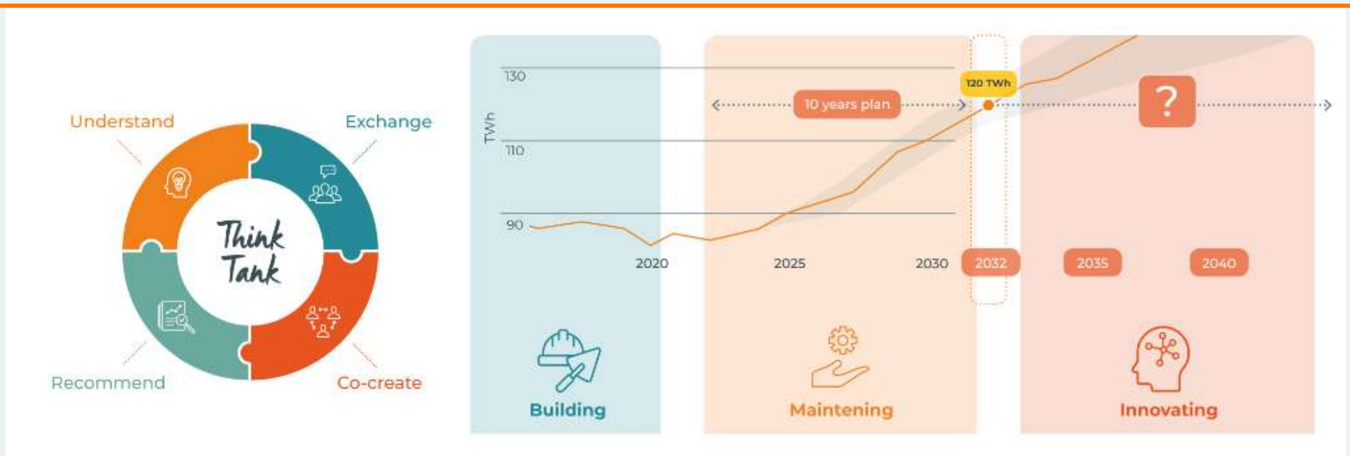
THE HORIZONTAL ELECTRICITY SYSTEM THINK TANK

November 25, 2024



1. **Fluxys** – Towards an optimal energy system for Belgium and neighbouring countries
2. **Elia** – Harnessing Flexibility in the Energy Transition
3. **Elia** – Offshore viewpoint
4. **Elia** – Viewpoint 2025 – Energy Storage
5. **Elia** – feedback, 1 year Think Tank

Towards one Integrated System Vision

Main insights from our 'Integration North Sea Model'

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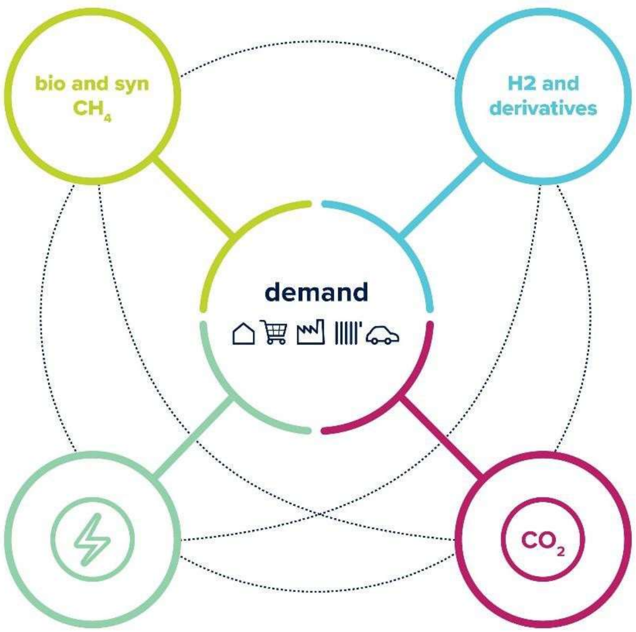
Elia Think Tank
25/11/2024

Fluxys multi-energy simulation model for informed decision-making



fluxys LIÈGE université economie Energy Transition Fund

The initial version of this model was developed by **ULiège** and **Fluxys**, with a financing from the **Federal Energy Transition Funds**

all interactions between electricity, methane, hydrogen and CO_2 on an **hourly basis**

energy systems of **all countries bordering the North Sea**

achieve **carbon-neutrality** at the **lowest cost** with **energy demand served at any time**

Informed decision-making
on infrastructure planning across sectors

1. MODEL & ASSUMPTIONS

The model aims to identify the optimal multi-energy system that can achieve carbon neutrality by 2050

INPUTS

Energy demand
(yearly values + hourly time series)

Renewable production
(max potential + hourly time series)

Import assumptions
(availability & cost)

Technical parameters
(for technologies & infrastructure)

Cost assumptions
(CAPEX, OPEX, WACC…)

CO_2 reduction target
(max budget & emission factors)

MODEL

Goal: simulate the interactions between electricity and molecules in a carbon-neutral energy system

CH_4 H_2 & derivatives CO_2

Scope?
- ➔ North Sea countries
- ➔ 2050, hourly resolution

How?
- ➔ linear optimization
- ➔ investments & dispatch

Modelling assumptions
- ➔ central planning / one player
- ➔ perfect foresight (no uncertainty, no 'N-1 SoS')
- ➔ no distances within countries

OUTPUTS

Optimal capacities
(investments in infra & technologies)

Optimal dispatch
(hourly flows)

Energy not served & curtailments

CO_2 emissions
(global & by country)

Global system cost

Marginal prices
(energy supply & CO_2 abatement cost)

INSIGHTS

H_2 and CO_2 transit
Which factors impact the transit through Fluxys potential pipelines?

Flexibility to the system
How, where and when can the molecules help to compensate the intermittency of renewables?

Impact of electrification
How does the system cost change for different demand scenarios?

Import dependency
Impact of import costs?
How to reduce import dependency?

…

The initial version of the model has been built for Belgium only by ULiège & Fluxys during an **ETF project financed by SPF Economie**
Results can be seen on https://integrationdemonstrator.github.io/

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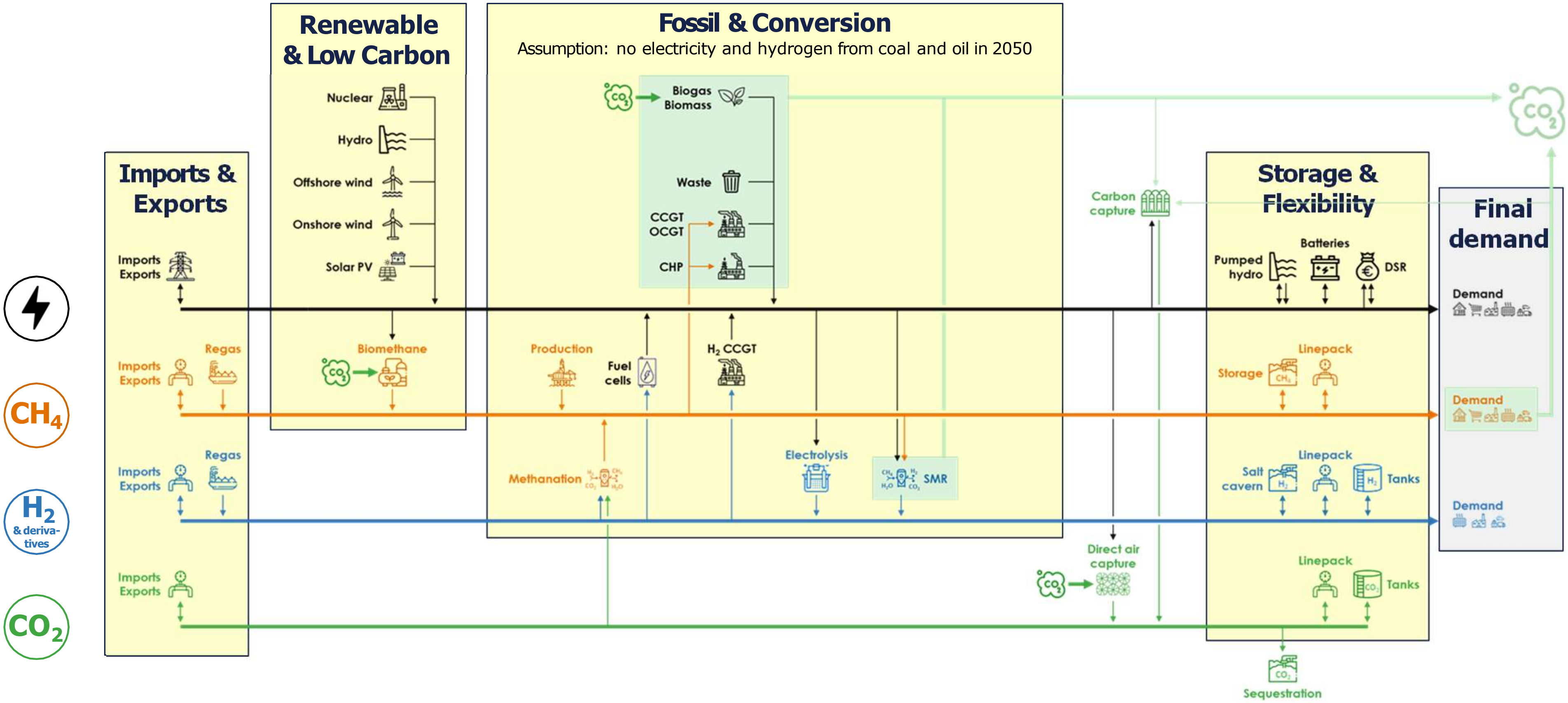
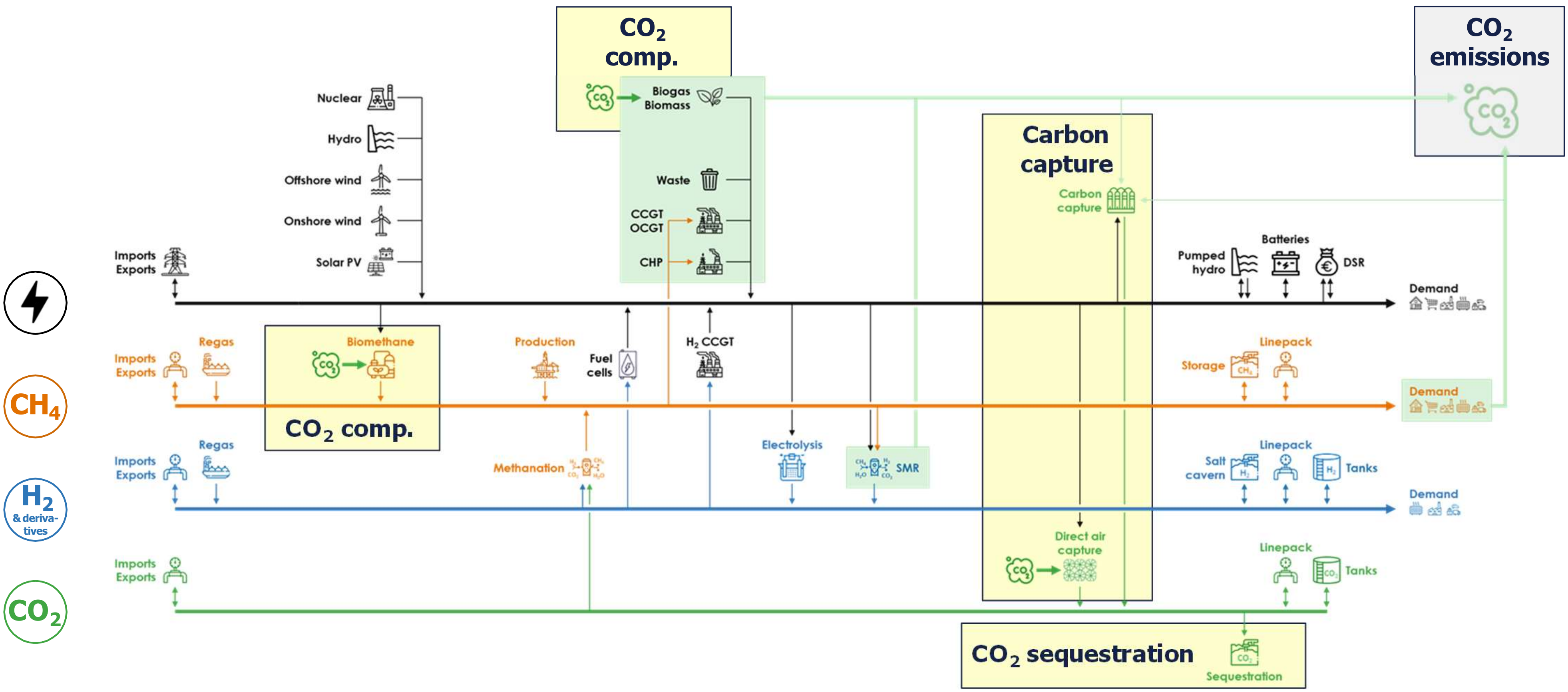
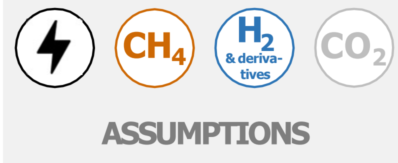
Integrated energy system with electricity, CH_4, H_2 and CO_2

Production, imports, conversion, storage and demand are connected through transmission infrastructure



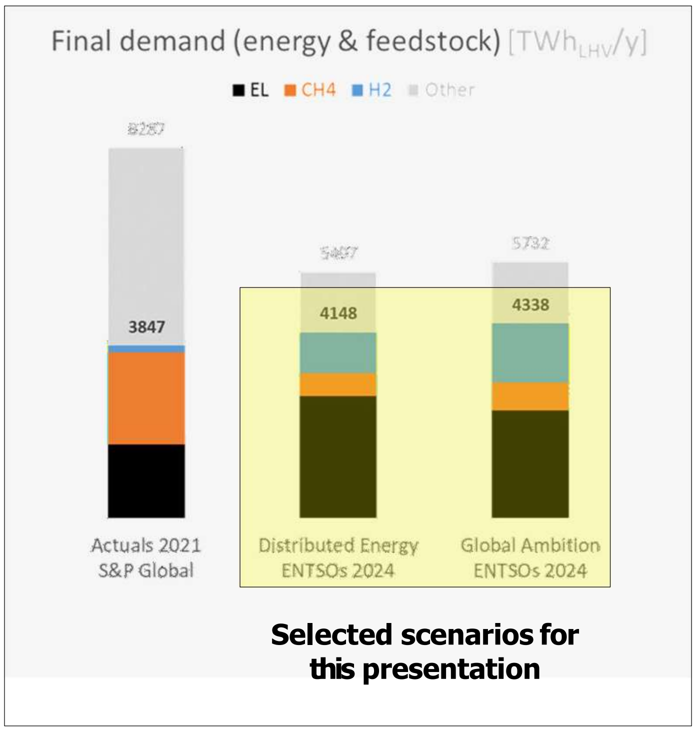
CO_2 emissions can be compensated or captured

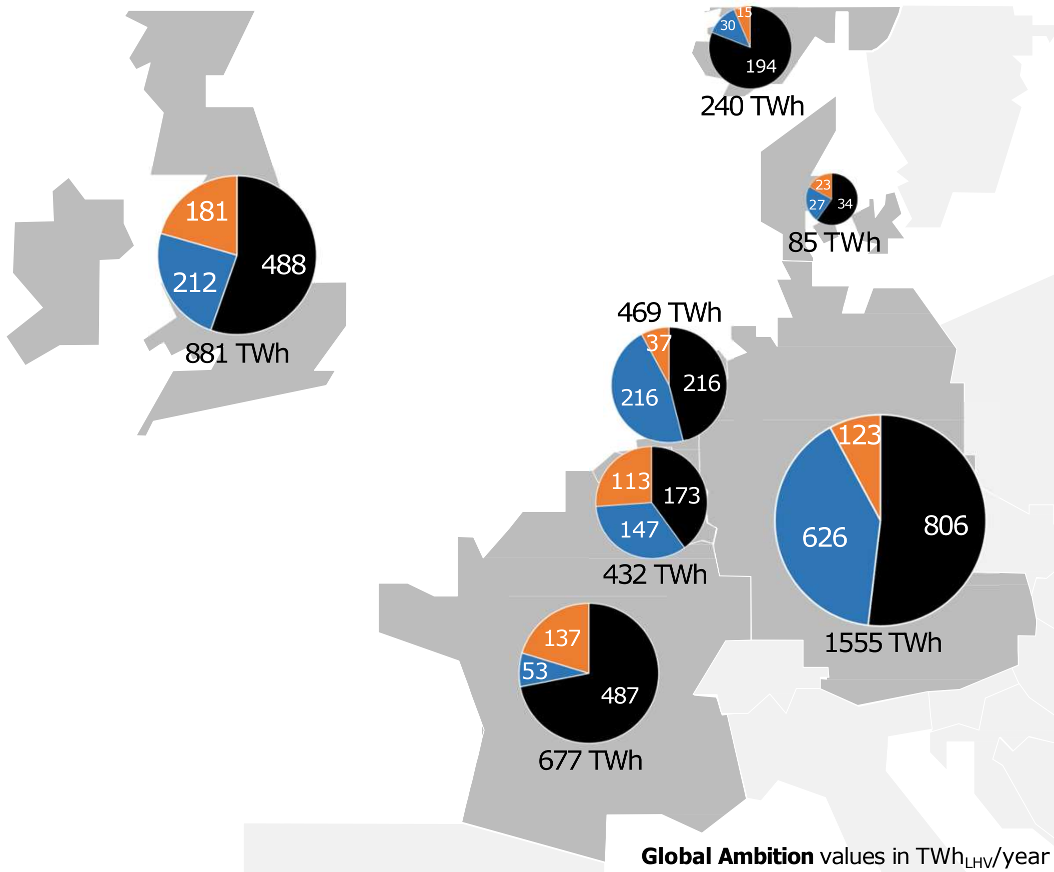




Starting position is a final demand scenario

Values for 2050 from Global Ambition and Distributed Energy were taken as final demand scenarios (ENTSOs' TYNDP 2024)



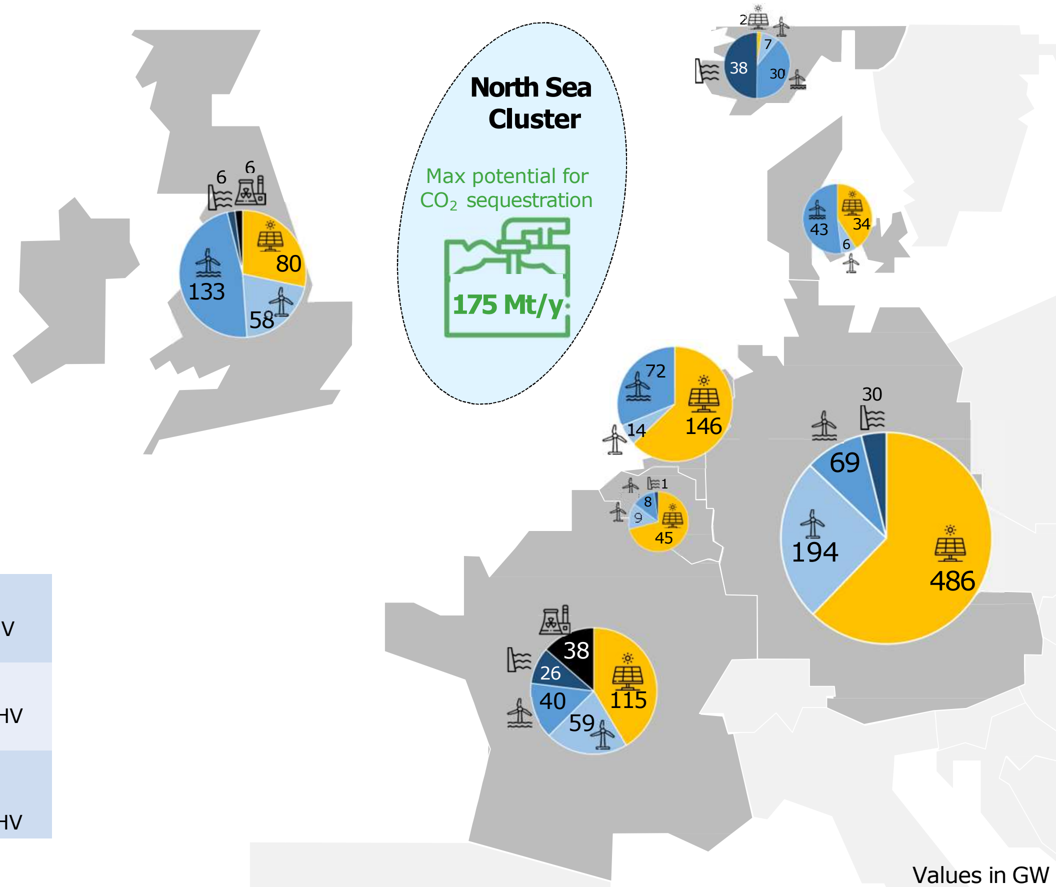


CH_4 H_2 & deriva-tives CO_2

ASSUMPTIONS

Various potentials for RES can be simulated

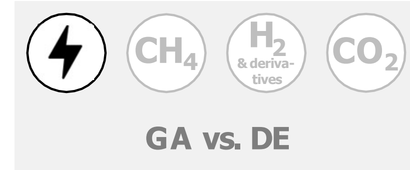
Maximal potentials for renewable electricity in 2050 comes from ENTSOs’ TYNDP 2024



Other major assumptions include:

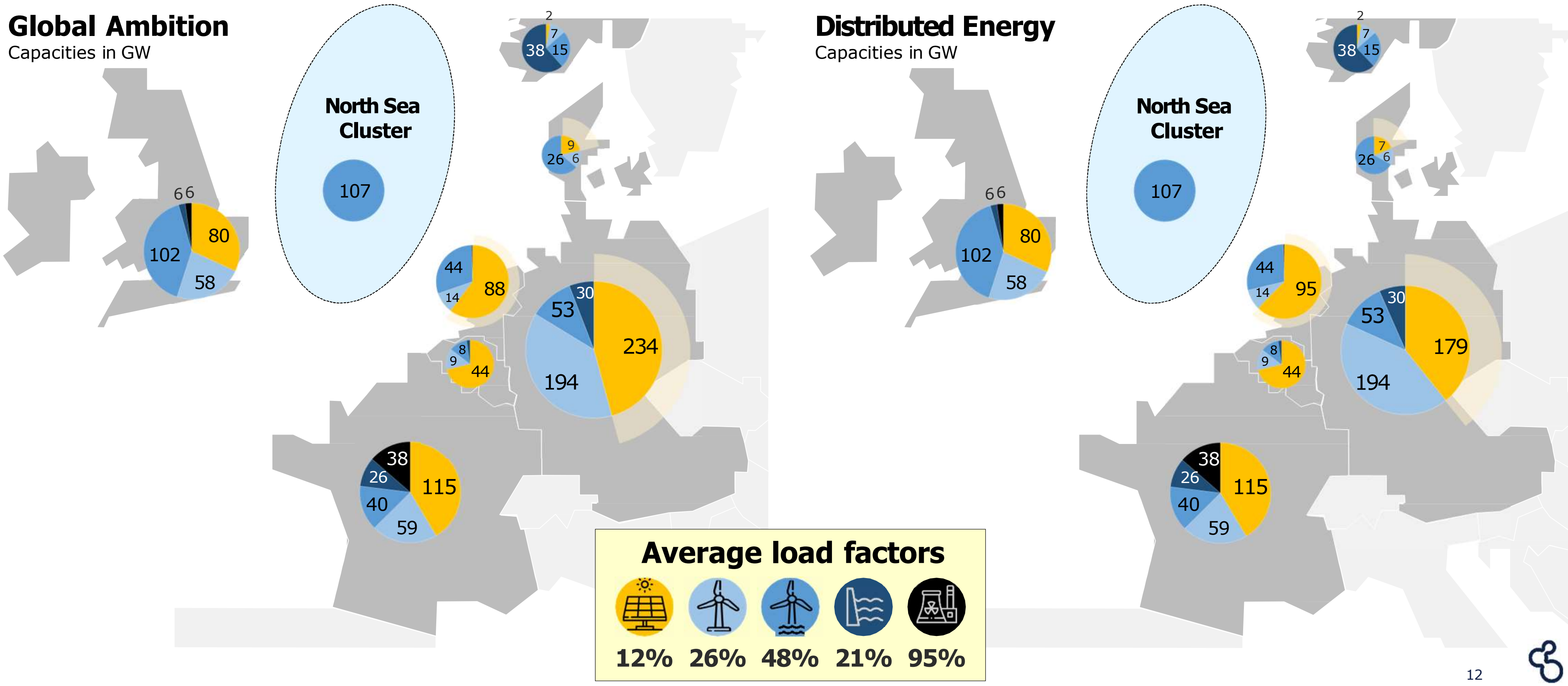
Import cost for grey methane	40 €/MWh_{HHV}
Import cost for low-carbon methane	100 €/MWh_{HHV}
Import cost for carbon-neutral H_2	4.0 €/kg 103 €/MWh_{HHV}

2. RESULTS & KEY INSIGHTS



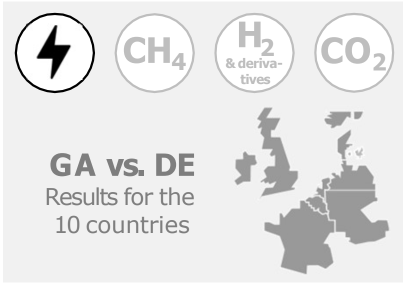
RES is massively built in both scenarios

Solar PV is the only RES not fully deployed, due to a lower load factor and the need to upgrade distribution grids

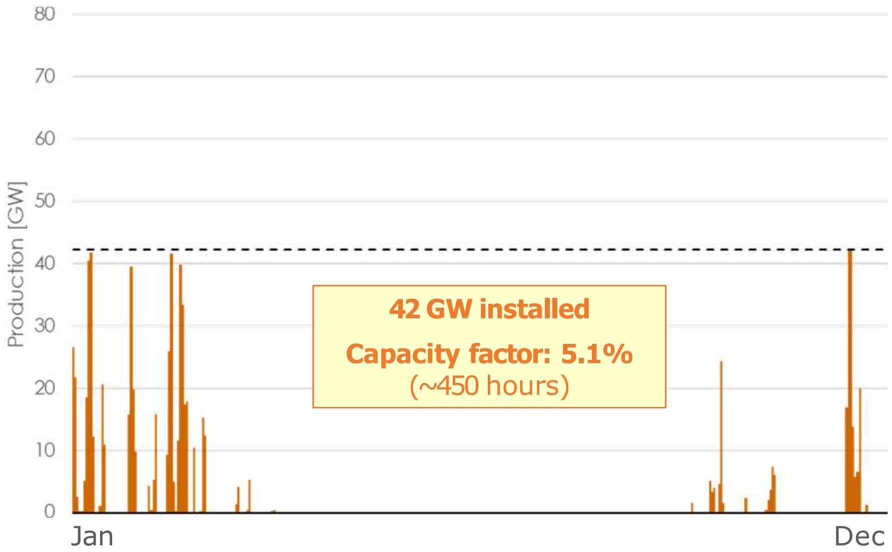


Dispatchable capacity is needed

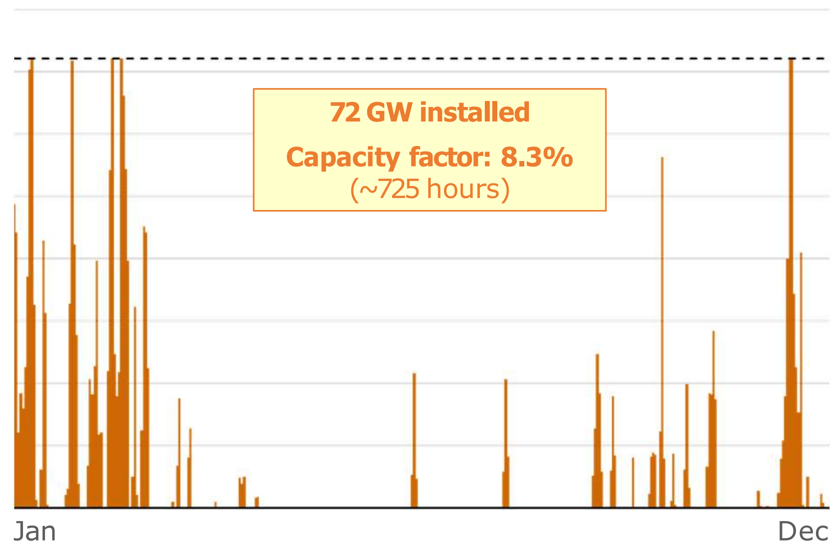
42 to 72 GW of gas-to-power is installed as dispatchable capacity to secure electricity supply during winter
(currently 113 GW of gas-fired power plants & 40 GW of coal-fired power plants – source S&P)



Global Ambition
Gas turbines usage

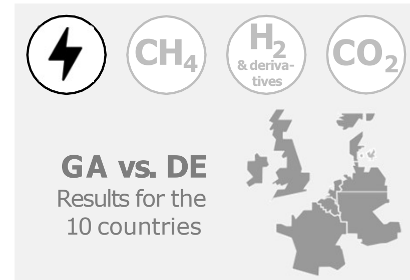


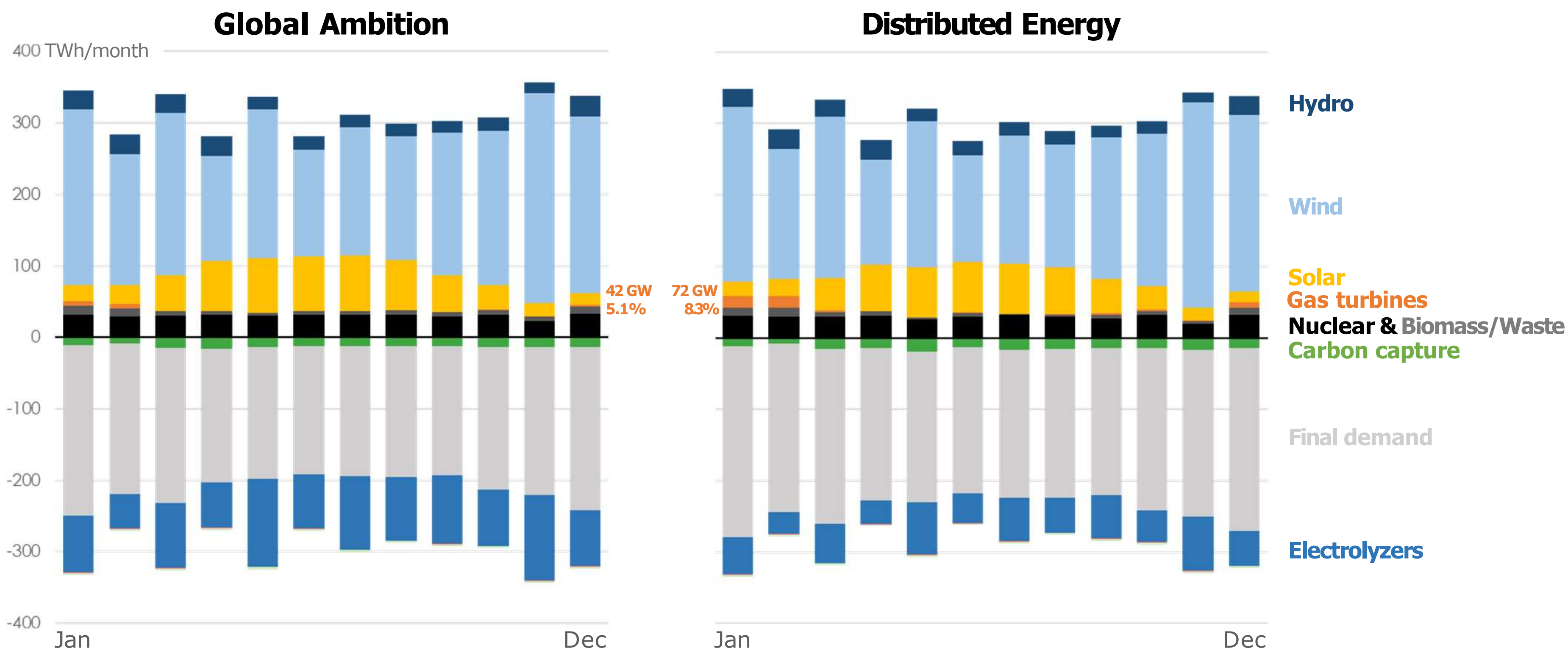
Distributed Energy
Gas turbines usage



Electricity system mostly supplied by RES

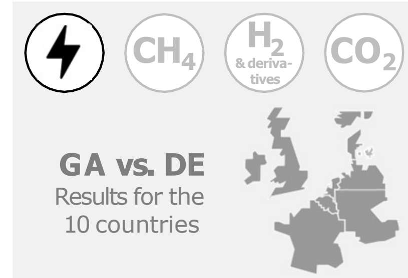
Renewable electricity (wind, solar, hydro) supplies most of the final electricity demand and green hydrogen production

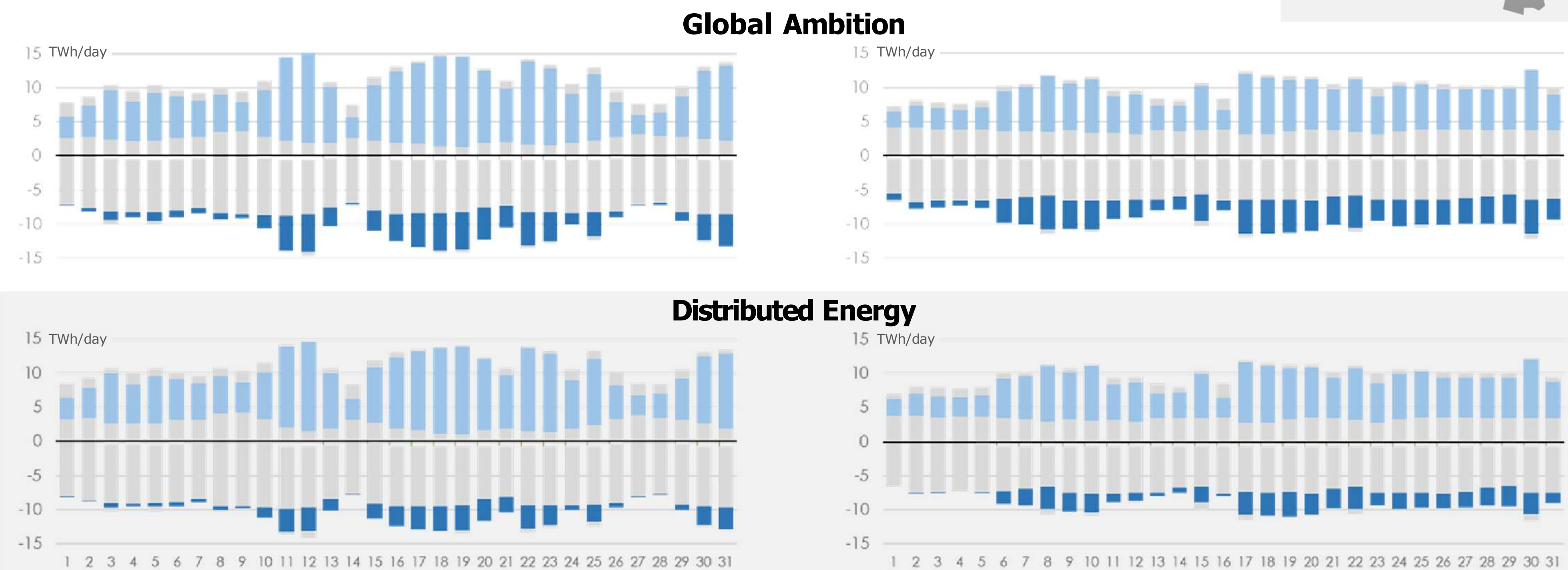




Electrolyzers enable optimal wind deployment

Daily balance shows that excess wind production is converted to hydrogen to avoid curtailments





January **July**

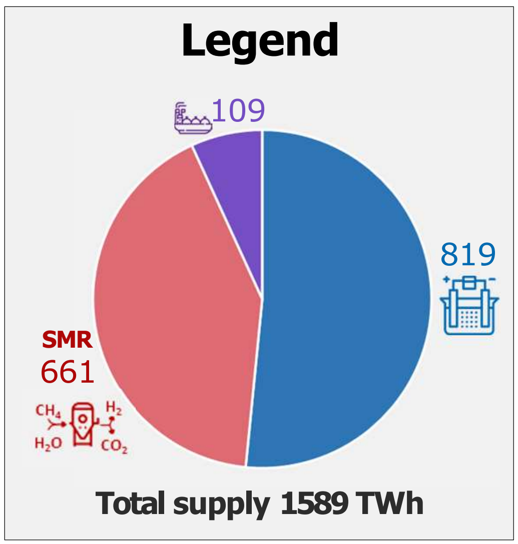
Supplies: Batteries Solar **Wind** Gas turbines Hydro Biomass & Waste

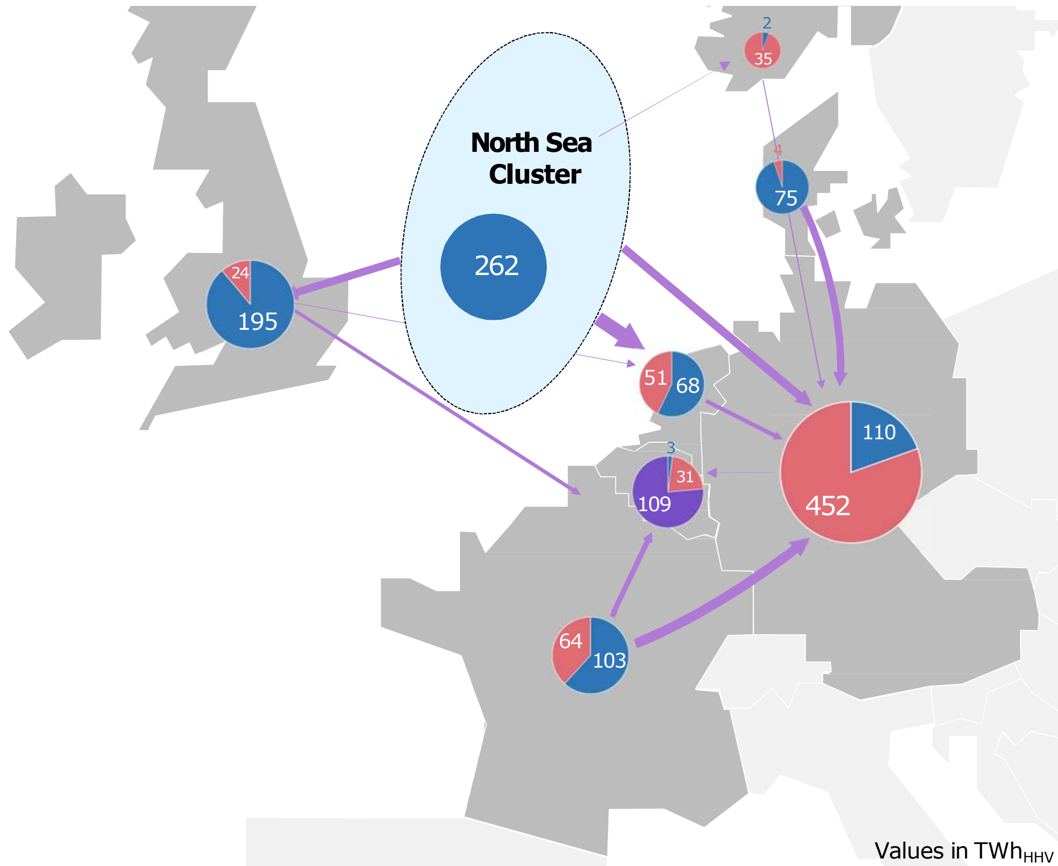
Consumption: Carbon capture Final demand **Electrolyzers** Batteries

GLOBAL AMBITION

Hydrogen is mainly produced within Europe

H_2 is produced locally by electrolysis and steam methane reforming (SMR); imports by ship from outside Europe occur only in Belgium

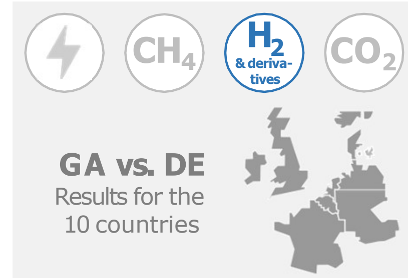


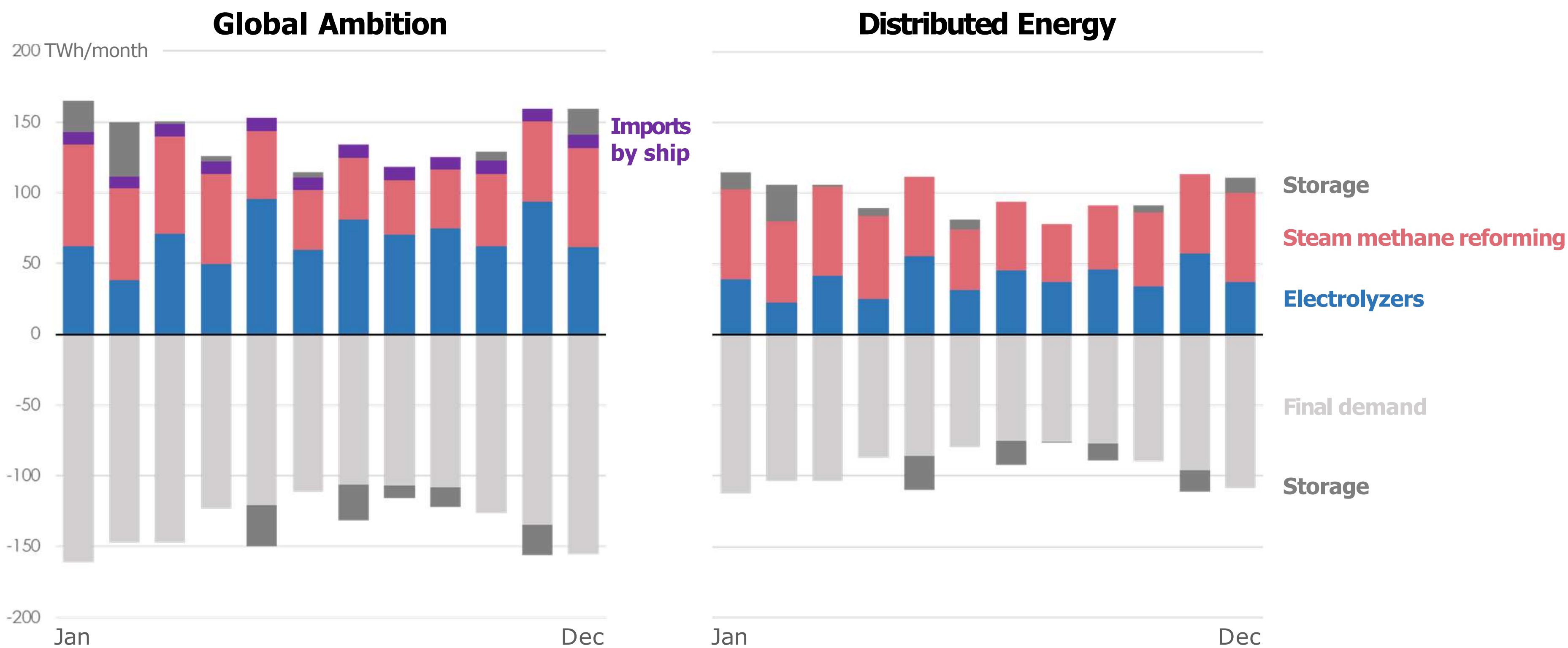


Values in TWh_{HHV}

Hydrogen is mainly produced within Europe

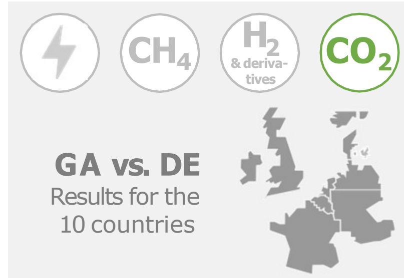
H_2 is produced locally by electrolysis and SMR; imports by ship from outside Europe occurs only in Global Ambition scenario

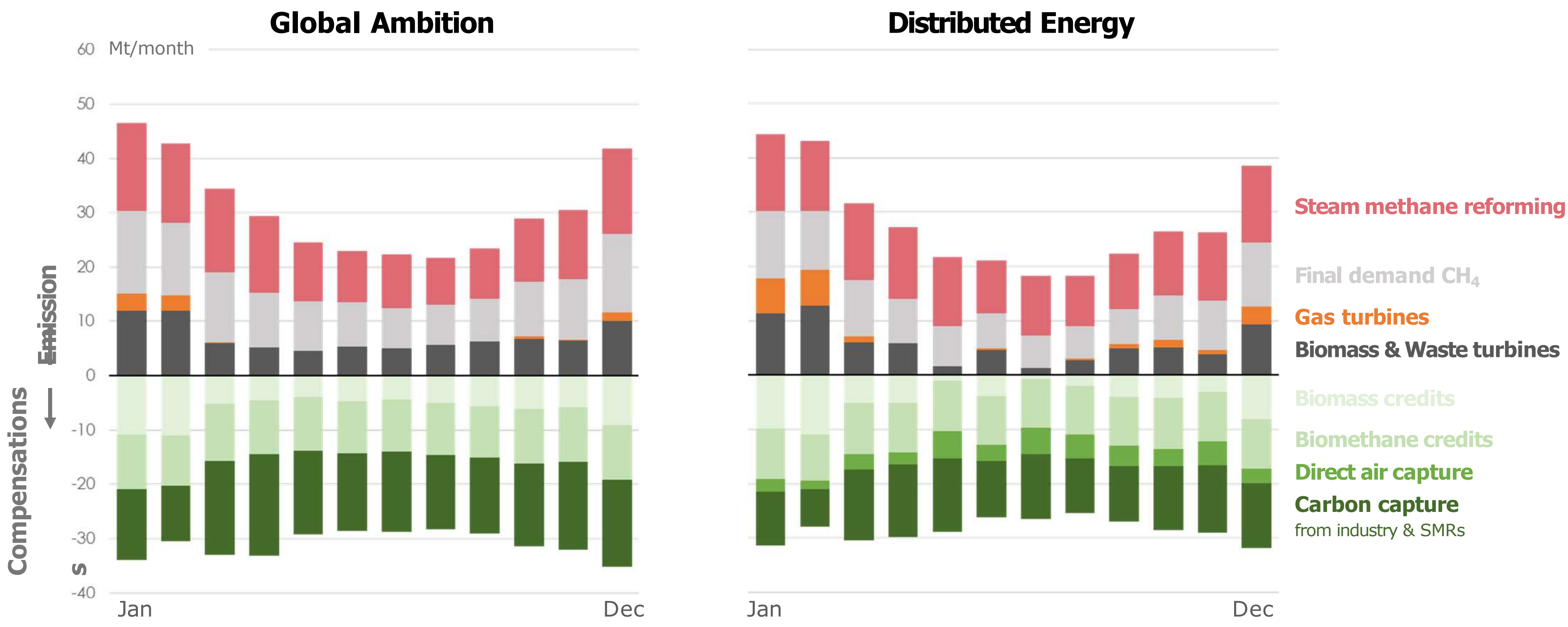




Biomethane and carbon capture are key

The whole system is carbon-neutral, with credits from bioenergy and carbon capture accounting each for half of CO_2 emissions reduction

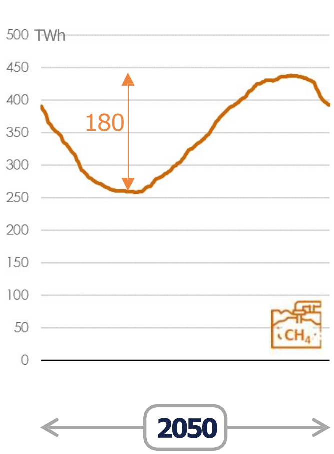




Molecule storages essential for seasonal demand

Seasonal storage is assured with methane, weekly storage with hydrogen and daily/hourly storage with batteries

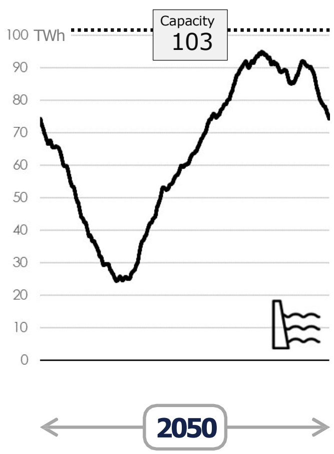
Methane
Underground storage



180 TWh of methane used in existing facilities, CH_4 stored in summer for use in winter

1 cycle/year

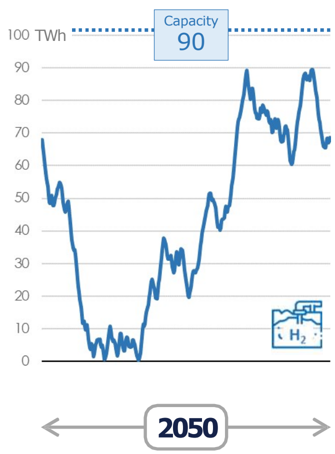
Electricity
Hydro



70 TWh of electricity used in existing facilities, stored in summer and used in winter

1 cycle/year

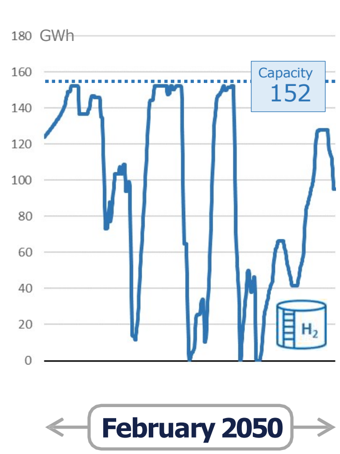
Hydrogen
Salt caverns



90 TWh of repurposed salt caverns, H_2 stored seasonally + short-term optimization

3.3 full cycles/year

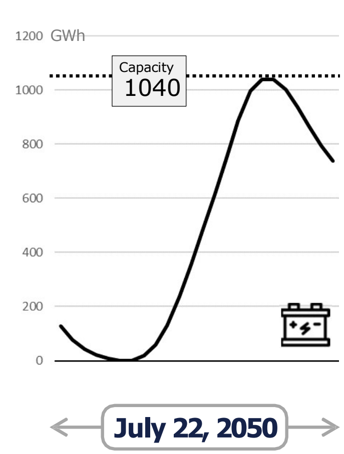
Hydrogen
Tanks



152 GWh of H_2 in new tanks, H_2 stored when high wind and retrieved when low wind

24 full cycles/year

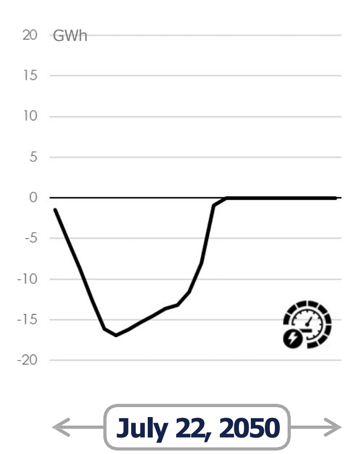
Electricity
Batteries



1040 GWh of new batteries, storing solar PV during day and releasing it at night

120-230 full cycles/year

Electricity
Load shifting

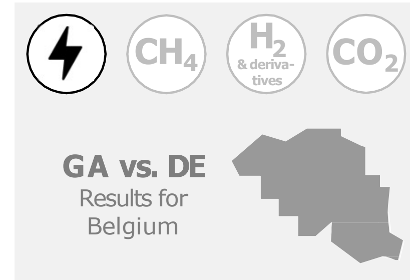


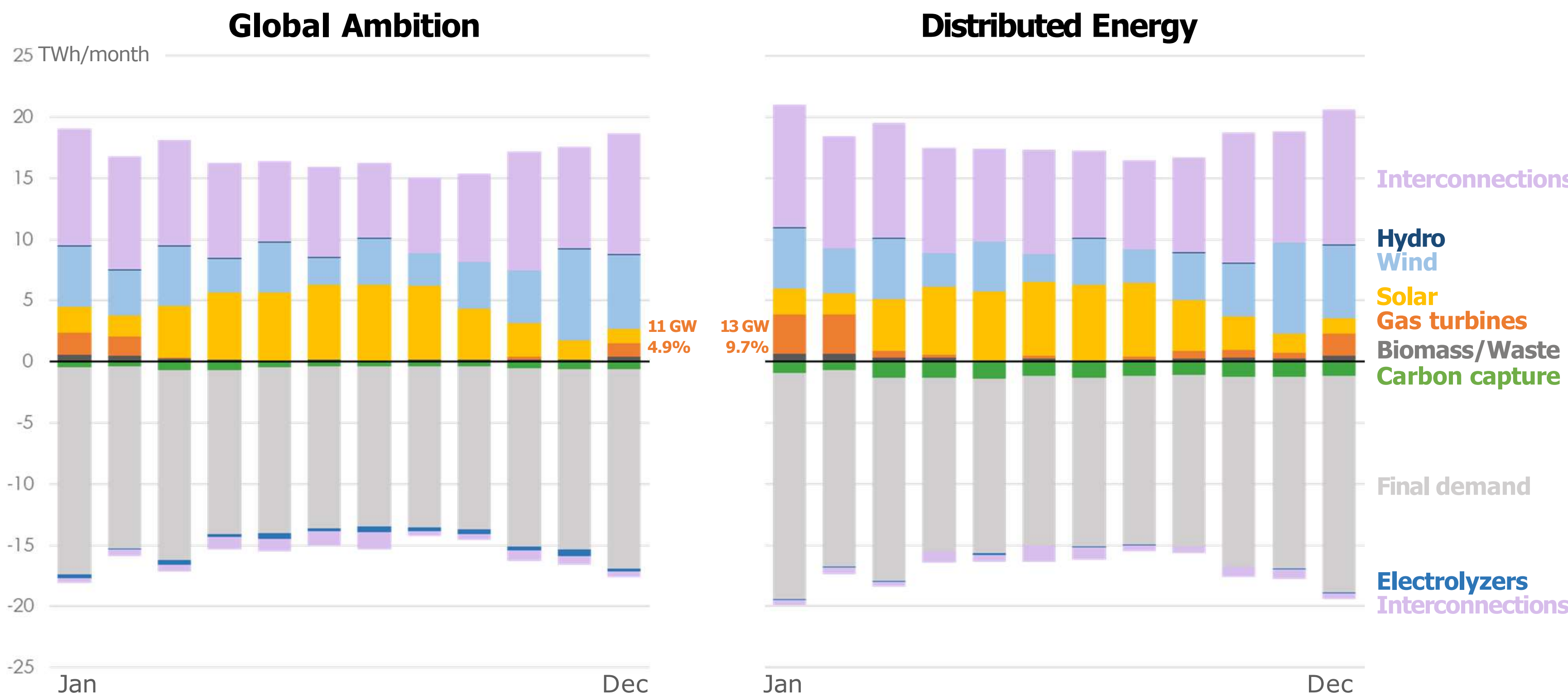
Up to **17 GWh** of load shifting occurs, with reduced load mainly during the day

>300 full cycles/year

Electricity supply in Belgium depends on imports

Nuclear from France, wind from North Sea cluster and Netherlands provide bulk electricity, while all interconnections improve balancing

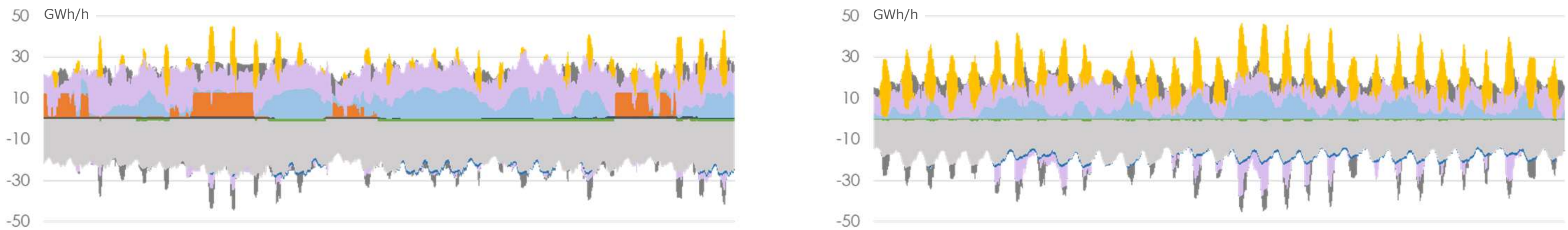




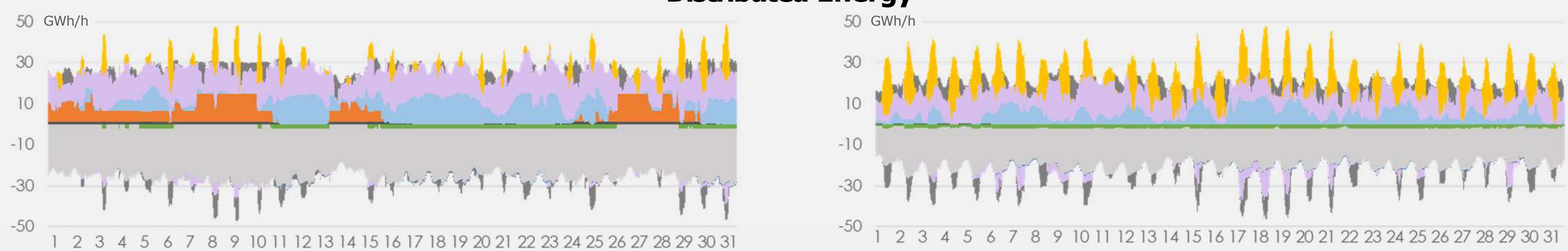
Gas turbines needed in both scenarios as SoS

More gas-fired power plants needed to balance the system when wind and sun do not cover final electricity demand during winter

Global Ambition



Distributed Energy

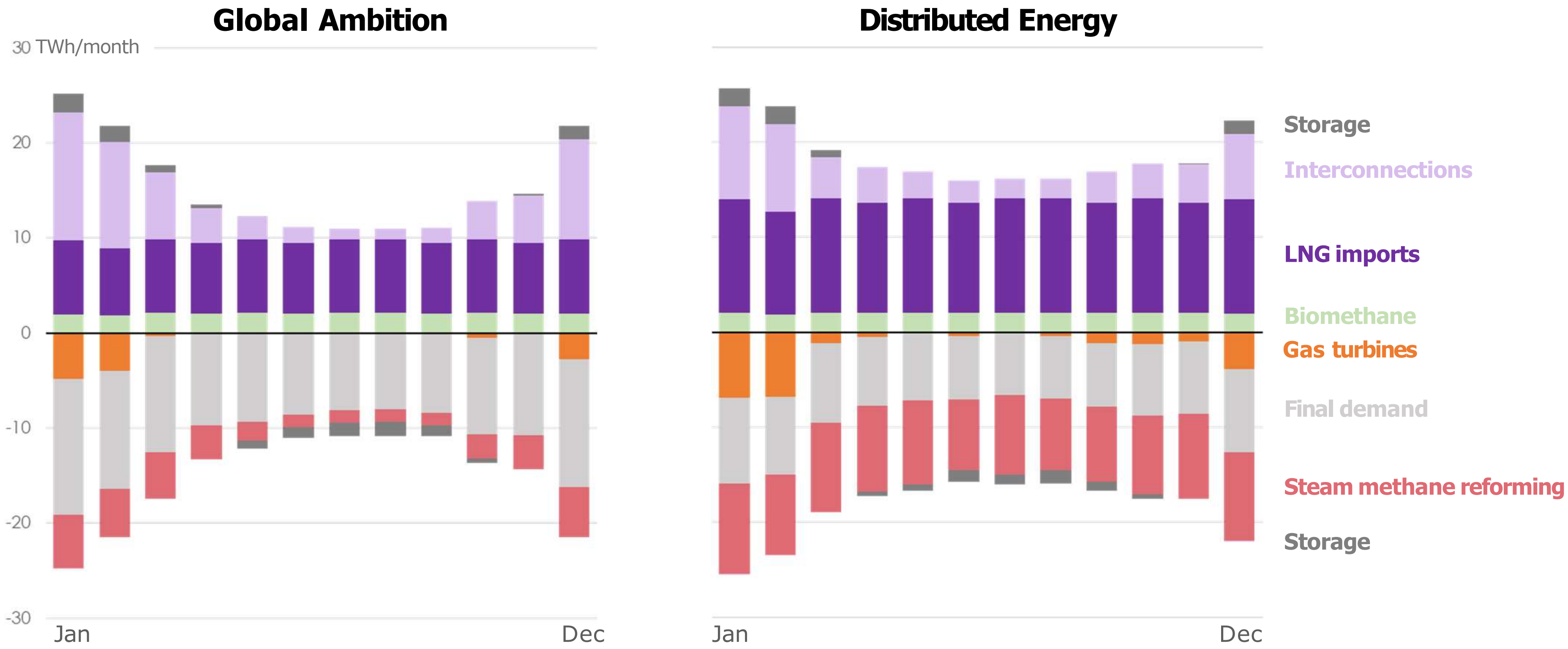


January **July**

Supplies: Batteries Solar Interconnections (imports) Wind Gas turbines Hydro Biomass & Waste
Consumption: Carbon capture Final demand Electrolyzers Interconnections (exports) Batteries

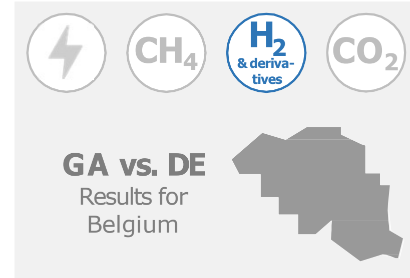
More methane is imported in Belgium

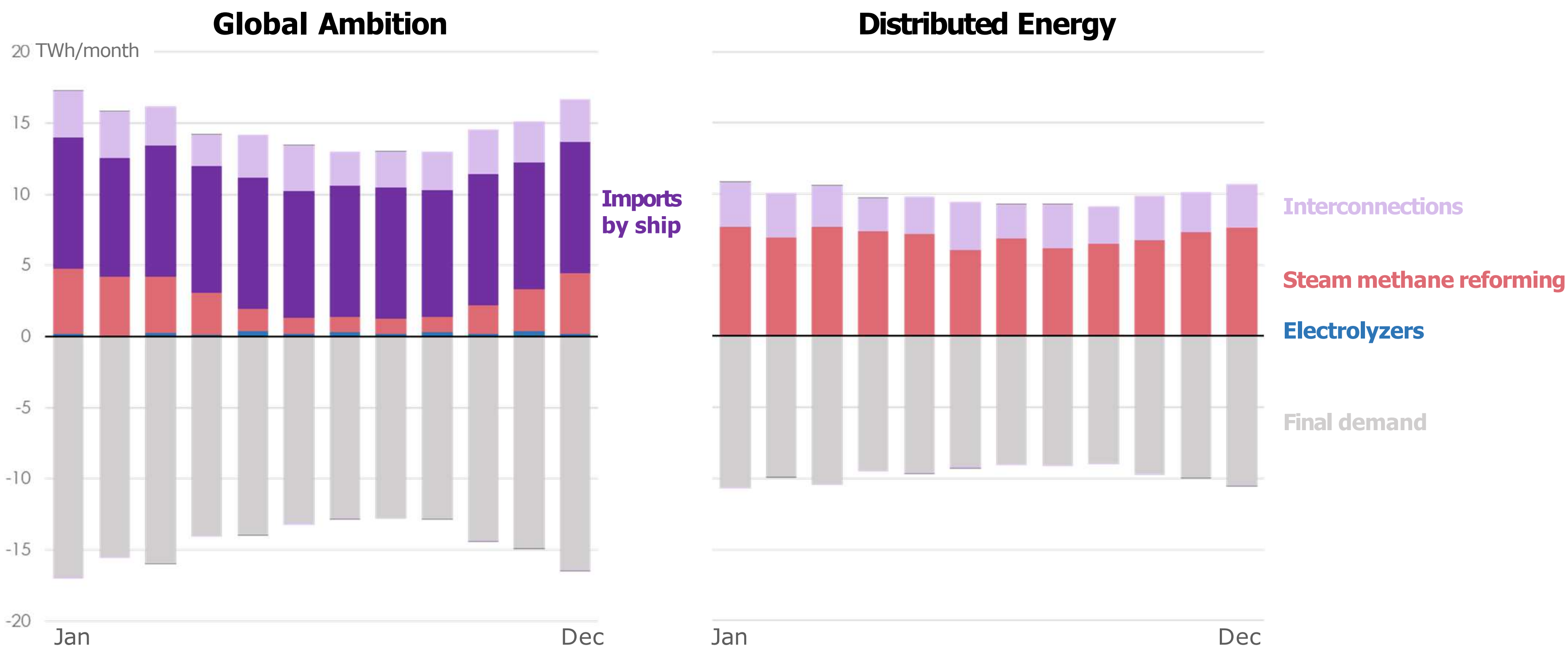
More LNG imports are needed to supply the additional demand from SMR and gas turbines



Hydrogen is mostly imported in Belgium

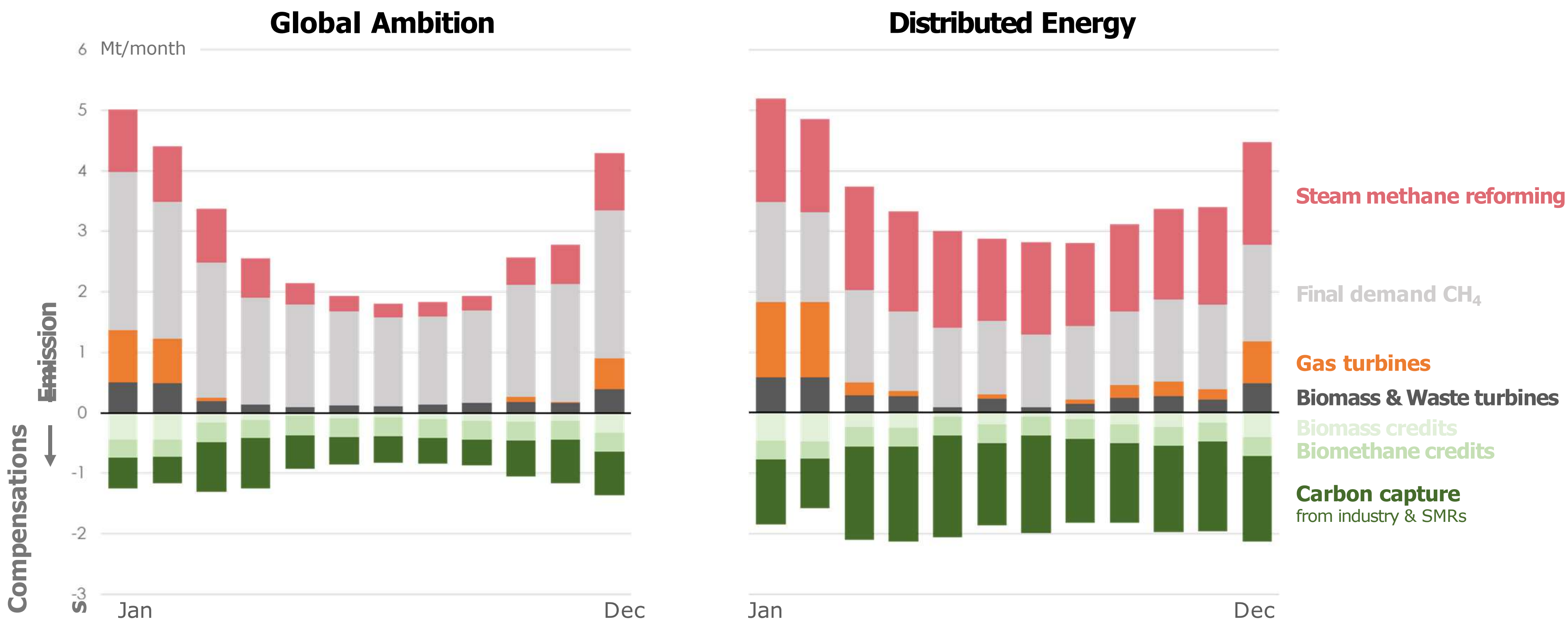
Huge bulk imports by ship (derivatives) are complemented by pipeline imports from FR and the UK, and local production by SMR





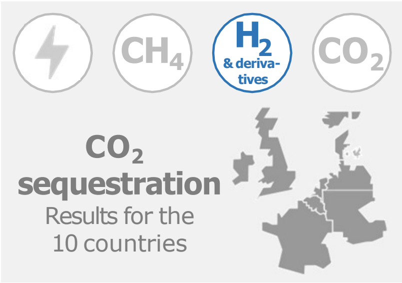
More carbon capture from SMR in Belgium

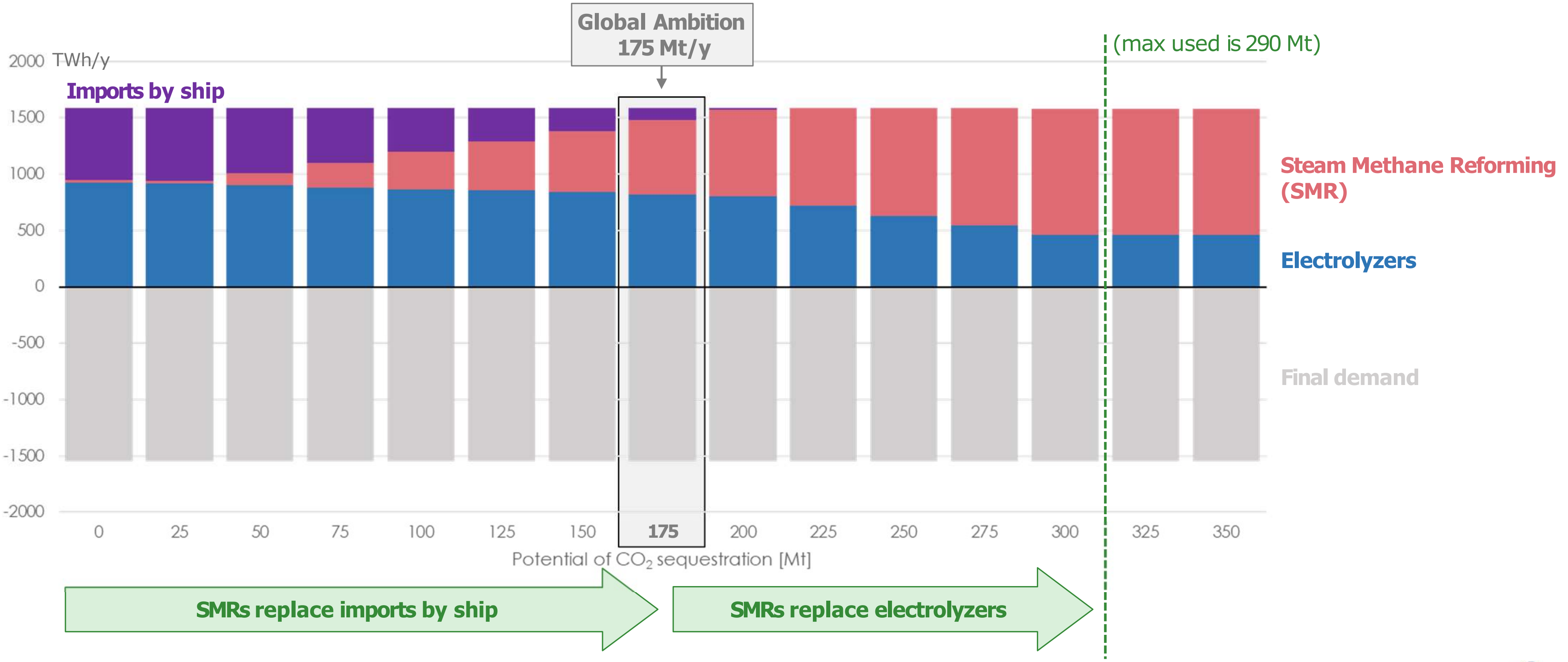
Additional emissions from gas-fired power plants and SMRs are compensated by more carbon capture exported to the North Sea



H_2 system strongly impacted by CO_2 sequestration

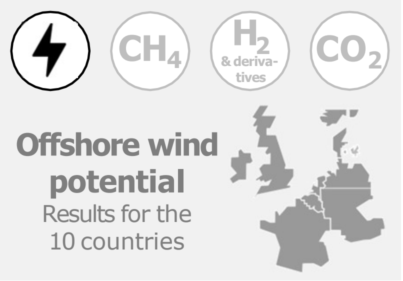
As more CCS is possible, H_2 imports and electrolyzers are replaced by SMRs, but some electrolyzers remain as dispatchable demand for RES

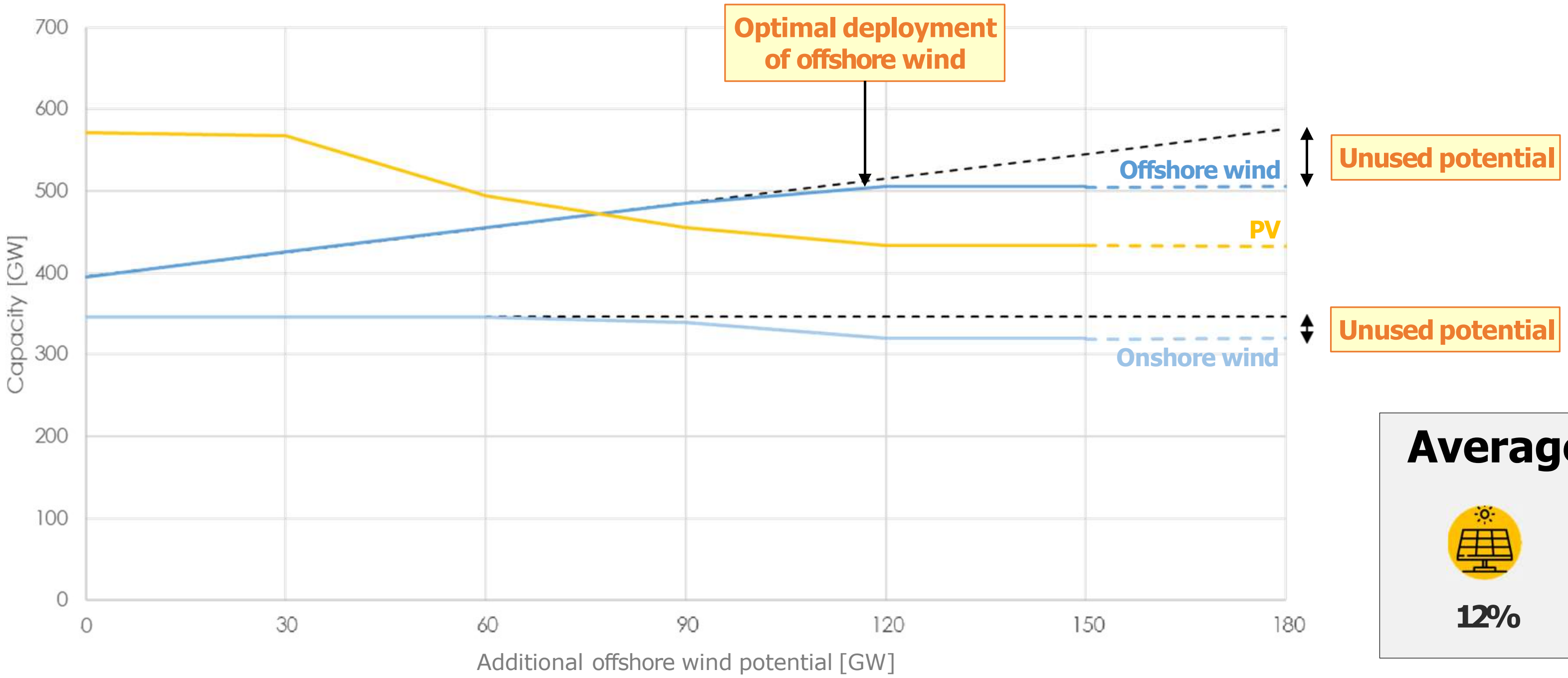


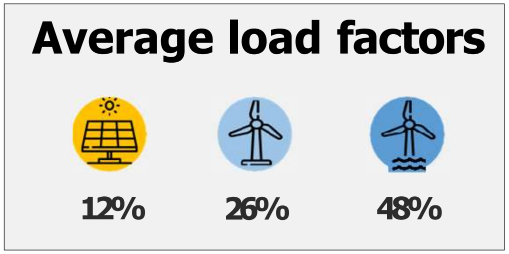


Impact of offshore wind potential in the North Sea

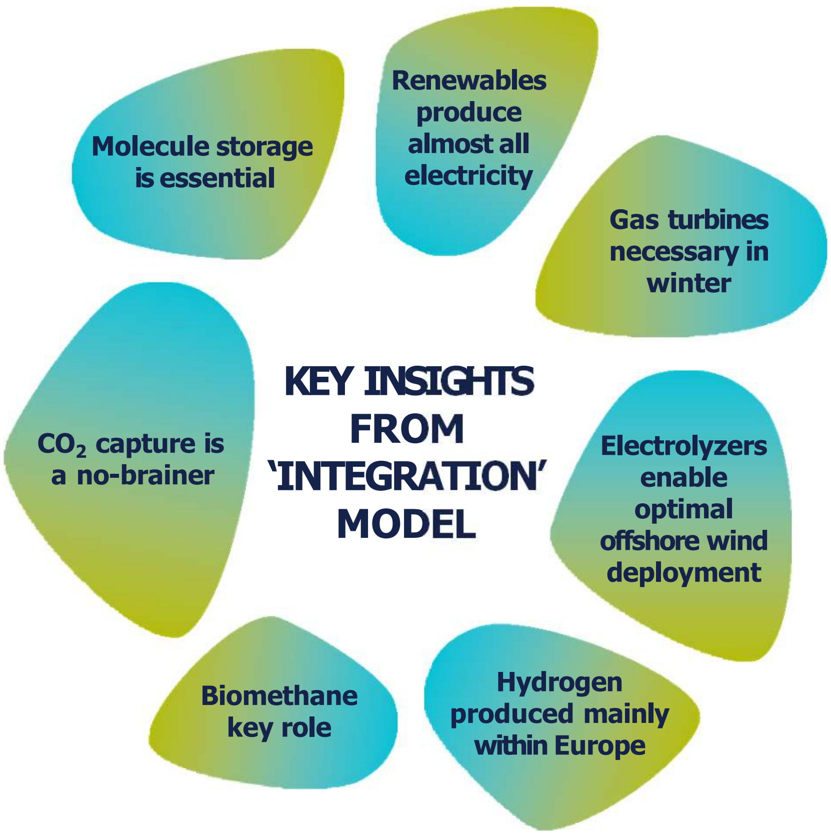
Up to 111GW of additional offshore wind capacity would be deployed, reducing solar PV and allowing more H_2 production by electrolysis







Key insights from simulating ENTSOs TYNDP2024 scenarios for 2050 with our North Sea Integration Model



A carbon-neutral energy system in 2050 in the North Sea countries is realistic and needs molecules

More details of our study can be found on **our website**

THANK YOU FOR YOUR ATTENTION!

Elia - Harnessing Flexibility in the Energy Transition

Harnessing Flexibility in the Energy Transition : A Comparative Study of Different Models to Balance the Electrical Grid

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Vandenberghe F.
Managing director at Onoma Energy Consult and former Chief Officer Customers, Markets and Systems at Elia

COMING SOON

Massive integration of RES in the electricity system creates a major challenge in terms of grid balancing…

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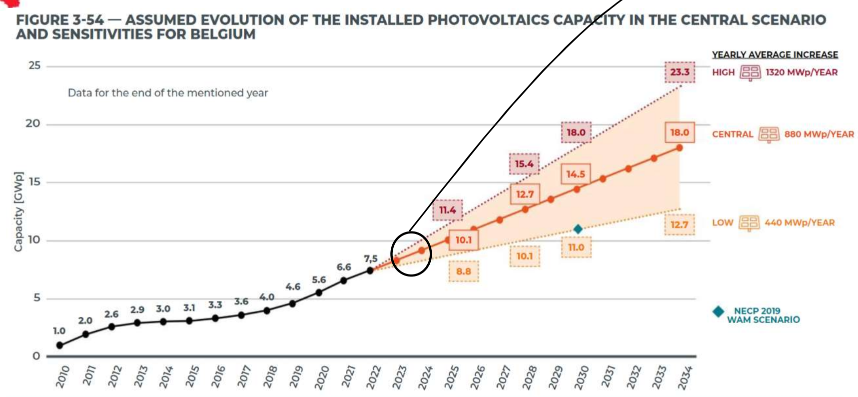
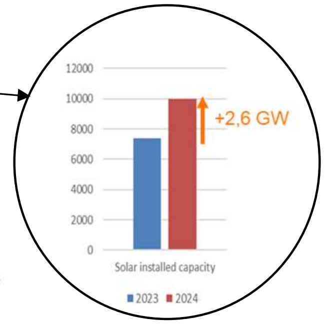
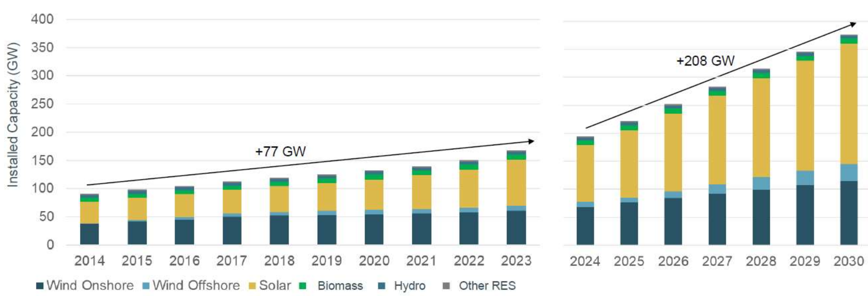
Solar evolution in Belgium





50hertz

Development of Installed Renewable Capacity



Peak consumption*	12 GW	76 GW
Solar capacity installed	10 GW	92 GW

RES production will exceed Load everywhere in EU leading to structural balancing challenges

*winter peak in 2023

Elia
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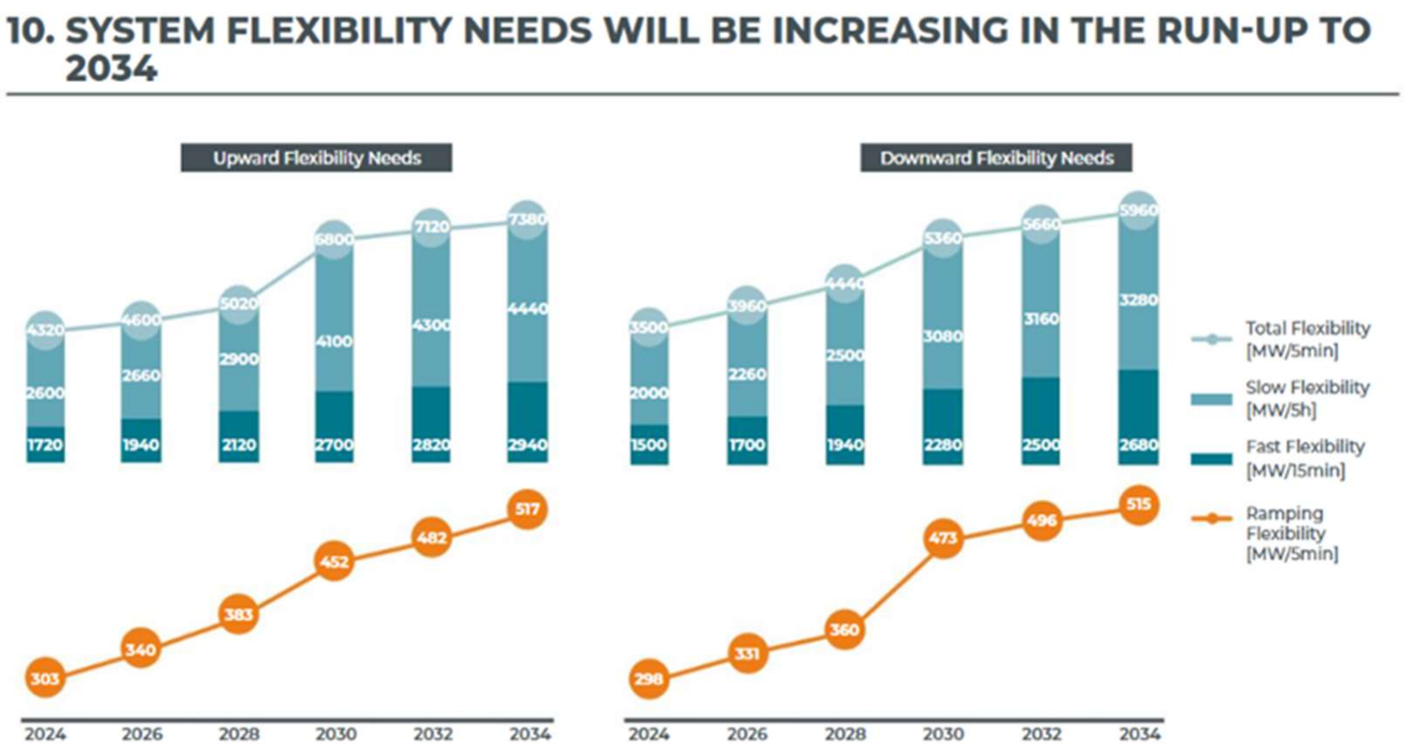
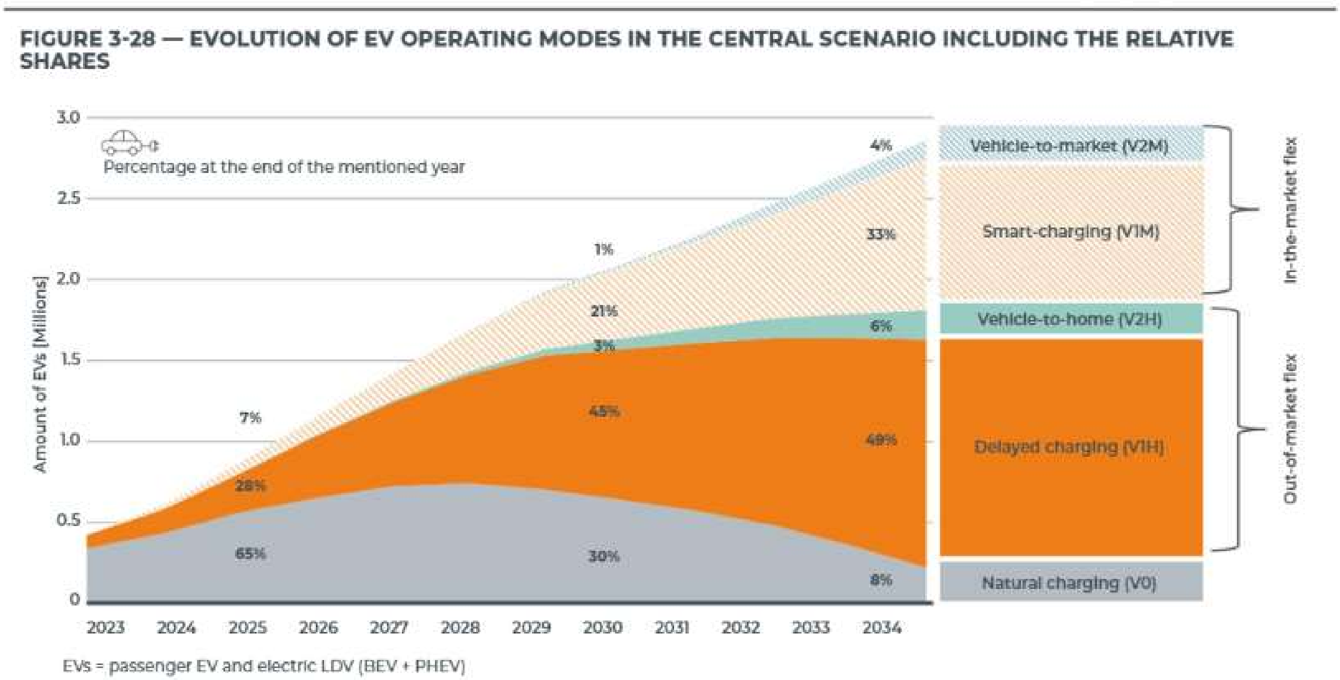
… and hence significantly increases the system flexibility needs



The amount of required fast flexibility (able to react within 15’ to cope with forecast errors) is expected to almost double in 10 years

Expected evolution of system flexibility needs in Belgium (figure extracted from the Adequacy and Flexibility study performed by Elia for the period 2024-2034)

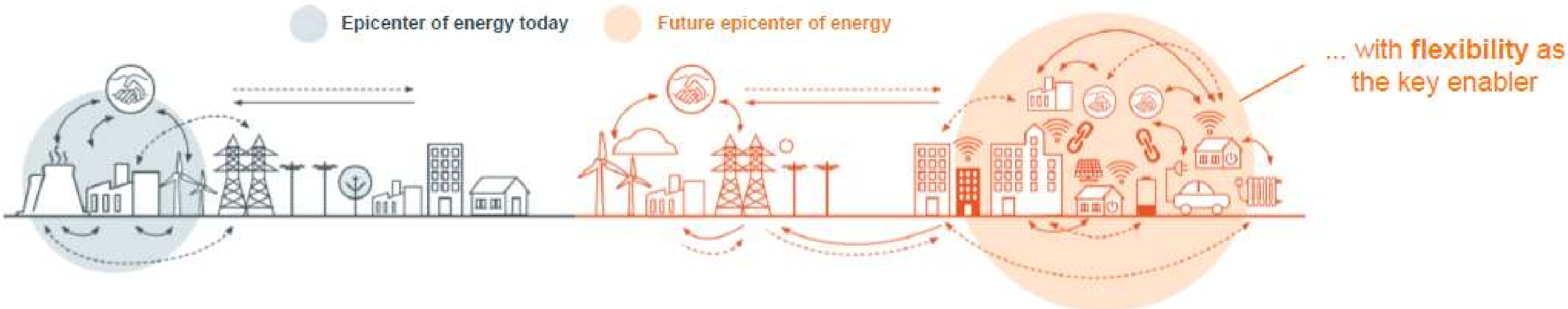
Meanwhile, as a consequence of the rapid electrification of industrial and residential sectors, more and more flexible assets are connected to the grid…



Significant volumes of emerging flexibility still need to be unlocked thanks to appropriate market models

Expected evolution of # EVs and related operating mode in Belgium (figure extracted from the Adequacy and Flexibility study performed by Elia for the period 2024-2034)

… offering a natural solution to deal with the intermittency of the new generation mix



Generation follows consumption

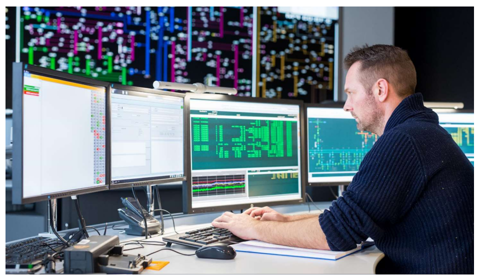
Demand will partly follow generation

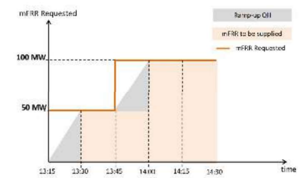
Provided that market designs evolve accordingly

These new flexible assets have two options to provide fast flexibility to the system for grid balancing purpose

✓ **Explicit bidding** to the System Operator

"Volume based" Flexibility





Activation request

Signal **sent by the System Operator to the Flexibility Service Provider** with a **specific required volume of flexibility**

✓ **Implicit reaction to price signals** (i.e. Imbalance Price during the balancing timeframe)

"Price based" Flexibility

€

BRPs are **incentivized by the imbalance price** to be balanced or even to **deviate from a balanced position** in real-time **to help the system** and are **remunerated @imbalance price**

In Europe, there exist two categories of grid balancing models : the centralized and the decentralized ones

The centralized balancing models

Explicit participation is the only way to help the system after a certain moment in time, where the TSO takes full control/ownership on the grid balancing and BRPs are no longer allowed to balance their portfolio or the system

E.g. France, UK

The notion of centralization is not about the type of resources (central or decentral), but rather about the entities making the decision to activate the flexible resources : either a unique centralized entity (i.e. the TSO only), or several decentralized entities (i.e. not only the TSO but also the operators of flexible assets).

E.g. Belgium, The Netherlands

The decentralized balancing model

Implicit reactions of BRPs to price signals are allowed and encouraged up to real-time in order to balance their portfolio or even to help balance the system.

Explicit activations by the SO are complemented by implicit reactions of BRPs to price signals

The objective of this presentation is to compare those two categories of models in light of the energy transition (i.e. considering the need to unlock the flexibility provided by lots of decentralized assets)

The theoretical appeal of centralized balancing models

100% explicit

Might seem appealing at first sight

01

Tight control

The TSO maintains a clear, immediate overview of available flexibility

02

Firm participation

There is a contractual obligation for service providers to deliver activated resources. Activations requested by the TSO are monitored and often penalized for non-compliance

03

High precision

Balancing services with short regulation steps (e.g., aFRR) allow precise control

The practical reality of centralized balancing models

Centralized balancing model might seem appealing at first sight but, in practice, their ability to deal with the challenges and opportunities brought by the energy transition can be questioned because they can exclude less conventional flexible assets from system participation

01 Technical barriers

02 Complex processes

03 Lead time

04 Difficulty to account for non-electrical constraints

05 Suboptimal dispatch of slow units

Example of flexibility exclusion

Under some specific circumstances, I could temporarily decrease the electrical consumption of my industrial process in order to valorize this flexibility at a very high imbalance price. However, I need to keep full control on if, when, how much and how long I decrease my consumption. Translating the non-electrical factors governing my decision into explicit bids is simply impossible…

Decentralized balancing models – a promising alternative in the context of the energy transition?

In decentralized balancing models, explicit participation in the system during the balancing timeframe (i.e. through explicit balancing bids offered to the TSO) is complemented by the implicit participation (i.e. as a reaction to the imbalance price signal) of the assets that cannot or are not willing to offer their flexibility explicitly to the TSO.

01 Reduced balancing energy costs

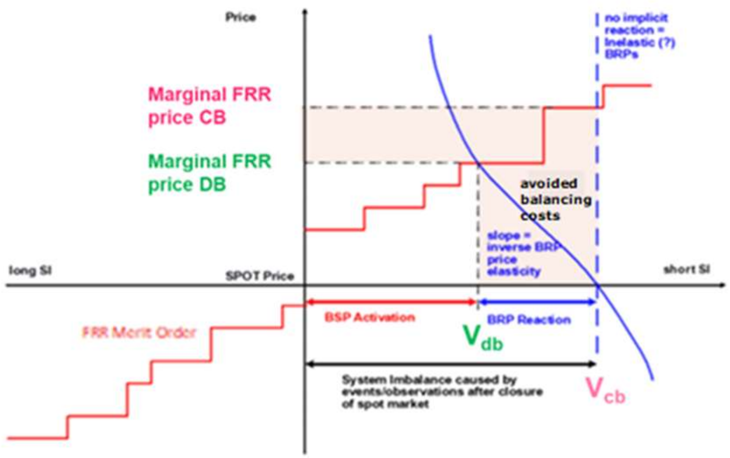
02 Reduced capacity reservation costs & market distortion

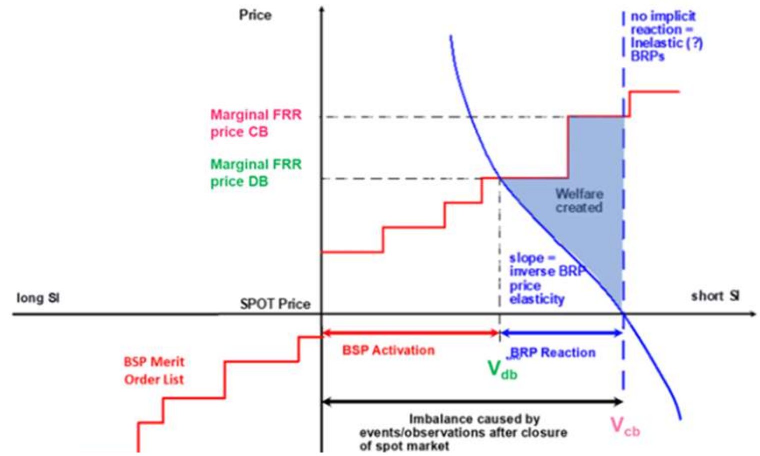
03 Increased social welfare

04 Less illegal and inefficient price reactions

05 Risk of system oscillations

Decentralized models are more efficient from an economic perspective





Expected upward reserve procurements [MW]

Expected upward reserve procurment savings [€]

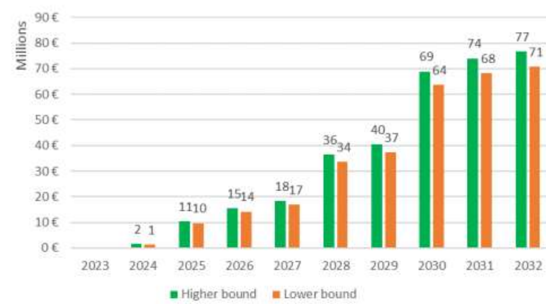
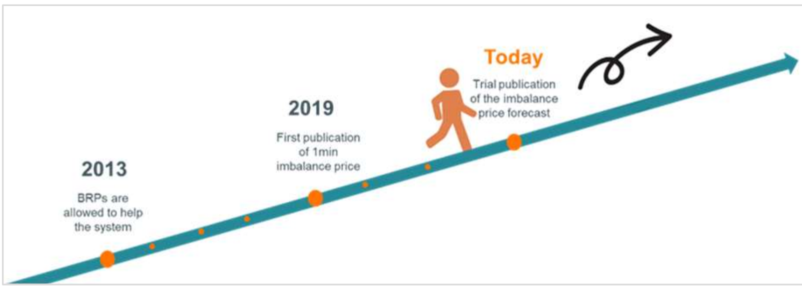
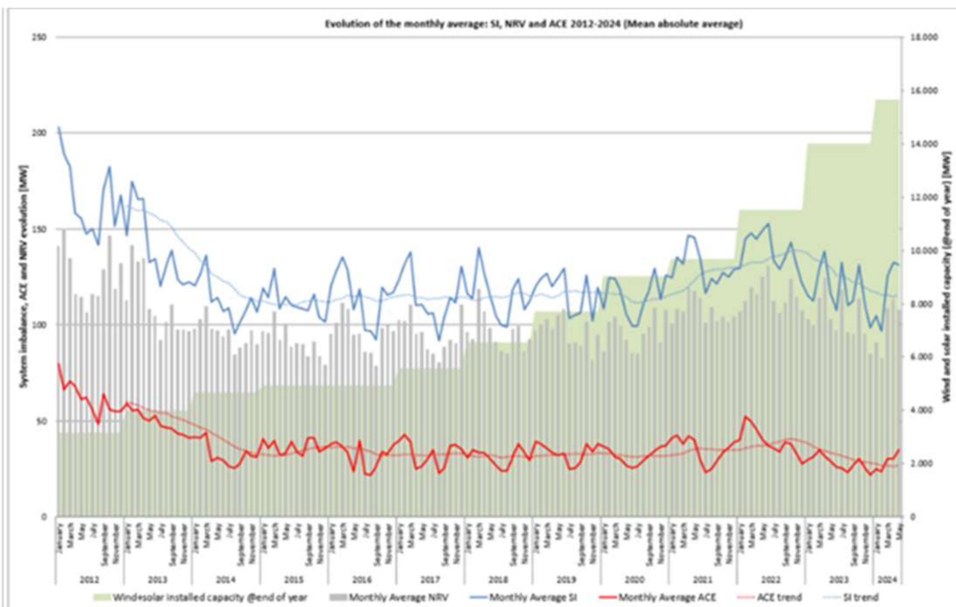


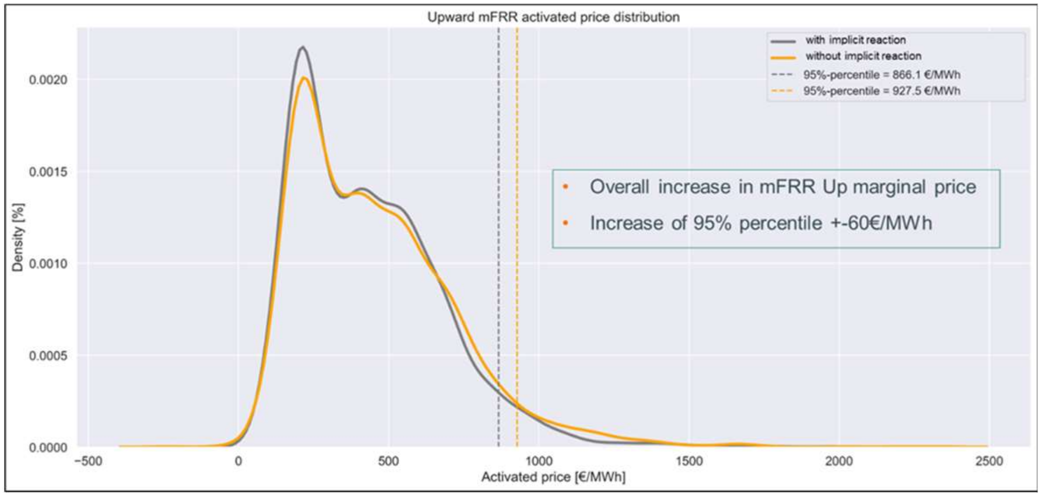
Illustration - Belgian experience with a decentralized balancind model

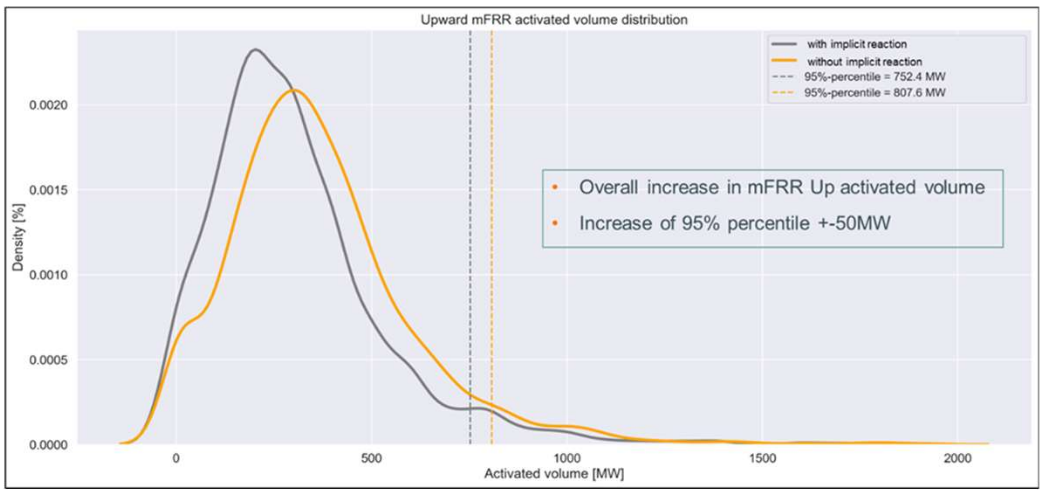




- ✓ The average System Imbalance significantly decreased when the BRPs were first allowed to help balance the system up to real time in Belgium.
- ✓ It then remained stable despite the huge increase in the installed capacity of intermittent renewable production in Belgium, which would be expected to worsen the System Imbalance due to higher forecast errors.

Illustration - Belgian experience with a decentralized balancind model





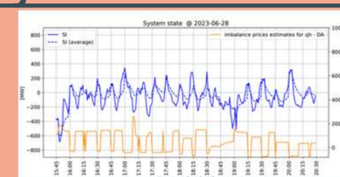
- ✓ These figures illustrate the impact of the implicit reactions to the imbalance price of one large demand facility located in Belgium
- ✓ They show that, without implicit reactions from this demand facility, an overall increase in both the mFRR activated volume and the mFRR marginal price would have occurred in the upward direction
- ✓ Since this demand facility does not offer its flexibility explicitly to the TSO, a centralized balancing model does not allow to valorize this flexibility and capture its benefits on system costs
- ✓ we can easily extrapolate the added value of decentralized balancing models in a world were and lots of (small decentralized) assets are able to (further) adapt their consumption to the real-time conditions of the system.

However the success of decentralized models, in the context of the energy transition, depends on a number of conditions

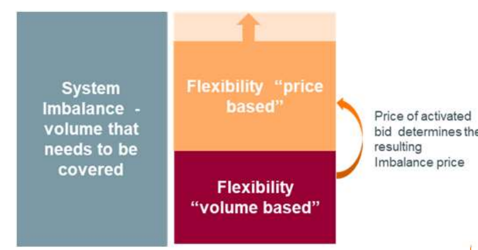
A design optimizing the potential of each flexible assets :
Despite the fact that an alternative exists, explicit participation in the system should remain sufficiently attractive in order to incentivize flexible assets to offer their flexibility in the service that brings the most value to the system.

My battery is able and pre-qualified to deliver aFRR. It is in my interest to offer my flexibility in this market.

A stable price signal, mitigating the risk of system oscillations :



Design and tools allowing a good complementarity between implicit reactions and explicit activations:
In order for a decentralized balancing model to be efficient, the sum of the volumes activated explicitly by the TSO and the implicit reactions of the market to the resulting price signal should be as close as possible to the real-time disturbance that needs to be covered.



For these reasons, the Belgian TSO has decided to bring its decentralized balancing model one step further

Next steps :

- Continue decreasing the barriers for participation to explicit balancing products (to the extent possible while preserving the nature and added value of these products);
- Review the imbalance price formula to make it more stable and more representative of the true value of energy over a 15-minutes period (which corresponds to the imbalance settlement period);
- Start publishing imbalance price forecasts to further help the market to efficiently calibrate its implicit reaction.
- Facilitate the development of market mechanisms that allow grid users to define different sourcing or optimization strategies for different assets that are located behind the same head meter, e.g. allowing to treat differently the flexible assets and the non-flexible load and hence to – directly or indirectly – expose the flexible assets to the imbalance price while securing the supply of the non-flexible load at less dynamic prices.
- Develop a decision-making tool that helps the TSO to define the volume to be activated explicitly, taking into account the complementary implicit reaction that these explicit activations would trigger.

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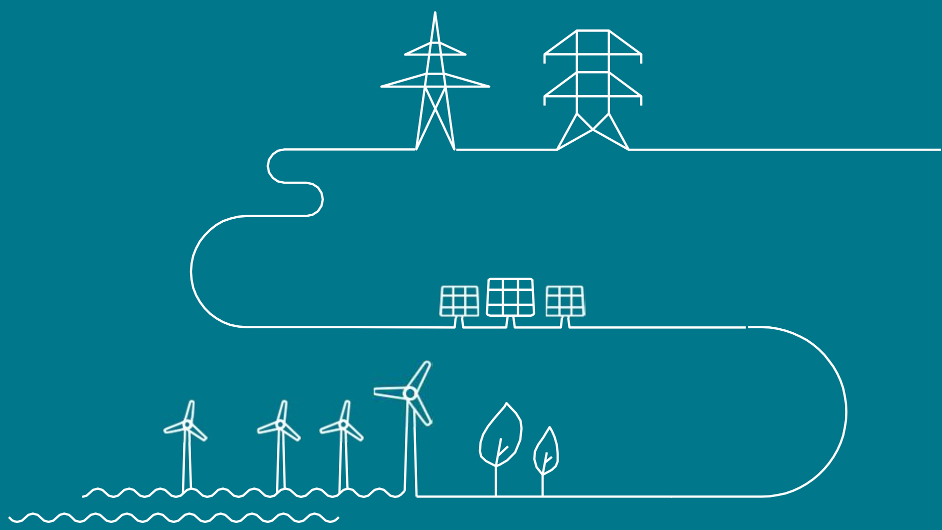
Thank you.



Elia Offshore Viewpoint Key Insights

Elia Think Tank presentation on 25 November 2024

WHAT IS A VIRTUOUS CIRCLE?

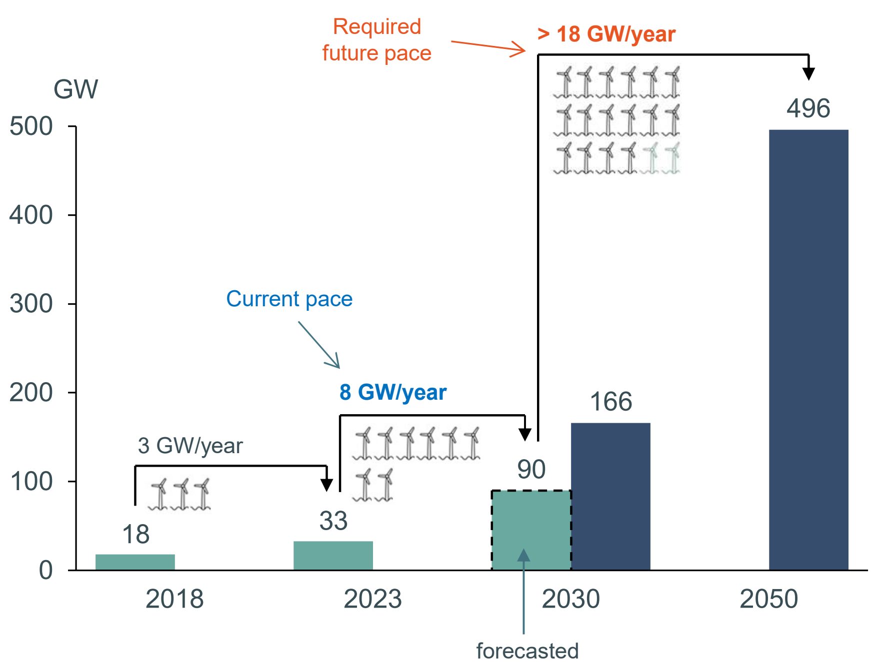
A virtuous circle is a positive cycle of events, as part of which each event contributes to the success of the next. In the context of offshore wind benefits, the expression refers to a scenario in which addressing one challenge will make subsequent challenges easier to tackle.

For example, by implementing risk-reduction strategies that lower project financing costs, more private investors can be attracted to invest in the development of offshore wind energy, ultimately supporting Europe's transition to a net-zero future.

Why an offshore study – now?

Offshore wind targets

European Union + United Kingdom + Norway



Data: WindEurope annual statistics, BNEF Wind Market Outlook 1H 2024, ONDP 2024
Net capacity additions, retrofit or decommissioning not considered

The ambition level is huge

- 500 GW by 2050 as per EU member state agreements, UK and NO ambitions
- Required installation pace needs to triple
- With project lead time of more than 10 years, we need to define our next steps now

Multiple challenges that need to be overcome

- Offshore wind potentials and electricity demand unequal across the continent
- Huge investment needs in need for de-risking and fair allocation of costs and benefits
- Constrained sea space
- Supply Chain shortages

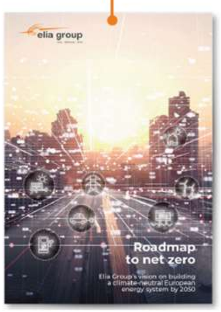
Study purpose is to outline steps to overcome them

- Map political ambitions into concrete actions
- Think coordinated planning and funding together
- Identify “self-enforcing” elements in offshore wind development

OUR RESEARCH

In recent years, Elia Group has published several papers on offshore wind development - and hybrid interconnectors in particular. We are convinced that this will help Europe to harness the full renewable potential of its seas while more effectively distributing the electricity produced among its Member States.

November 2021



Elia Group publishes its *'Roadmap to Net Zero'* study, which explores the building of a climate-neutral European energy system by 2050.

One of the study's main conclusions is that Europe's direct electricity demand can be met - but only if we accelerate RES expansion by a factor of three and build more interconnectors to balance out the uneven distribution of renewable energy sources (RES) across Europe.

Aside from their key role in enabling the exchange of RES between countries, interconnectors also level out (weekly) fluctuations in wind production. Therefore, they are also important for reducing the impact of local RES supply dips.

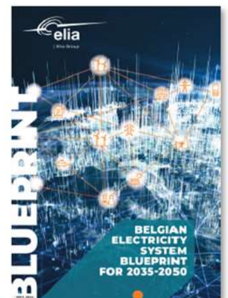
April 2022

Elia Group publishes a white paper on the importance of hybrid interconnectors. *'Harvesting Europe's Full Offshore Potential'* proposes methods for incentivising countries with different amounts of RES potential to collaborate and de-risk the investments provided by wind generation and transmission developers.

March 2024

Elia Group and the Danish wind farm developer Ørsted launch a joint paper which proposes novel approaches to offshore development, including the adoption of a regional planning approach (across entire sea basins) to offshore development and mechanisms to give developers visibility on long-term commodity prices, thus strengthening their business case. The paper also proposes the concept of an Offshore Investment Bank for the first time.

September 2024



Elia Transmission Belgium publishes its blueprint for the Belgian electricity system in the lead-up to 2050. The study concludes that without a long-term strategy and new policy measures in place for its future energy mix, Belgium will become increasingly reliant on imports. The study outlines several options for dealing with this change, each of which carries its own economic and technical impacts. One of the study's insights is that, as an additional large-scale electricity source, non-domestic offshore wind seems to be more cost effective (from a system cost perspective) than the development of new nuclear capacity.

THIS STUDY AIMS TO ADDRESS THE FOLLOWING KEY QUESTIONS:

1 | What essential steps are needed to bridge the gap between current offshore wind capacities in our seas and future offshore targets?

2 | What is the value of offshore wind for Europe today, and what will it be in future?

3 | How can offshore wind development be undertaken in the most efficient way possible whilst respecting wind resources and sustainability and economic feasibility considerations?

4 | How can planning, funding and risk allocation procedures be set up to facilitate the development of sets of offshore wind projects across the same sea basin, and/or across borders?

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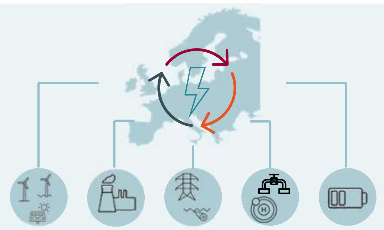
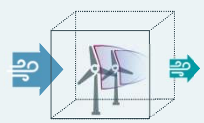
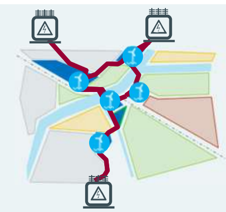
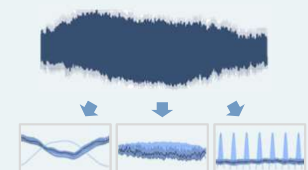
Overview of the analyses carried out for this study



Scenarios	Europe's energy system in 2050	2023 power market simulation	Wake loss analysis	Spatial planning and supply chain analysis	Fourier analysis
			In collaboration with MAX PLANCK INSTITUTE FOR BIOGEOCHEMISTRY	In collaboration with FfE Forschungsstelle für Energiewirtschaft e.V.	
No more offshore development after 2030	●				
Limited offshore collaboration	●	●	●		
Strong offshore collaboration	●	●	●	●	●

Minimising the **system cost**, i.e. the total cost of investments in generation and transmission, operations, fuel and imports…

A **simulation facility** replicated the historical market and system conditions to assess the effect of an additional offshore hub

Wake effects are caused by wind turbines; they reduce wind speeds and cause turbulence, which impacts the efficiency of neighbouring turbines

A **Fourier analysis** can be used to better understand the variability of renewable energy sources across different time horizons

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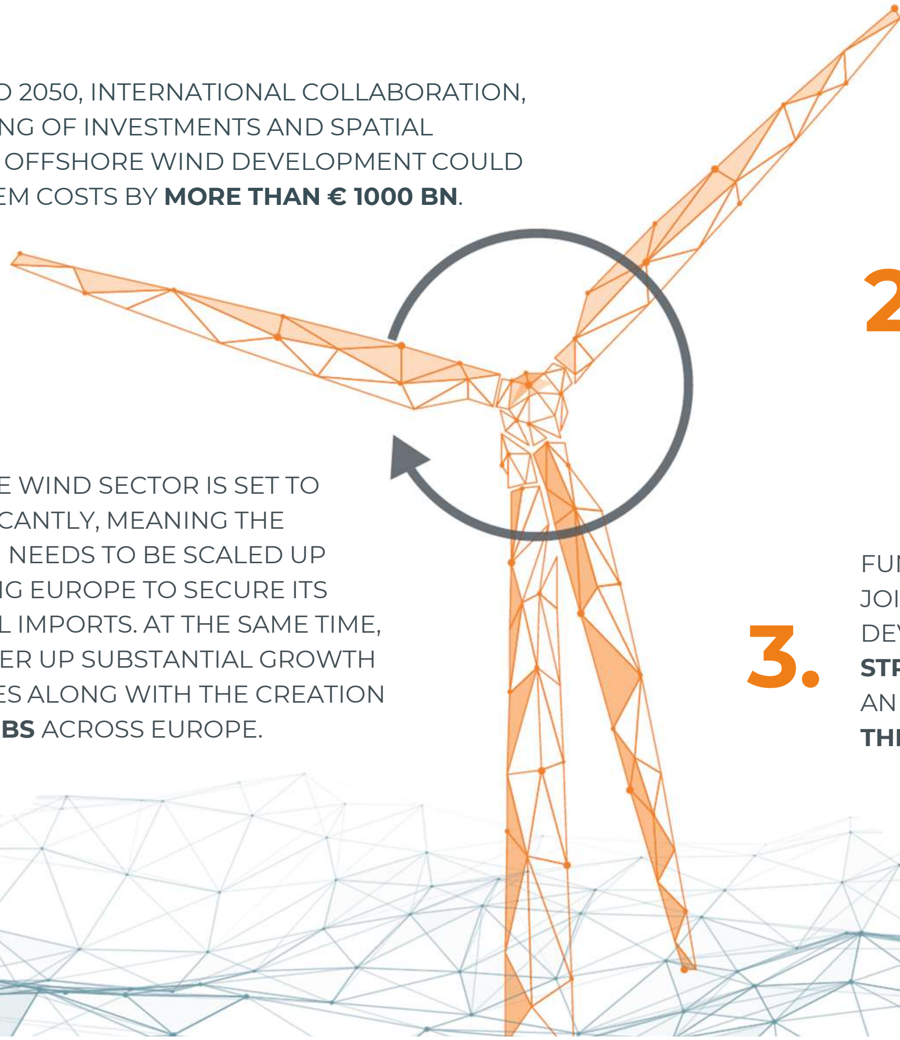
We held discussions with over 50 companies, associations, universities and think thanks to calibrate assumptions and put results into perspective

‘Going like the Wind’ is Elia Group’s key publication on the road towards the North Sea Summit in Hamburg, 2025

THE VIRTUOUS CIRCLE OF OFFSHORE WIND BENEFITS IN EUROPE

1. FROM 2030 TO 2050, INTERNATIONAL COLLABORATION, THE DE-RISKING OF INVESTMENTS AND SPATIAL PLANNING IN OFFSHORE WIND DEVELOPMENT COULD LOWER SYSTEM COSTS BY **MORE THAN € 1000 BN**.

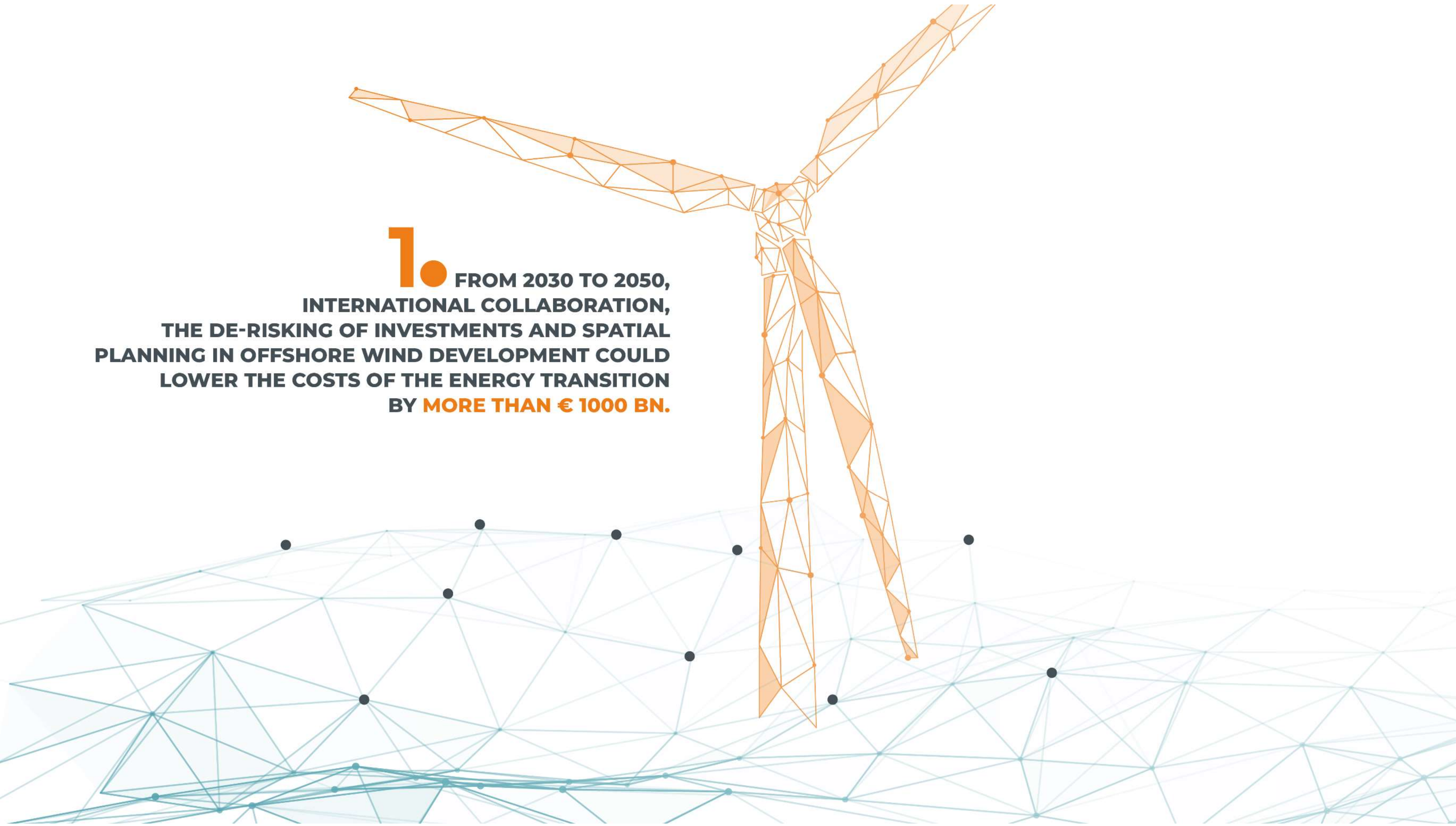


2. ADOPTING A COORDINATED APPROACH TO SEA-BASIN-WIDE PLANNING IS REQUIRED FOR EUROPE TO TAP INTO THE MOST EFFICIENT OFFSHORE WIND LOCATIONS AND HARNESS ALMOST **500 GW** OF OFFSHORE WIND ENERGY **BY 2050**.

3. FUNDING AND PLANNING GO HAND IN HAND. A JOINT FRAMEWORK TO FUND FUTURE OFFSHORE DEVELOPMENT WILL BE CRUCIAL FOR EFFECTIVELY **STREAMLINING LIMITED FINANCIAL RESOURCES** AND WILL BE A CRITICAL ENABLER FOR **UNLOCKING THE BENEFITS OF SEA-BASIN-WIDE PLANNING**.

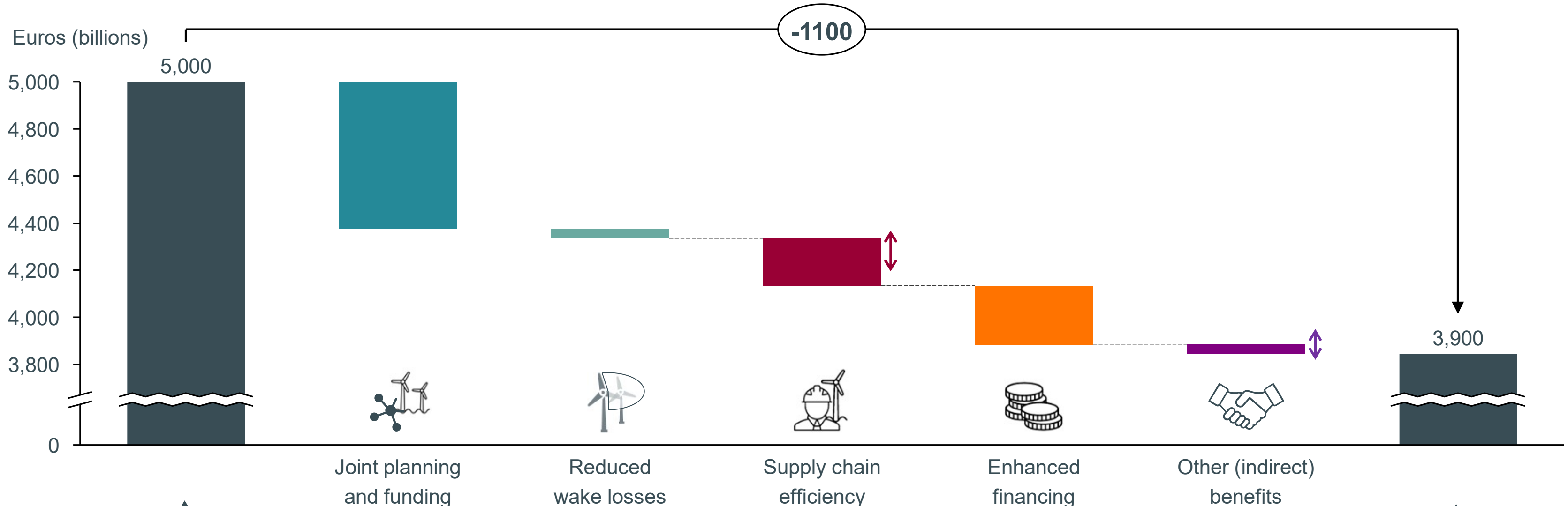
4. THE OFFSHORE WIND SECTOR IS SET TO GROW SIGNIFICANTLY, MEANING THE SUPPLY CHAIN NEEDS TO BE SCALED UP AND REQUIRING EUROPE TO SECURE ITS RAW MATERIAL IMPORTS. AT THE SAME TIME, THIS WILL OFFER UP SUBSTANTIAL GROWTH OPPORTUNITIES ALONG WITH THE CREATION OF **300,000 JOBS** ACROSS EUROPE.

1. FROM 2030 TO 2050, INTERNATIONAL COLLABORATION, THE DE-RISKING OF INVESTMENTS AND SPATIAL PLANNING IN OFFSHORE WIND DEVELOPMENT COULD LOWER THE COSTS OF THE ENERGY TRANSITION BY MORE THAN € 1000 BN.



SYSTEM COST BENEFITS ARE ONLY A FIRST STEP OF SEVERAL OTHER BENEFITS THAT A STRONG CROSS BORDER COLLABORATION WOULD UNLOCK

Benefits of collaboration: Reduction in system costs (€ bn) for the period 2030-2050 in Europe



Energy system costs for 20 years when not developing offshore wind effectively

Exporting and importing countries co-develop projects of highest European value first.

A key benefit is the addition of offshore wind above 150 GW (the 2030 targets of Europe)

→ Chapter 1 & 3

Smarter spatial planning improves economic efficiency of wind farm investments through higher capacity factors.

→ Chapter 2

Realise efficiency gains through standardisation, innovation & large quantities.

only likely in the long run and when shortages are reduced.

→ Chapter 3

Reducing the cost of capital through an enhanced approach to funding and cost allocation

→ Chapter 2

Local value creation in many countries, increased resilience to external (energy price) shocks, technology leadership

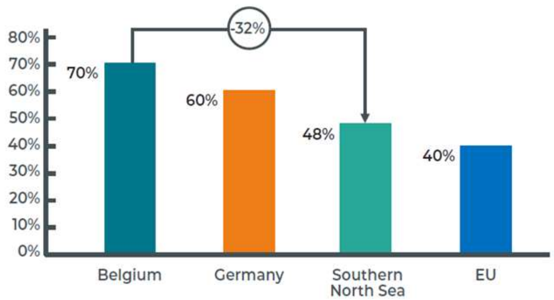
→ Chapter 2

Energy system costs for 20 years when all levers act together in a virtuous circle

THE LONG DISTANCE (INTER-)CONNECTION OF OFFSHORE WIND FARMS TO THE SHORE REDUCES VARIABILITY

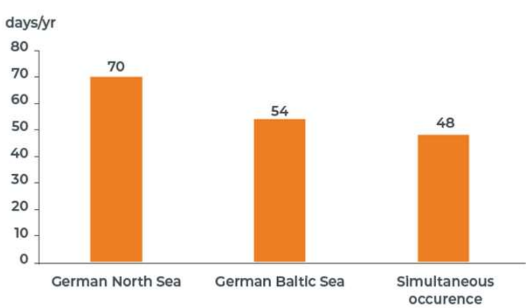
Weekly variability of offshore wind*

In % of installed capacity, covering p99.97 percentile

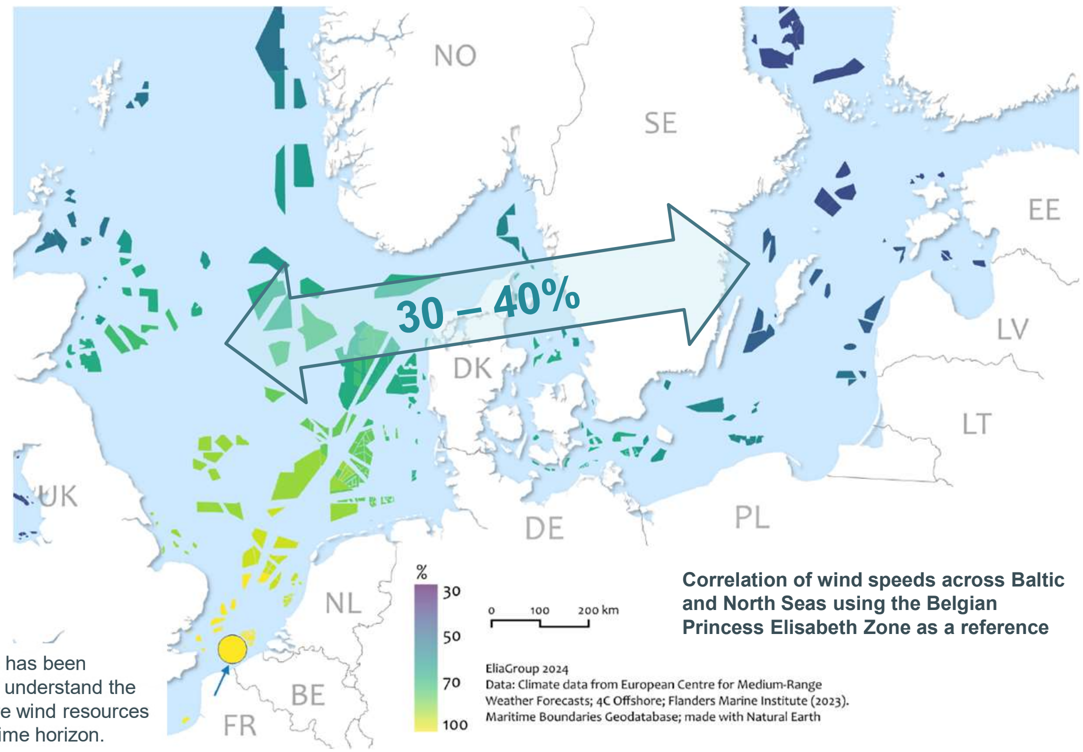


Days with low offshore wind capacity per year

Average over the period 1979-2023



A **Fourier analysis** has been conducted to better understand the variability of offshore wind resources across the weekly time horizon.



Correlation of wind speeds across Baltic and North Seas using the Belgian Princess Elisabeth Zone as a reference

*The findings should be regarded as theoretical optima (with the assumption of perfect interconnection), which will not entirely be reached

HAD MULTIPLE HYBRID INTERCONNECTORS BEEN BUILT BY NOW, WE WOULD BE REAPING THEIR BENEFITS

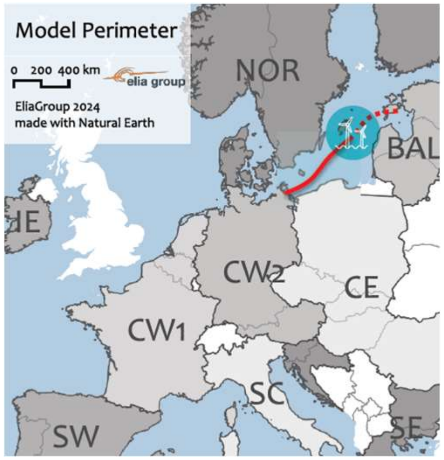
PRICE EFFECTS OF AN ADDITIONAL HYBRID INTERCONNECTOR

Price effect of an additional 2 GW cross-border radially connected offshore hub in the Baltic Sea in the 2023 day-ahead market

Price effect of an additional 2 GW hybrid connected offshore hub in the Baltic Sea in the 2023 day-ahead market

A **simulation facility** replicated the historical market and system conditions to assess the effect of an additional offshore hub. The bidding zones of the day-ahead market were grouped into relevant macro-regions according to the procedure adopted in the TYNDP

No.	Offshore Hubs	Connected to
1 cross-border *radial*	**2 GW** Baltic HUB	CW2 <**2GW**> Baltic HUB
2 *hybrid*	**2 GW** Baltic HUB	CW2 <**2GW**> Baltic HUB <**0.5GW**> BAL



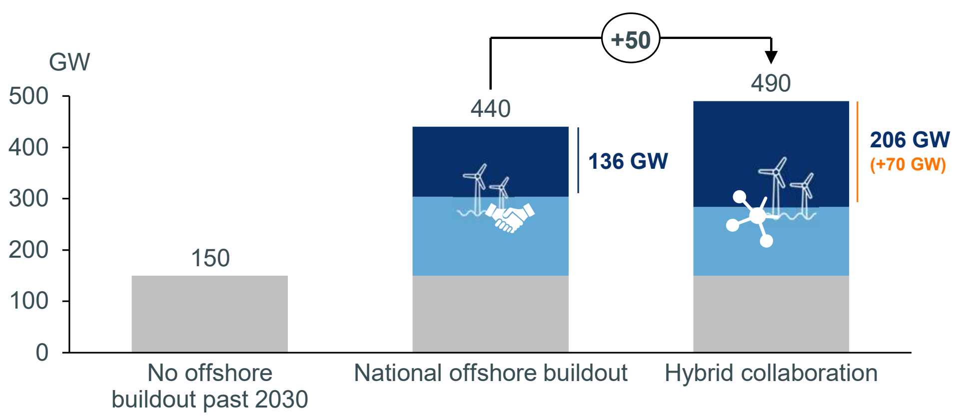
Note: Whilst the price effects in this calculation would allow the wind farm and transmission infrastructure to pay off within the expected lifetime of the assets, it is clear that actual investment decisions cannot be taken based on one single example.

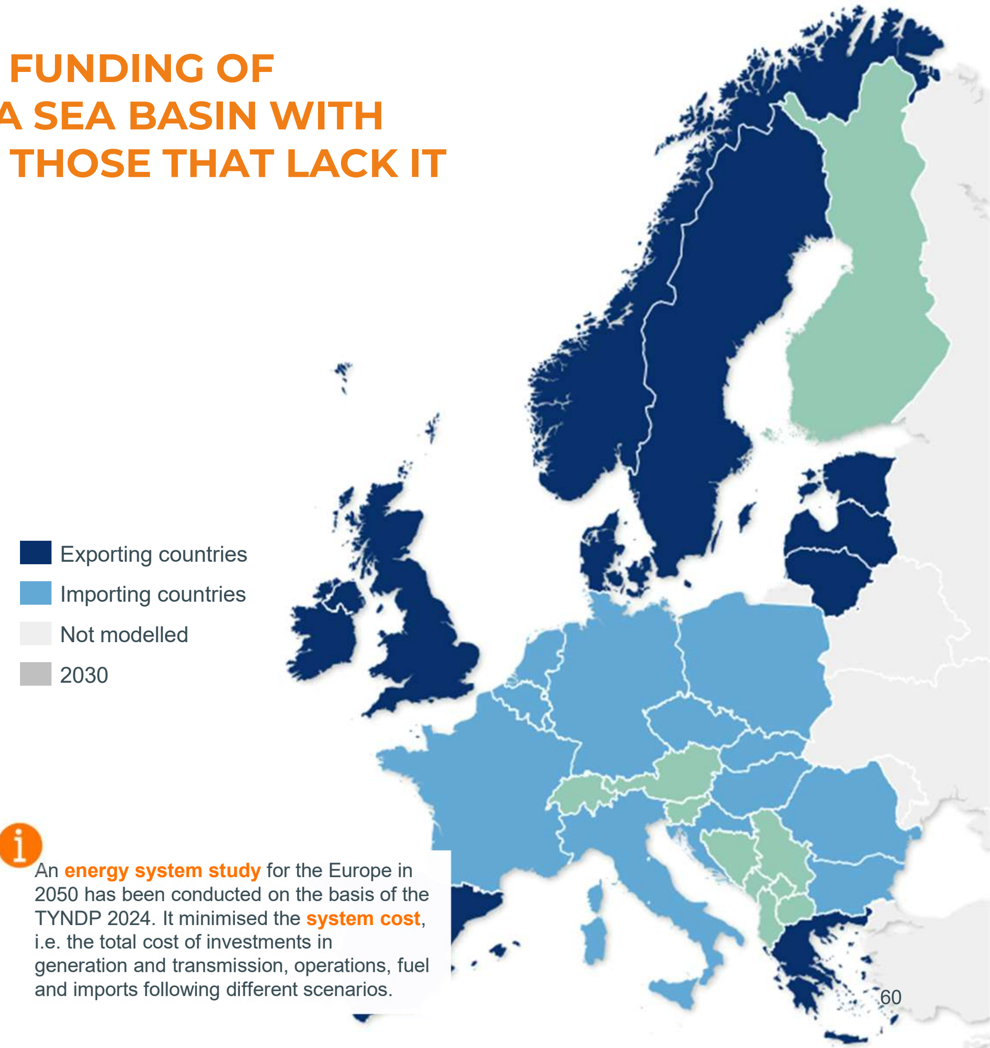
2. ADOPTING A COORDINATED APPROACH TO SEA-BASIN-WIDE PLANNING IS REQUIRED FOR EUROPE TO TAP INTO THE MOST EFFICIENT OFFSHORE WIND LOCATIONS AND TO HARNESS ALMOST 500 GW OF OFFSHORE WIND ENERGY BY 2050.

COORDINATED PLANNING SHAPES THE JOINT FUNDING OF PROJECTS AND UNITES COUNTRIES AROUND A SEA BASIN WITH HIGH LEVELS OF OFFSHORE POTENTIAL WITH THOSE THAT LACK IT

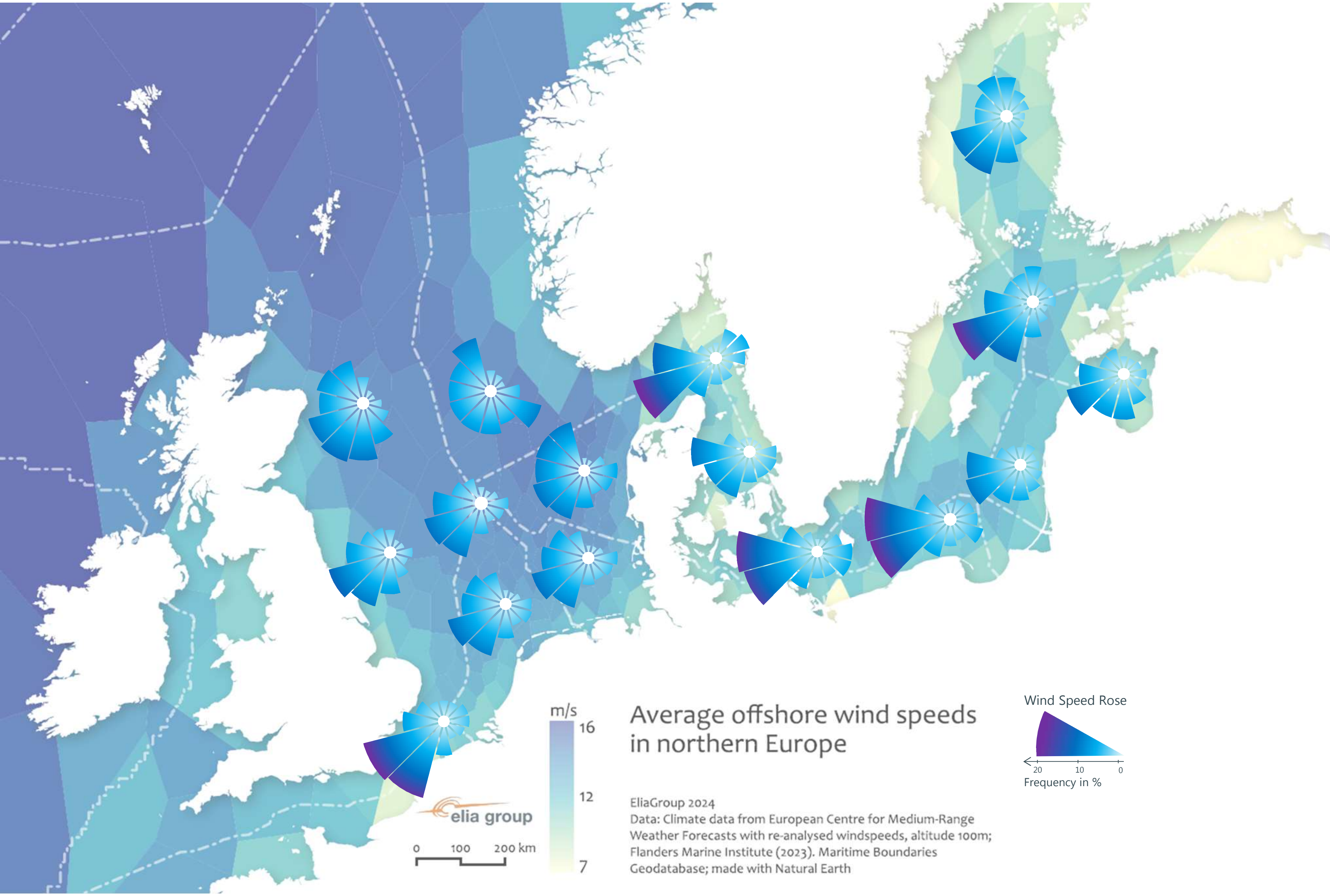
A lack of collaboration may stall the realisation of offshore projects after 2030, due to a lack of appetite to support the costs of these projects in countries that have too much RES potential than they need.

Simulation results for offshore buildout in exporting and importing countries across the scenarios for 2050





An **energy system study** for the Europe in 2050 has been conducted on the basis of the TYNDP 2024. It minimised the **system cost**, i.e. the total cost of investments in generation and transmission, operations, fuel and imports following different scenarios.


Average offshore wind speeds in northern Europe
m/s
16
12
7
0
100
200 km
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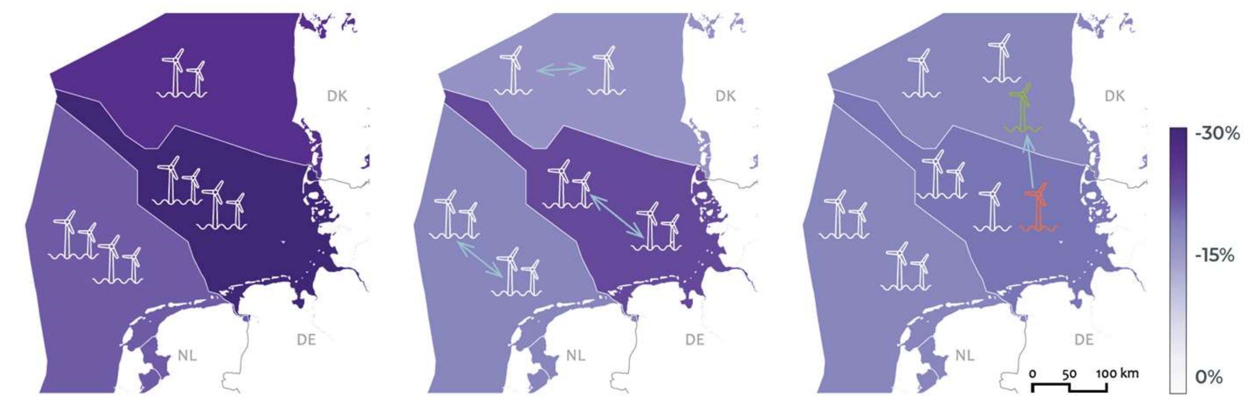
EliaGroup 2024
Data: Climate data from European Centre for Medium-Range Weather Forecasts with re-analysed windspeeds, altitude 100m; Flanders Marine Institute (2023). Maritime Boundaries Geodatabase; made with Natural Earth
Wind Speed Rose
20
10
0
Frequency in %

CROSS-BORDER COLLABORATION MUST BE CAREFULLY SPACED OUT TO MAINTAIN PRODUCTION EFFICIENCY

MITIGATION OF FULL LOAD HOUR REDUCTIONS DUE TO WAKE EFFECTS IN THE GERMAN BAY OF THE NORTH SEA FOR THREE SIMULATED 2050 SCENARIOS



Base case with current planning | More space for wind farms | Cross-border cooperation

1

- ► 35 GW
- ► 66 GW
- ► 72 GW

Base case (business as usual)
Power density:
Between 5 and 12 MW/km²

2

- ► 35 GW
- ► 66 GW
- ► 72 GW

More space for wind farms
Power density:
Between 1 and 3 MW/km²

3

- ► 50 GW
- ► 51 GW
- ► 72 GW

Cross-border cooperation
15 GW shifted from Germany to Denmark

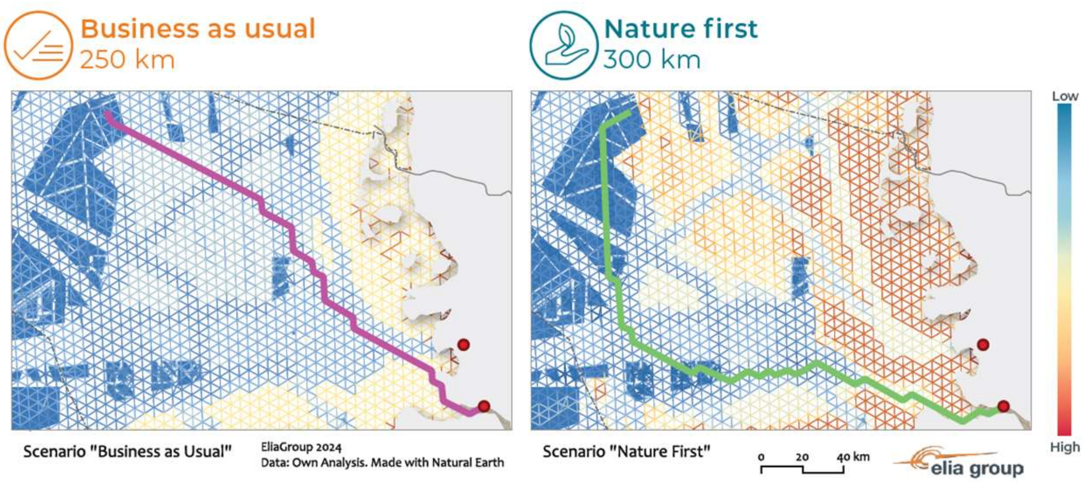
Wake losses are unavoidable in offshore wind development. They are a result of wind turbines extracting some energy from the air and creating turbulences further downstream. Smarter wind farm designs and placements can reduce (but not eliminate) losses.

8-9 GW

- The savings that can be achieved for the German Bight amount to **about 30 TWh, which is equivalent to 8-9 GW** of offshore wind capacity
- This equals approx. €20 bn in CAPEX

COORDINATED PLANNING FACILITATES THE EFFICIENT AND SUSTAINABLE PLACEMENT OF OFFSHORE ASSETS

Example of an optimal cable corridor in the two scenarios with penalty cost raster being shown



Business as usual

1,039 crossings across protected areas.
Total length corridors in protected areas:
17,150 km

-50%

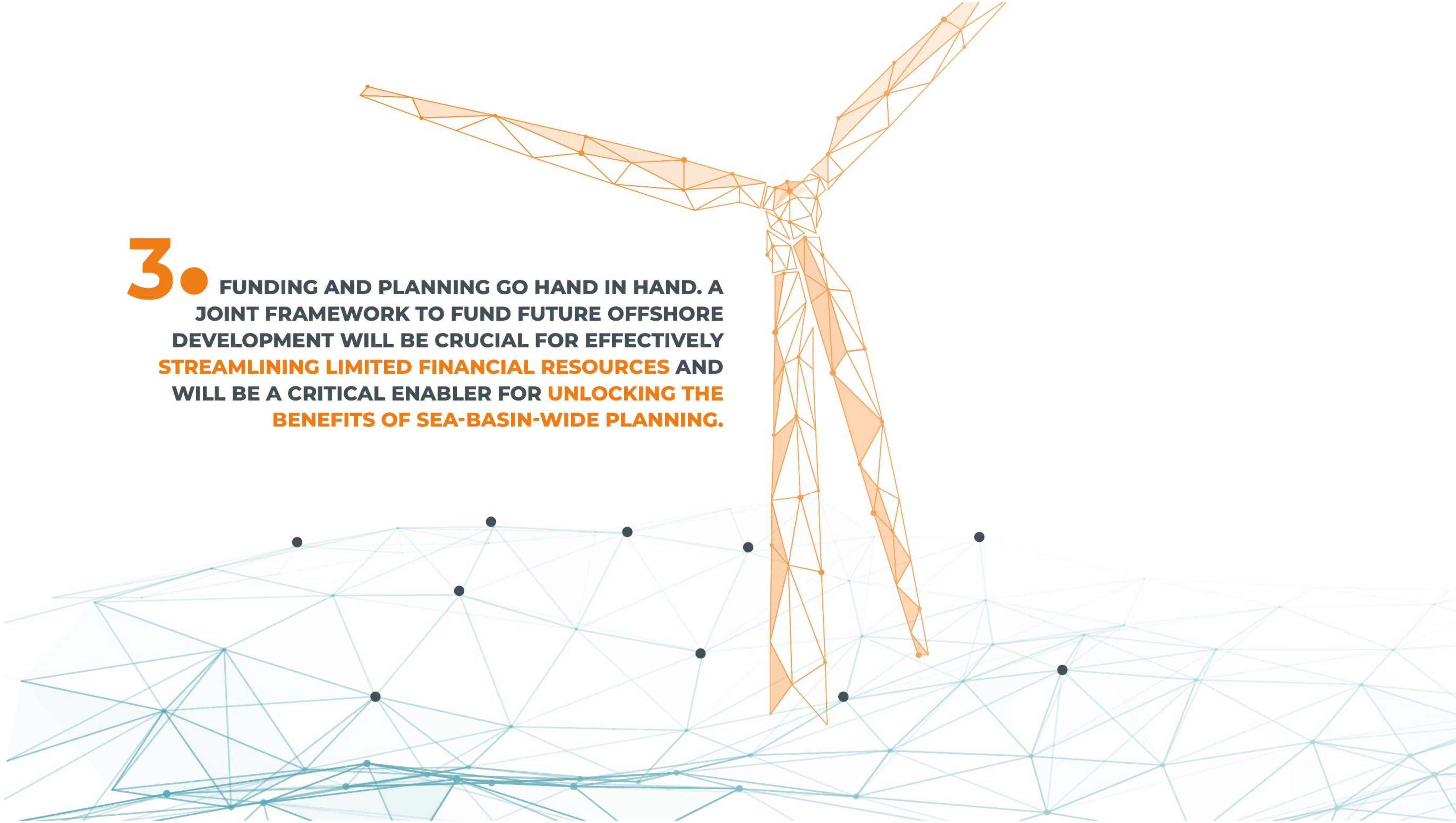
Nature first

780 crossings across protected areas.
Total length corridors in protected areas:
8159 km

The illustrative example shows, what has been analysed with a geographical information system at a larger scale for the Baltic and North Sea for a 2050 scenario of offshore wind development. Two scenarios were compared, in which wind farm connection routes were identified by an optimiser that minimised cost of cable installations as well as crossings of otherwise dedicated areas such as natural conservation or military areas.

A **geographical information system** is capable of consolidating a wealth of geographical information such as spatial planning data and information on the sea depth. It can be used to analyse scenarios for future infrastructure corridors in the sea.

3. FUNDING AND PLANNING GO HAND IN HAND. A JOINT FRAMEWORK TO FUND FUTURE OFFSHORE DEVELOPMENT WILL BE CRUCIAL FOR EFFECTIVELY STREAMLINING LIMITED FINANCIAL RESOURCES AND WILL BE A CRITICAL ENABLER FOR UNLOCKING THE BENEFITS OF SEA-BASIN-WIDE PLANNING.



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JOINT FUNDING IS THE KEY ENABLER FOR JOINT PLANNING

Fund together what we plan together and plan together what we fund together.

- *Efficient and coordinated planning go hand in hand with funding.*
- *The Offshore Investment Bank, a concept for such a joint framework, brings different funding sources together.*

Fair cost and benefit allocation

- *Offshore hybrid interconnector projects have distributional effects.*
- *A fair and adequate distribution of costs and benefits, takes them into account.*
- *A multi-country approach, including all sea basin countries, for a set of projects should be facilitated.*
- *Allocation keys must provide long-term confidence, while remaining flexible to adapt to unexpected changes in the market.*

Efficient risk allocation and de-risking

- *The sea basin scope of the Offshore Investment Bank, allow for a natural risk spreading over different projects in the sea basin.*
- *Further derisking of the projects remains a key factor to generate confidence by investors.*
- *This goes through allocating the risks to parties that are best equipped to manage them.*

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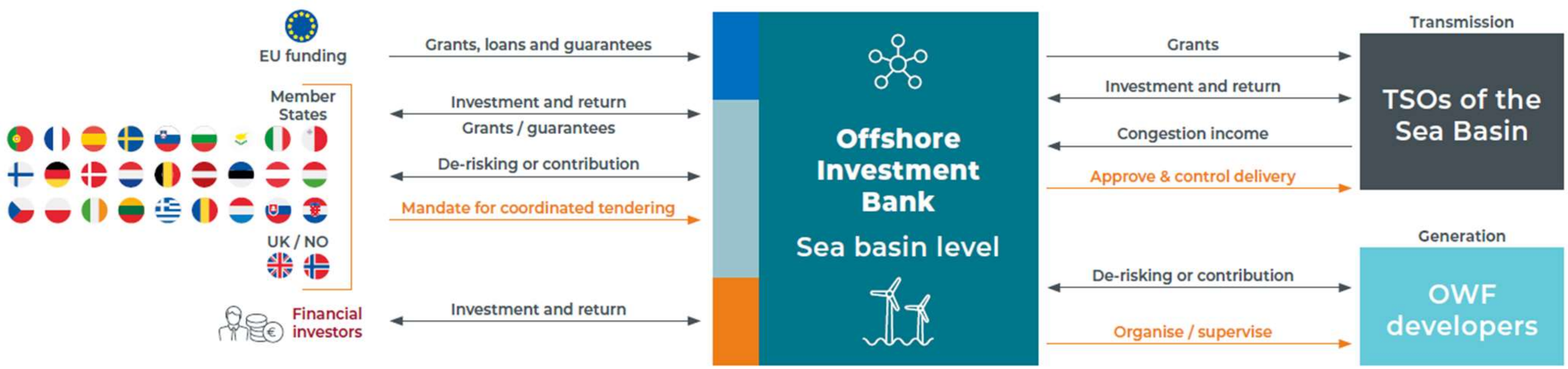
ADOPTING A SEA BASIN APPROACH TO OFFSHORE COOPERATION TO REACH AN OPTIMAL GRID BUILDOUT

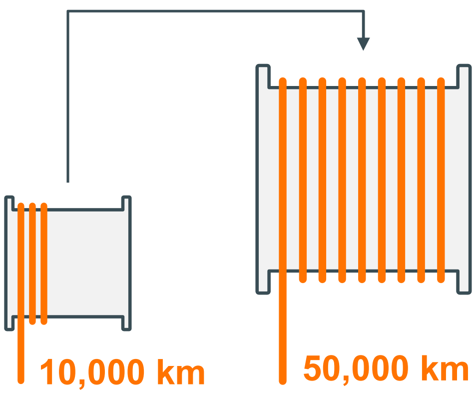
ADDRESSING THE INTERDEPENDENCE OF PLANNING AND FUNDING: ALIGNING THE INTERESTS OF ALL PARTIES INVOLVED



4. THE OFFSHORE WIND SECTOR IS SET TO GROW SIGNIFICANTLY, MEANING THE SUPPLY CHAIN NEEDS TO BE SCALED UP AND REQUIRING EUROPE TO SECURE ITS RAW MATERIAL IMPORTS. AT THE SAME TIME, THIS WILL OFFER UP SUBSTANTIAL GROWTH OPPORTUNITIES ALONG WITH THE CREATION OF 300,000 JOBS ACROSS EUROPE.

GIVEN THAT OFFSHORE WIND SUPPLY CHAINS WILL CONTINUE TO BE INTERNATIONALLY AND GLOBALLY INTERLINKED, EUROPE WOULD BENEFIT FROM MAINTAINING ITS STATUS AS A STRONG SUPPLIER OF OFFSHORE WIND ASSETS

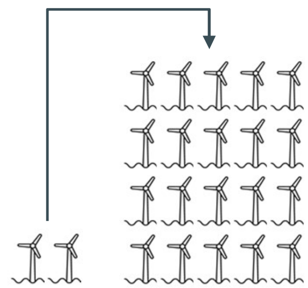
The annual buildout and its financing will need to double to achieve this (next to inter-array cables and onshore grid development)



10,000 km — *Installed corridor length in 2023**

50,000 km — *Minimum required corridor length in 2050**

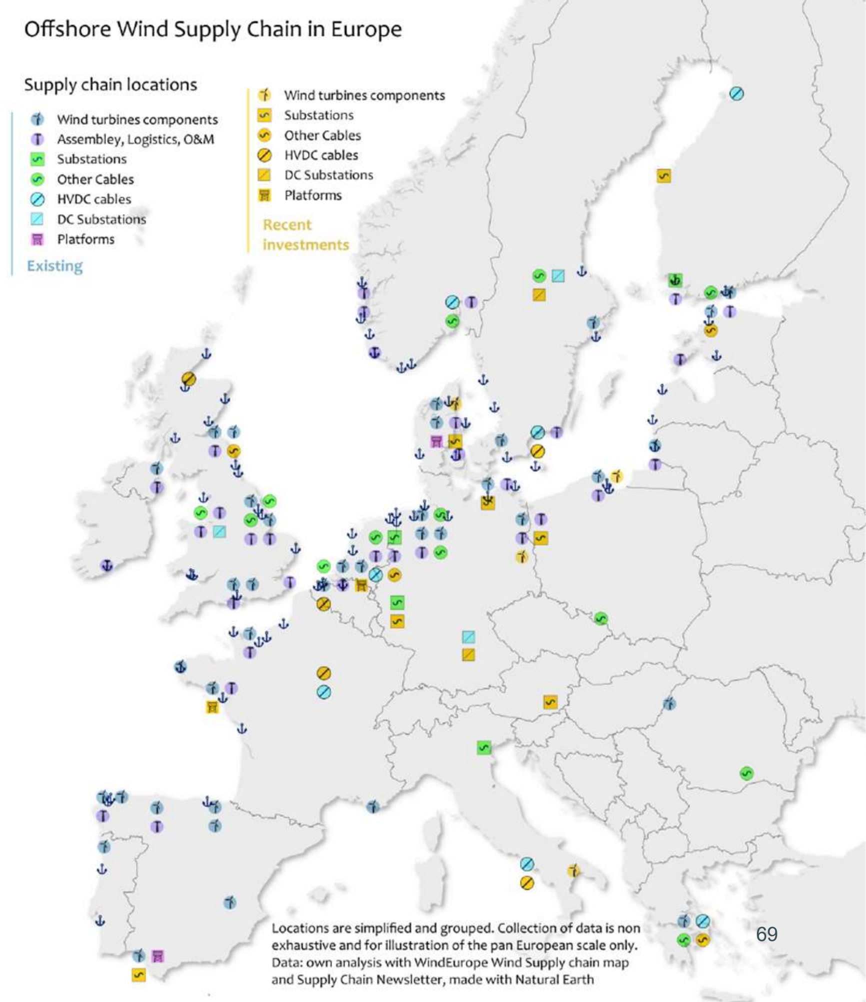
The annual buildout and its financing will need to triple to achieve this.



33 GW — *Installed in 2023*

500 GW — *Political targets for 2050*

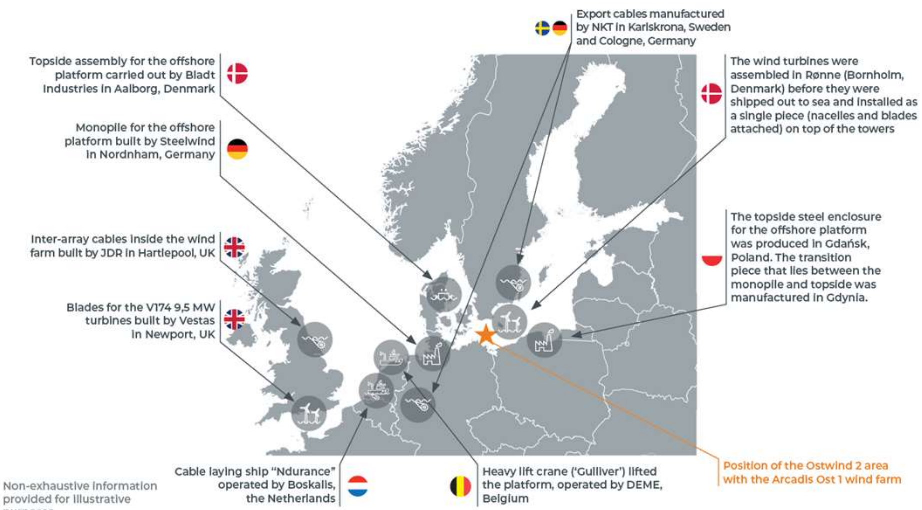
* For Baltic and North Sea alone



EVIDENCE FROM EXISTING PROJECTS: SUPPLY CHAINS ARE INTERNATIONALLY LINKED

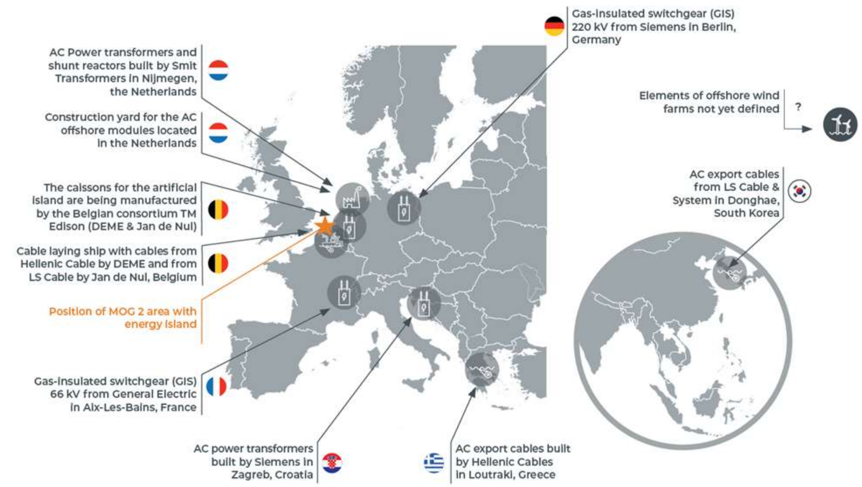
Overview of supply chain locations for…

50Hertz' Arcadis Ost 1 project in the Baltic Sea



Non-exhaustive information provided for illustrative purposes.

Elia's Princess Elisabeth Island Project in the North Sea



Illustrative and non-exhaustive information for the HVAC-part of the island. Information about HVDC parts and wind turbines is not yet available

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TO MEET EUROPE'S OFFSHORE TARGETS, MANUFACTURING CAPACITY MUST BE SCALED UP; EUROPE'S LEADERS MUST THEREFORE ESTABLISH FRAMEWORKS THAT MAKE POLITICAL TARGETS RELIABLE VIA JOINT APPROACHES TO PLANNING AND FUNDING

Asset	Current capacities in Europe p.a.		Demand in Europe p.a. from 2030 to 2050
Offshore wind turbines (10-20 MW each)	8-9 GW	2x ↗	at least 18GW(2)
Cables (HVDC 525kV)	4000 km	2x ↗	5000-7000 km(3) front-loaded with peak demand appearing over the next few years
Converters (HVDC on- & offshore)	6-8 GW(1)	3x ↗	20 GW

Data: WindEurope and own calculations
(1) for a point-to-point HVDC connection for a wind farm, two converters are required. In addition: for offshore converters, the jacket manufacturing capacity is another bottleneck
(2) Depending on the installed capacity until 2030 the demand can increase to more than 20 GW annually
(3) depending on the technical design (metallic return or not)

Directly related jobs

300,000+

- Reaching Europe's 496 GW target will produce the opportunity to create 300,000 jobs, stimulate economic growth and promote local European value creation

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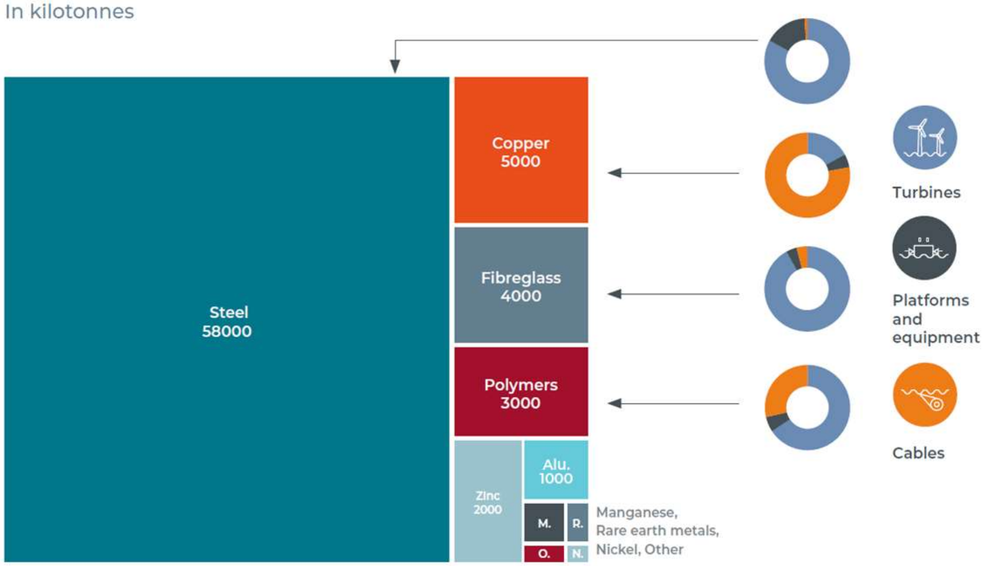
RAW MATERIAL DEMAND IS A CORNERSTONE OF OFFSHORE WIND DEVELOPMENT BUT NOT UNMET BY HISTORICAL STANDARDS

MATERIAL TONNAGE NEEDS AND MAIN ASSET TYPES THAT DRIVE IT

In kilotonnes



For scale: the total amount of steel for North Sea and Baltic Sea oil and gas pipelines and platforms amounts to about 60,000 kt with this infrastructure being erected over over a period of 30 years.

FUTURE RAW MATERIAL DEMAND INCREASE IN EUROPE

Not significant | Medium | Substantial

Raw material	Demand increase in the lead-up to 2050 (compared with 2022)	Criticality ranking[7]
Steel and Iron	8x ↗	Not significant
Copper	8x ↗	Substantial
Fibreglass	7x ↗	Medium
Polymers	3x ↗	Not significant
Zinc	2x ↗	Not significant
Aluminium	6x ↗	Medium
Manganese	5x ↗	Not significant
Nickel	5x ↗	Substantial
Rare earth metals[8]	8x ↗	Substantial

Risk mitigation strategies include...
material substitution, increased recycling quotas, decreasing material intensity per capacity, standardisation of assets

6. Based on an assessment of reliability of supply (diversity of suppliers, origin of materials, resilience of Europe against disruptions), affordability (price, fluctuations and diversity of offers) and overall importance for the sector relative to the demand increase.
7. In particular Neodymium, Molybdenum and Prasedymium.

WE URGE THE EUROPEAN COMMISSION AND NATIONAL GOVERNMENTS TO...

1 | continue to commit to the path set out in the European Green Deal
by fostering European competitiveness, the decarbonisation of industry & end-use sectors and investing in clean energy infrastructure.

2 | prioritise projects that carry the highest levels of European value
by establishing a joint planning and a funding framework that aligns the interests of all involved parties. It is only this framework which will contribute to a more cost-efficient and affordable energy transition for consumers.

3 | collaborate on spatial planning and the development of cross-border projects at regional level
when planning the future offshore grid, and take into consideration spatial constraints and the efficiency of wind power production.

4 | mobilise and streamline the necessary capital for wind farms, transmission systems and manufacturing capabilities
by maximising public investment, leveraging and de-risking private capital, and implementing risk-absorbing measures to make it easier for commercial banks, investors, and venture capital firms to finance projects and companies.

5 | capitalise on Europe's technology leadership in the offshore wind sector and grid sector
by stimulating a collective approach to industrial policy across Europe in order to step up critical manufacturing capabilities and secure the supply of raw materials. Research and innovation funding must be increased to improve efficiencies in the substitution of critical materials. Initiatives which ensure that Europe has a big enough workforce that has the right skills must be introduced.

GOING LIKE THE WIND – THE VIRTUOUS CIRCLE OF OFFSHORE WIND BENEFITS IN EUROPE

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An online version of this study, alongside an interactive map, can be accessed here:
https://www.eliagroup.eu/goinglikethewind

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Elia – Viewpoint 2025
Energy Storage

Our Viewpoint publications

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2018

Consumer-centricity

2019

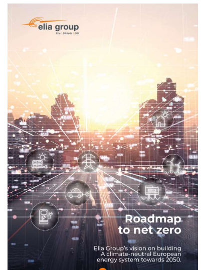
Market Design Updates towards 2030

2020

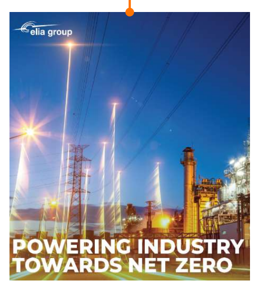
E-mobility

2021

Climate neutral energy system



2022



Industry decarbonisation

2023

Flexibility

2024

Offshore wind

2025

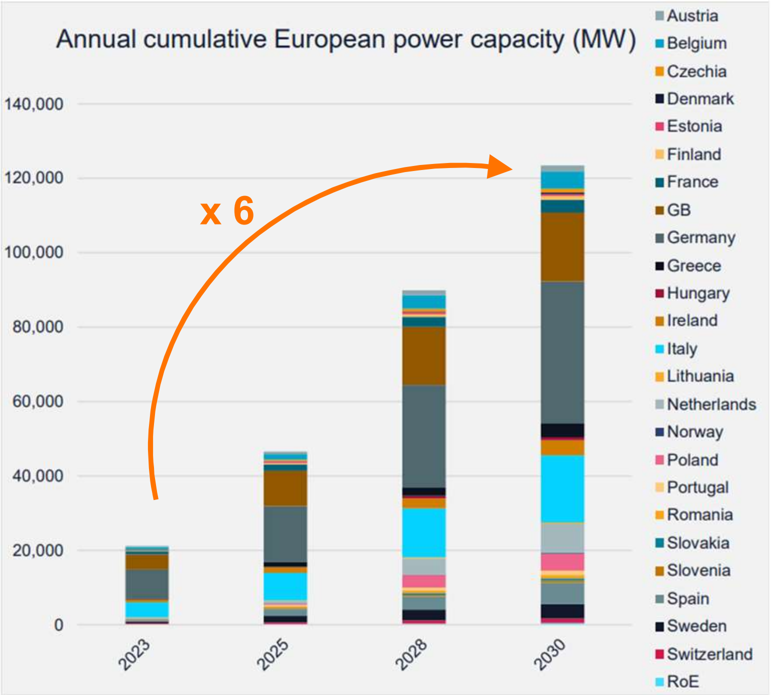
Energy storage

Publication foreseen for Q4 2025

Our aim is to spotlight a critical issue and bring actionable guidance, supported by the broader industry, to develop the future energy system that serves society's best interests.

Why an Energy Storage Viewpoint now?

- Fast deployment of energy storage in Europe (and BE)
- High increase in number of storage connection requests
- To further examine the impact of significant storage capacity on the (electrical) energy system
- To gain deeper understanding whether storage can serve as a solution for current and future challenges such as congestion, solar excess …



Source: LCP Delta. (March 2024).

There is a **consensus on the need of storage to reach the Net zero ambitions.**
Yet, we would like **to further investigate what constitutes storage, how much** is needed, **where** it should be located**, its impact on the energy system**, and **ways to unlock its potential**.

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The Energy Storage Viewpoint will focus be on storage in the future electricity system.

Potential directions

What is storage?	*Do we need storage?*	*Storage & Industry*	*Storage & grid build-out*	*System supportive storage*	*Impact on energy prices & energy bill*
How much & Where ?	*Storage & RES*	*Supply chain*	*Storage in future energy system*	*Financially interesting*	*Technologies*
Grid connection	*Short- or long-term*	*Storage regulations*	*Market saturation*	*Future-proof storage systems*	*Resilience, independency*

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1. Is your company considering storage solutions?

ⓘ Start presenting to display the poll results on this slide.

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2. What topics come into mind when thinking about storage?

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3. What are your concerns regarding storage solutions? What information would you like to have on storage? What questions do you have?

ⓘ Start presenting to display the poll results on this slide.

The Viewpoint seeks to integrate diverse perspectives & deliver messages endorsed by a broad range of stakeholders

Interested to collaborate or to be involved?

Share your questions/challenges on Energy Storage
Your inputs will help to understand the current challenges and inquiries on Energy Storage across different sectors. This will enable us to focus on the most important topics and deliver actionable guidelines.

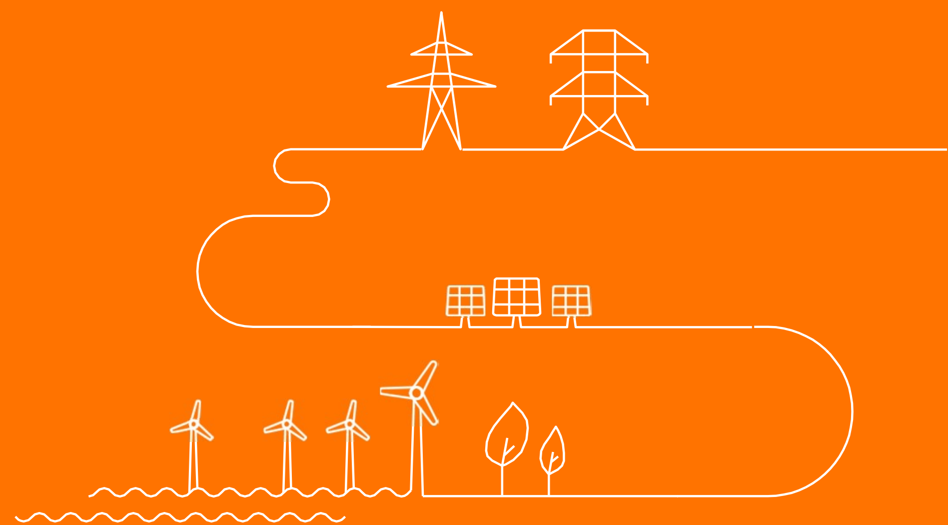
Share your experiences & knowledge on Energy Storage
You share your experiences and knowledge which can enrich the report with detailed deep dives, informative boxes, best practices and other valuable insights. You can contribute to the messages of the report.

Become a sparring partner
You challenge and evaluate our findings, provide critical insights and enhance the quality of our work.

Working together
We collaborate on topics of mutual interest and create impactful outcomes together (f.e. setting up use cases, providing services, shared investigations …).

Provide a testimonial
Your testimonial (quote, video …) will be showcased in the report and/or during the publication event.

Thank you!



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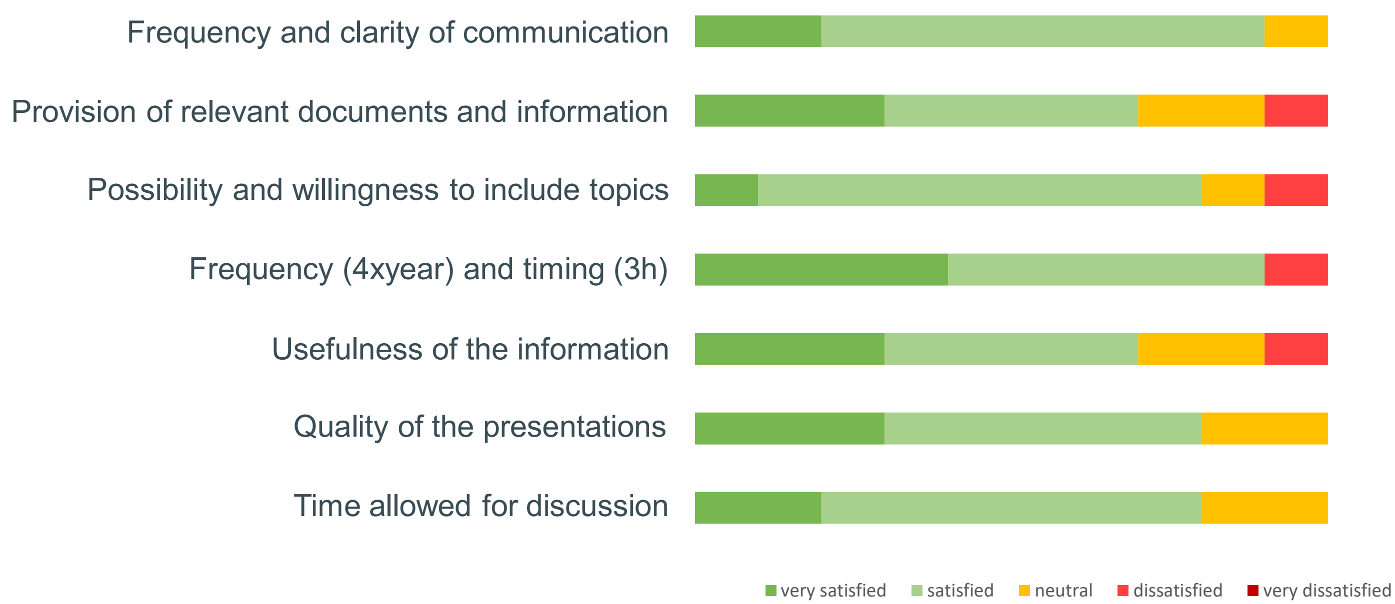
One year Think Tank

James Matthys-Donnadieu

Results survey « one year Think Tank »



Change suggestions from members

More long term perspective/analysis

More novel ideas and thought provoking speakers could be brought

Good platform and organisation

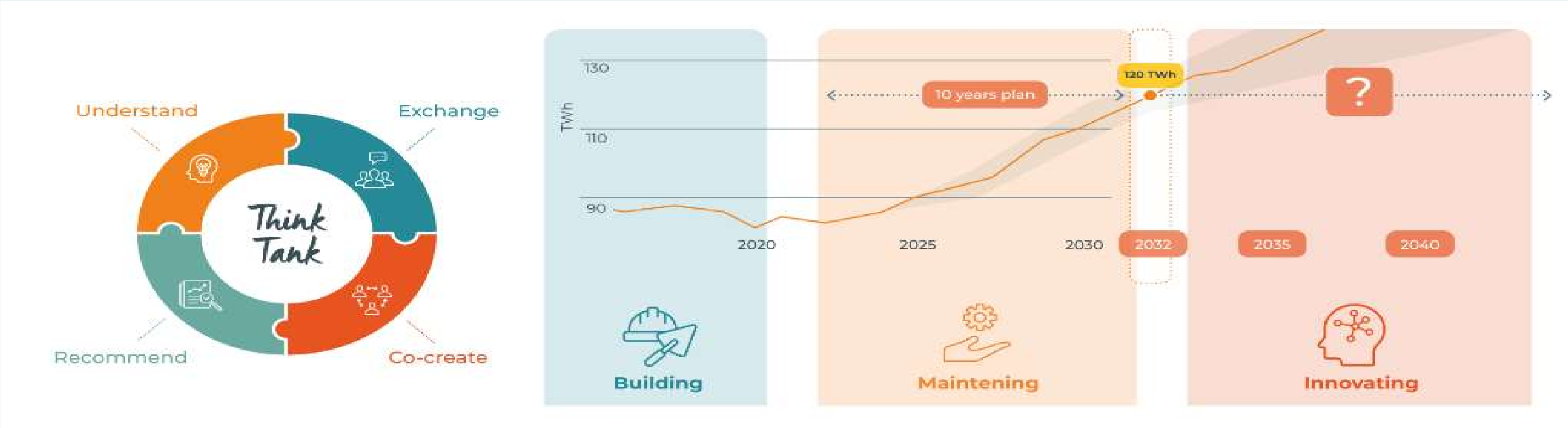
More contribution from other parties

Be more innovative - Currently too many overlaps with other fora

Other suggestions?

Any other Business

proposed dates 2025



Tue. 11 Feb.
13-16h

Fri. 6 June
13-16h

Fri. 19 Sep.
13-16h

Mon. 8 Dec.
13-16h