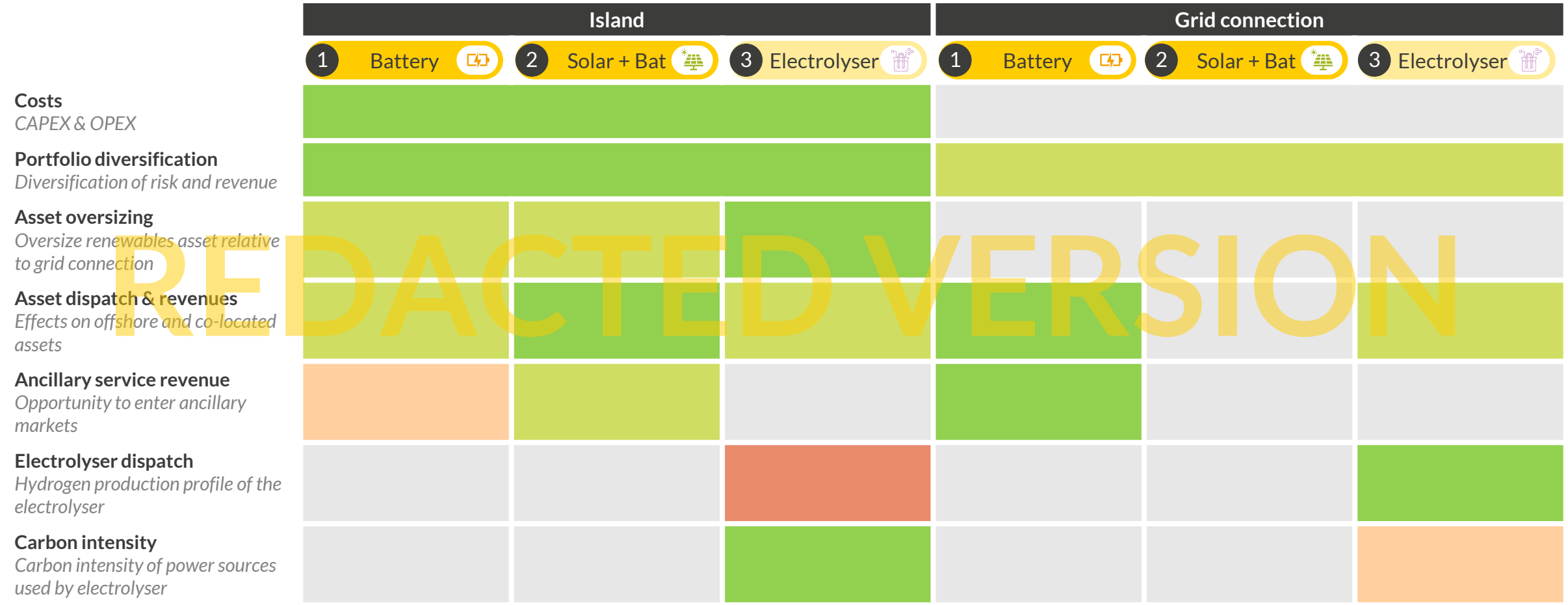

Sources: Aurora Energy Research

Co-location of a battery and offshore wind asset in Ireland could increase IRRs by [redacted].

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1 Co-location of offshore wind asset and battery

Case study co-location in Ireland: Assumptions

Battery duration	Entry year	CAPEX savings	Fixed OPEX savings
[redacted]			

[redacted]

New build IRR for a representative offshore wind asset in Ireland

%

Sources: Aurora Energy Research

[redacted] provides a stable revenue stream while co-location with solar is mostly beneficial to the battery

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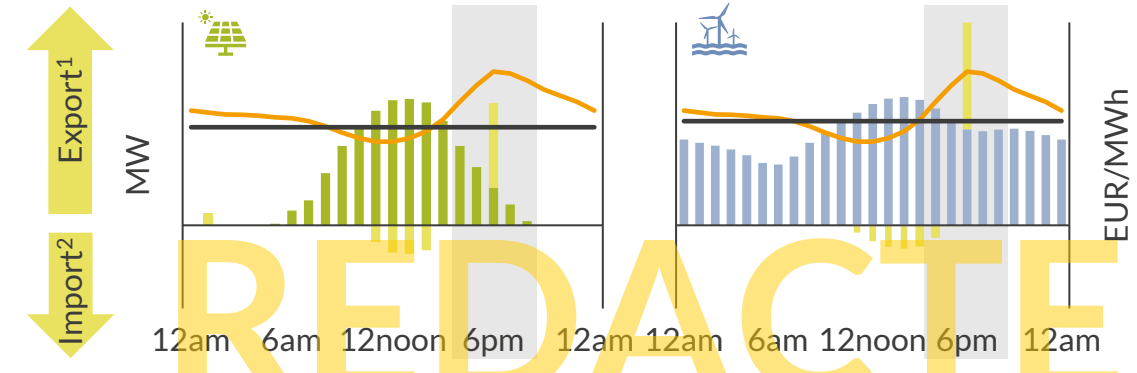
2 Co-location of offshore wind with battery + solar

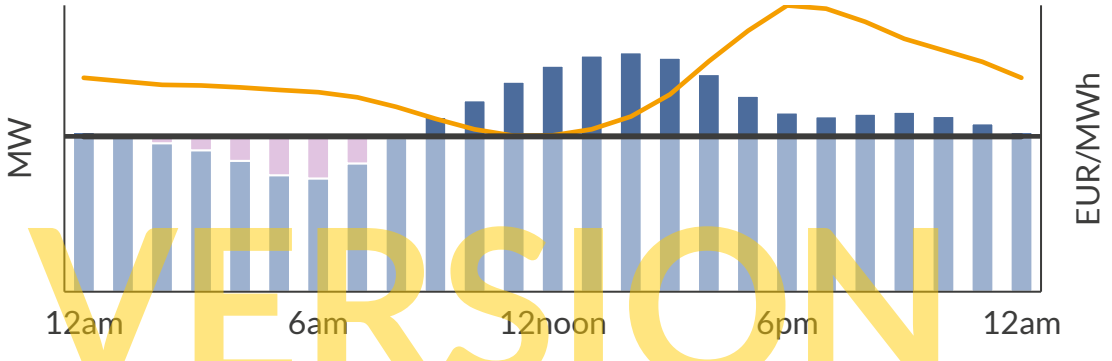
Illustrative electricity generation profile



[redacted]

3 Co-location of offshore wind with electrolyser

Illustrative electricity generation profile



[redacted]

Sources: Aurora Energy Research

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[redacted]

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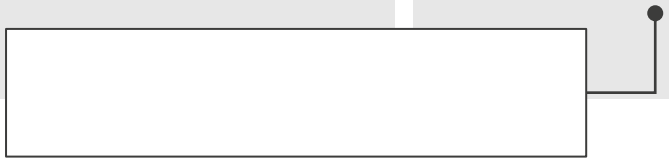
	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Description					
Milestones at the end of phase					



[redacted]

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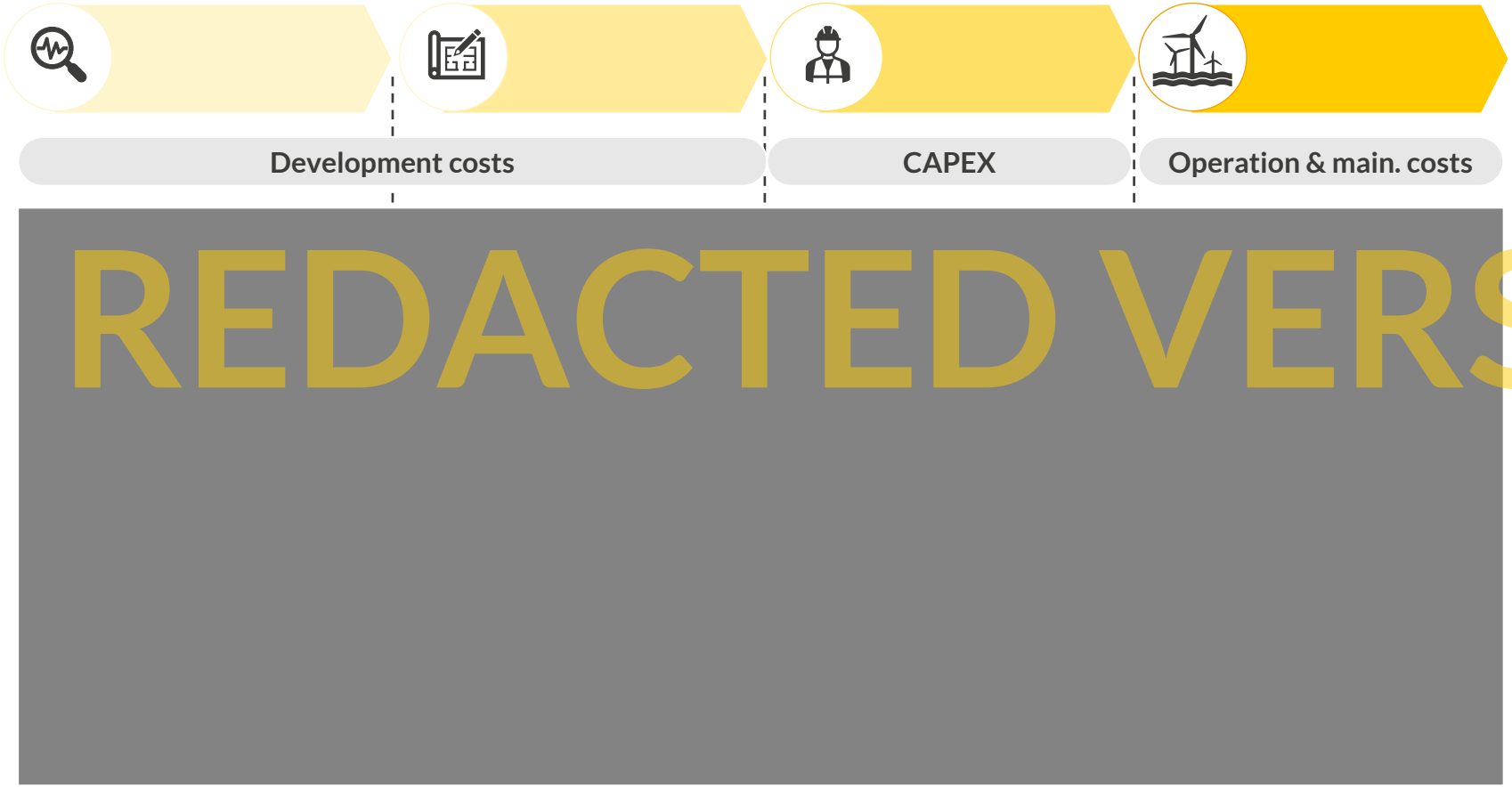
Risks

Accumu-lated project risks

Even though most risks are contained after [redacted], largest increase in project value realised in [redacted] due to [redacted]

Expected value[1] for offshore wind projects at different development stages
% of final project value



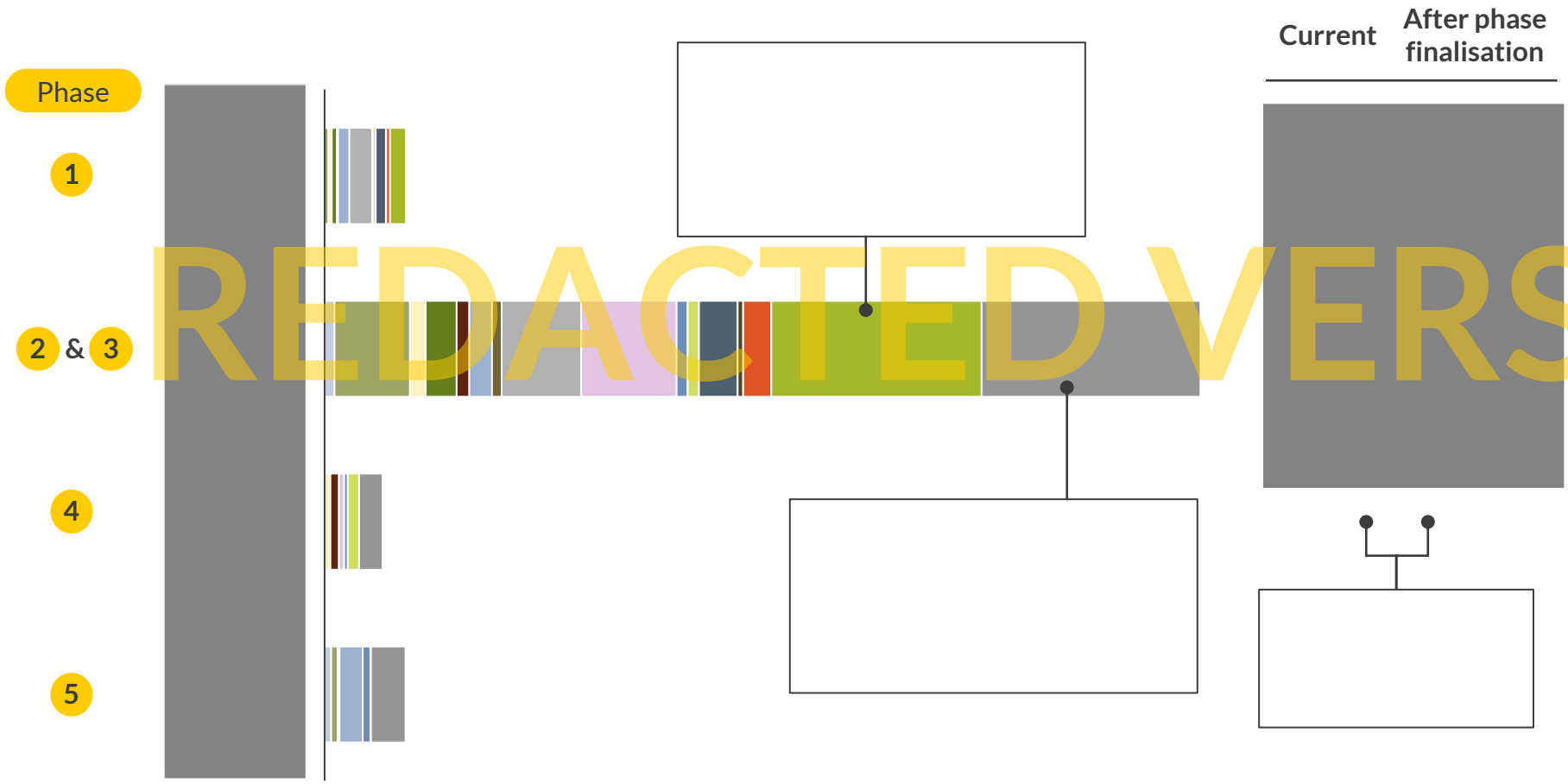
Comments

[redacted]

Sources: Aurora Energy Research

At present, the biggest investment opportunity is in assets [redacted], although this will change as [redacted]

Offshore wind project database as of March 2023
GW



Investment opportunity[1]
EUR billions (real 2022)

Comments

[redacted]

Sources: Aurora Energy Research, Global Energy Monitor

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Operational projects are on average owned by [redacted] parties – with the median owner owning [redacted]

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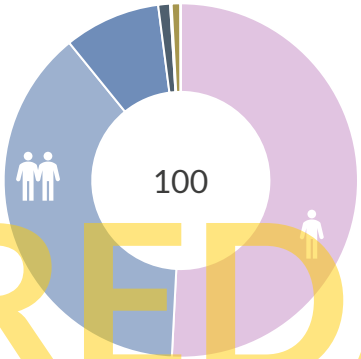
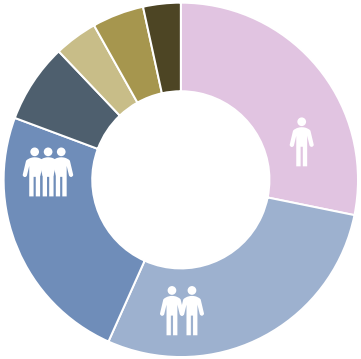
Share of offshore wind capacity by number of owners
% of capacity

Planning, development & construction phases



Operational



Distribution of ownership shares
% of projects

[redacted]

[redacted]

Comments

[redacted]

Sources: Aurora Energy Research, IJG Global

For investment funds, [redacted] are most attractive

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Typical investor appetites by project development stage

Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5

[redacted]

Comments

[redacted]

Sources: Aurora Energy Research, Green Giraffe

[redacted]

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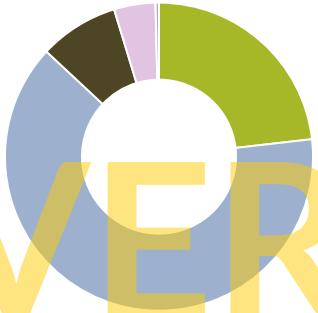
Majority owner and main cooperation partner
% of European offshore wind capacity

Summary main cooperation partner
% of European offshore wind capacity

Comments

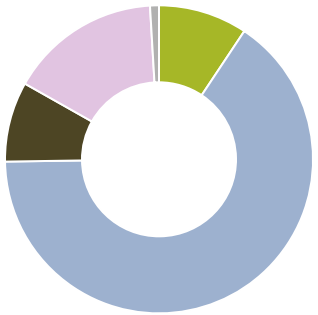
Planning, development & construction phases

[redacted]



Operational

[redacted]



[redacted]

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Appendix

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Support scheme and auction format only known for established markets [redacted] and [redacted], indicative for [redacted]

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Country	Auction type	Auction volume[1]	Auction frequency	Support type	Contract length	Payment structure	Indexation	Negative bids	Competition
Belgium[2]									
Bulgaria									
Croatia									
Denmark[3]									
Estonia									
Estonia/ Latvia[5]									
Finland									
France									

Sources: Aurora Energy Research

Germany has a big auction-pipeline with [redacted] GW, though only [redacted] GW would be applicable for government support

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Country	Auction type	Auction volume[1]	Auction frequency	Support type	Contract length	Payment structure	Indexation	Negative bids	Competition
Germany – pre-screened									
Germany – not pre-screened									
Great Britain									
Greece									
Ireland[2]									
Italy									
Latvia									

Sources: Aurora Energy Research

[redacted], [redacted], [redacted], [redacted] and [redacted] all plan auctions, but auction volumes, terms and support schemes are not decided yet

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Country	Auction type	Auction volume[1]	Auction frequency	Support type	Contract length	Payment structure	Indexation	Negative bids	Competition
Lithuania									
Nether-lands									
Norway									
Poland									
Portugal									
Romania									
Spain									
Sweden									

Sources: Aurora Energy Research

Summary of assumptions for two-way CfD calculations

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Region	Lifetime[1]	Capacity market derating factor[3]	Construction period[1]	Merchant WACC[2]	Subsidised WACC	Subsidy period[1]
Belgium						
Bulgaria						
Croatia						
Denmark						
Estonia						
Finland						
France						
Germany						
GB						
Greece						
Ireland						
Italy						
Latvia						
Lithuania						
Netherl.						
Norway						
Poland						
Portugal						
Romania						
Spain						
Sweden						

Source: Aurora Energy Research