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Modeling offshore grid systems

Modeler's Exchange Workshop

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Outline

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Modeling offshore energy infrastructure

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Offshore zones in the European system

Offshore wind farms and energy hubs are becoming one main pillar of the energy infrastructure of different European countries.

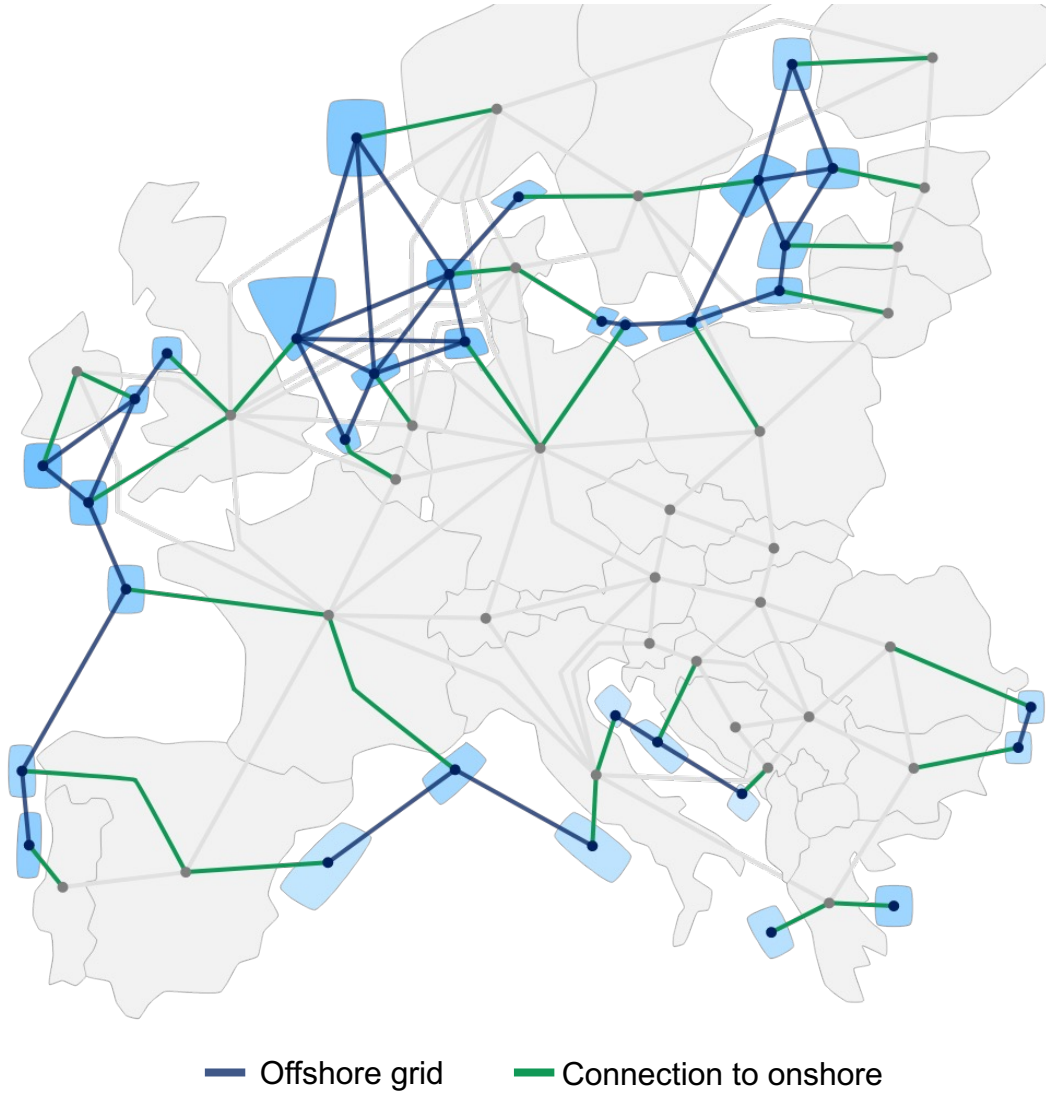
They are located at distances between tenths and hundredths of kilometers from shore. Therefore, this energy needs to be delivered over these distances.

A zonal model can be used for representing the European energy system.

It is necessary to also include offshore zones that can represent the main locations of the energy infrastructure developments in the sea basins from the different countries.

Each country with sea access is modeled to have one offshore zone per sea basin. These zones are radially connected to their host countries.

Direct connections between the offshore zones are allowed, enabling the possibility for the capacity expansion tool to build offshore grids.



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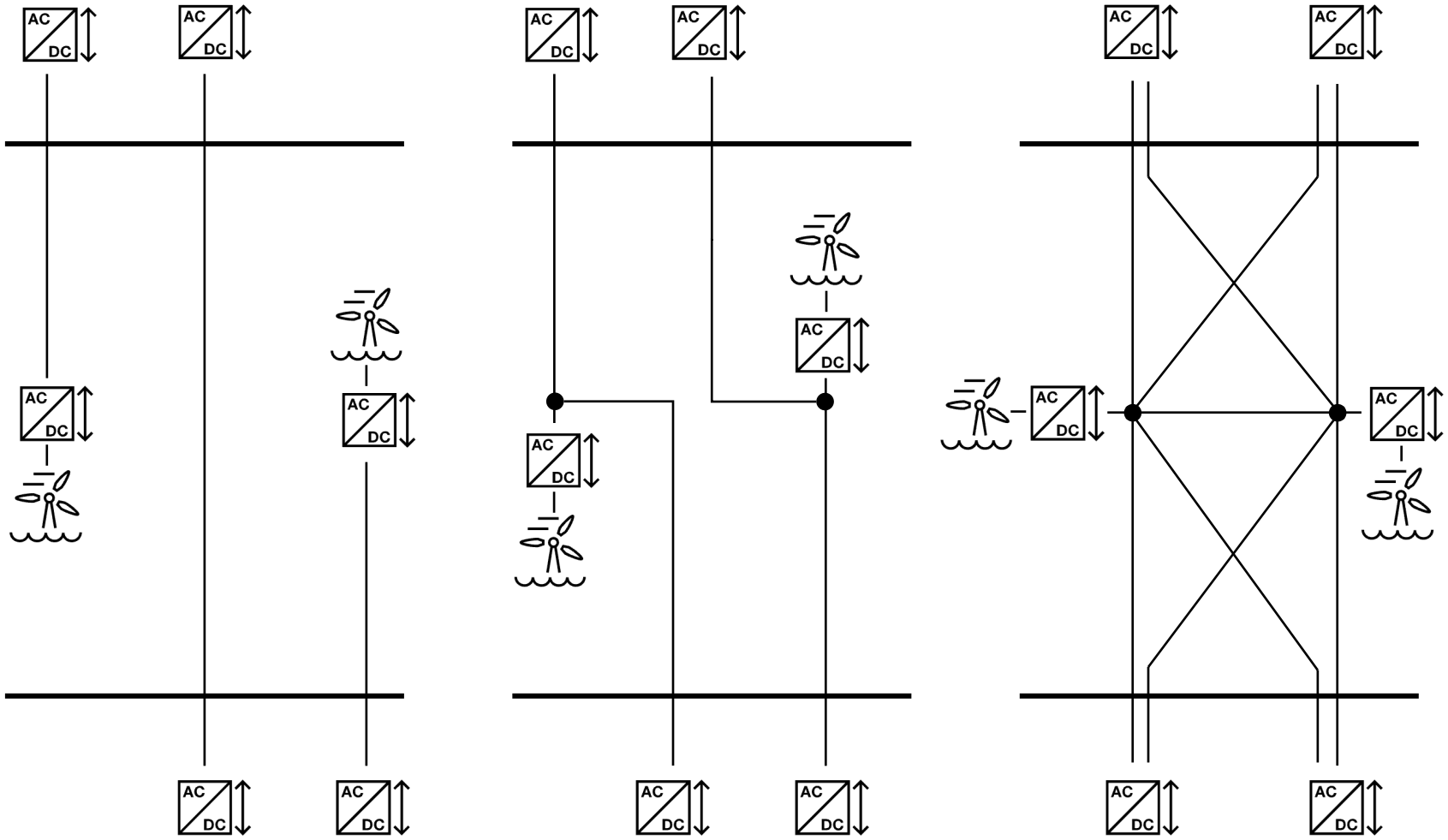
Different options

There could be several options for the design of the offshore grids.

It has to be decided whether the best option is the use of AC or DC connections. Each one has its own advantages, and it is crucial to choose the best fit for the specific application.

DC technology allows for a higher controllability of the power flows in the grid. However, establishing a DC grid with only point-to-point connections is not optimal.

The topology is also of great importance. Each configuration will give certain operation capabilities, but also it will influence in the final cost of the system.



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Modeling offshore energy infrastructure

How granular should the model be?

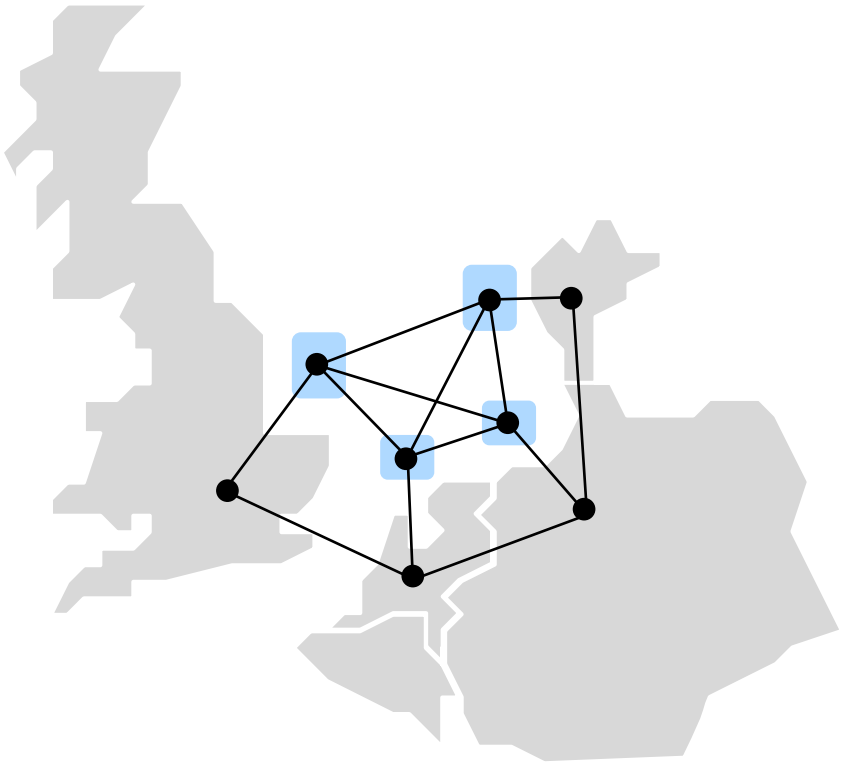
The spatial granularity of the model will influence the detail and investment of offshore grids in the different sea basins.

If only one offshore zone per country per sea basin is modeled, the options of creating an offshore grid lie only between countries and it would assume all offshore stations of a country as a single hub.

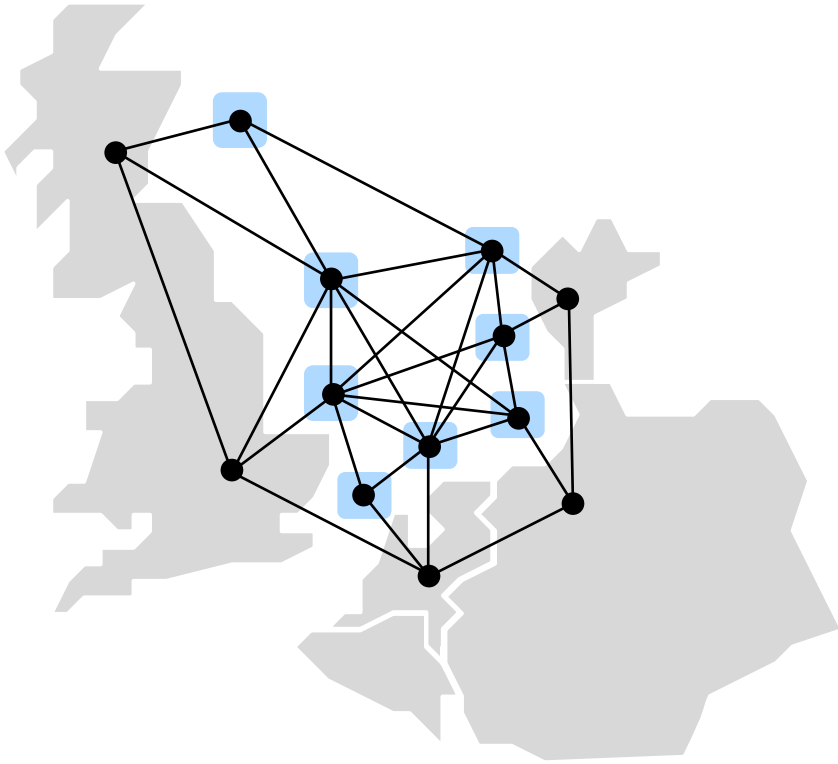
The addition of more offshore zones per country per sea basin would enable more possibilities for an optimal offshore grid.

Even by increasing the granularity of the onshore zones to represent a country, a local offshore grid can also be created, bringing more benefits than with the single zone approach.

North Sea basin with one offshore zone per country



North Sea basin with multiple offshore zone per country



Modeling offshore energy infrastructure

Impact of weather variability and climate change

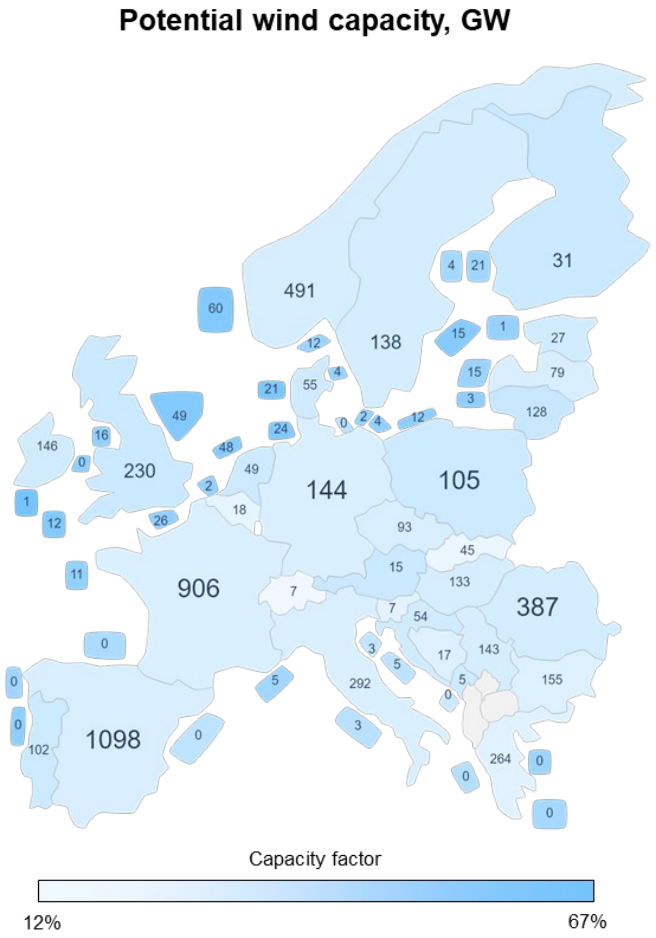
- Different weather parameters can impact the supply- and demand-side of the power system, as well as transmission.
- Beyond the wind and solar reanalysis profiles, the impact of the variation of specific weather parameters can be included in the model.
- It is important to include the weather variability/uncertainty in the model as it may critically affect the required investment outcome.

		Air Temperature	Wind Speed	Precipitation	Solar Irradiance
Electricity Demand		High	Low	Low	Low
Generation	Wind	Low	High	Low	Low
	Solar PV	High	Medium	Low	High
	Hydro	Low	Low	High	Low
	Thermal	High	Low	Medium	Low
Transmission	Substations	Medium	Low	High	Low
	Overhead Lines	High	High	Low	Medium
	Underground Cables	Low	Low	Medium	Low
Storage	Pumped Hydro	Low	Low	High	Low
	Battery Energy Storage	High	Low	Medium	Low

High impact Medium impact Low impact

Variable renewable availability

- Reanalysis data is used for the wind and solar profiles. A representative year profile is taken from renewables.ninja database for each one of the countries and the offshore zones.
- The technical potential of wind and solar installed capacity is taken from the EU JRC ENSPRESSO project, which calculates the renewable potentials based on energy source density and land availability.
- The offshore wind potential and capacity factors allocations play a large role in the outcome of the capacity expansion model.



Source: EU JRC ENSPRESSO project, renewables.ninja

Connecting capacity expansion with power system studies

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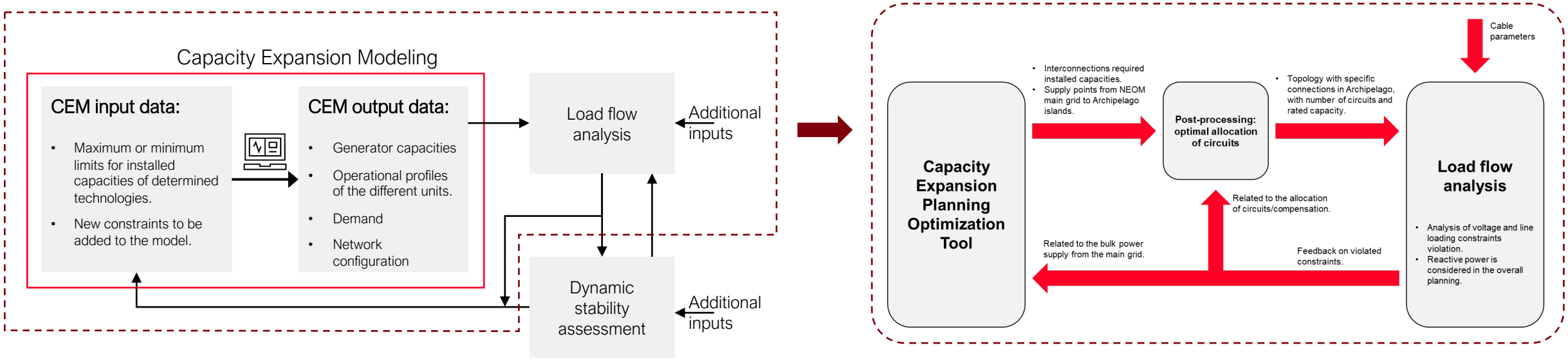
Beyond capacity expansion



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Connecting capacity expansion with power system studies

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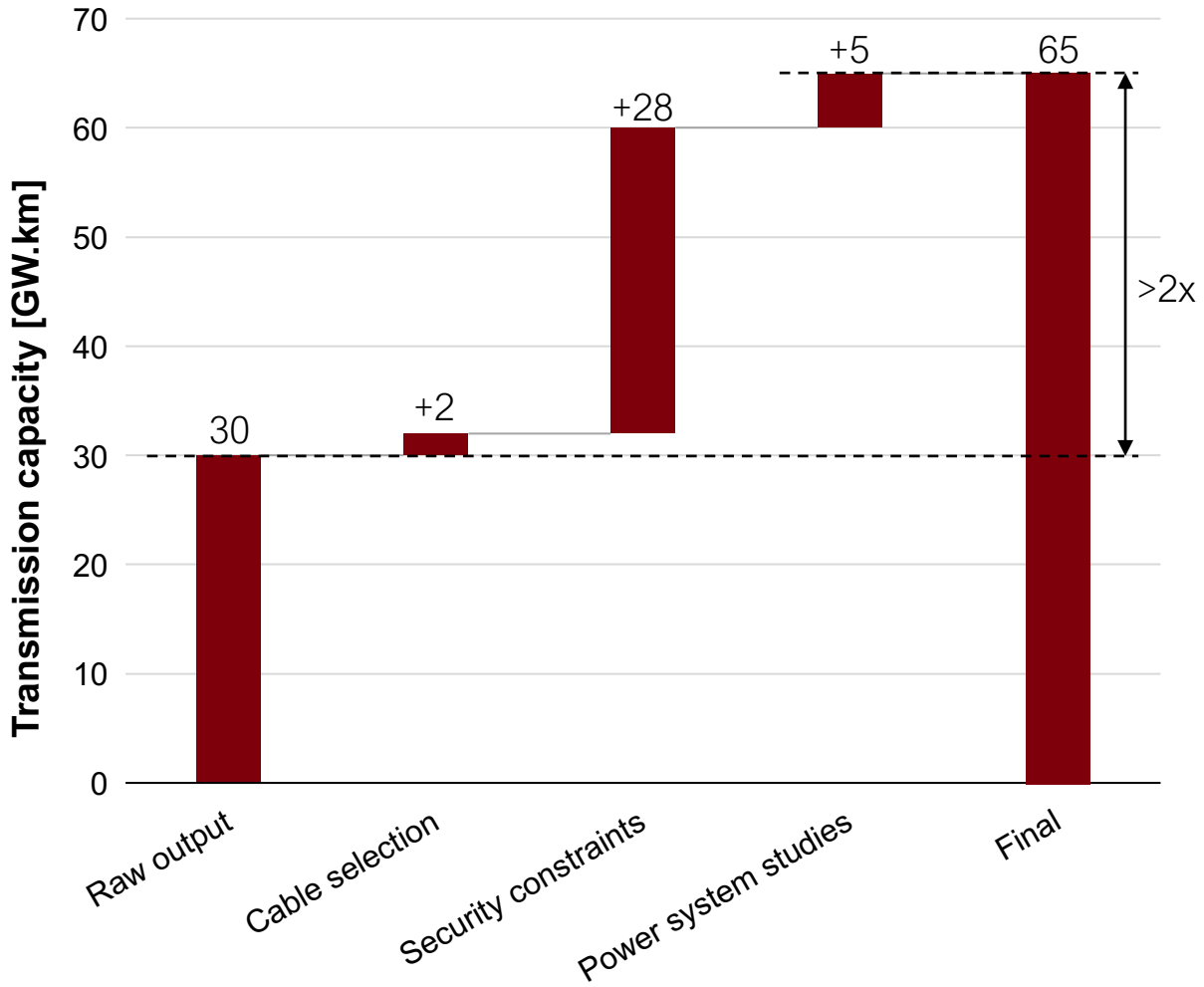
Case Study: NEOM Archipelago

NEOM Archipelago is a set of islands in the Red Sea shore of NEOM region, a new development zone in the north-west area of Saudi Arabia. After the design of the main grid, it was necessary to analyze and determine the optimal offshore topology to interconnect the islands with the main grid.

The zones were modeled in the capacity expansion tool, integrated in the model of the entire NEOM region, in order to consider the supply points, obtaining the principal corridors which are more optimal to supply the islands.

After performing the post-processing of the output from the capacity expansion model, which included the allocation of cable sizes, ratings and voltage levels, also considering the N-1 security constraint for each one of the connections, the transmission capacity (in GW.km) is almost doubled for the offshore grid corresponding to Archipelago.



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Offshore hydrogen production

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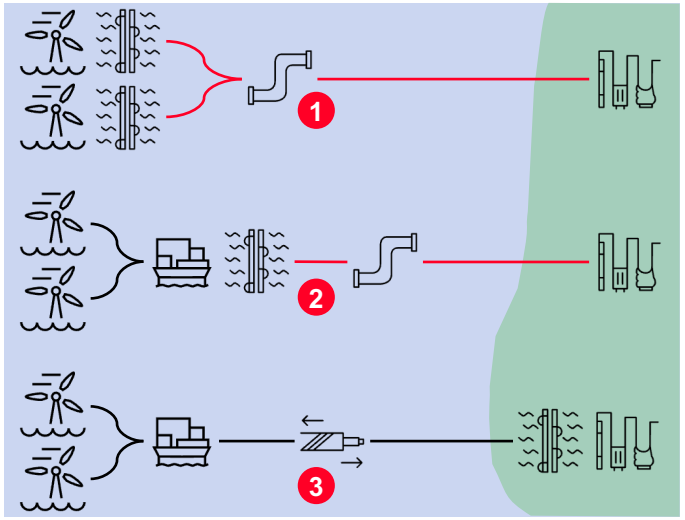
Additional energy vector in the offshore grids

Hydrogen will play a crucial role in the decarbonization on hard-to-abate sectors where direct electrification is not possible.

Offshore hydrogen production has acquired an especial interest as it is commonly less expensive to transport large volumes of energy as hydrogen, when it is destined for final end-use.

An extensive existing natural gas network, as the one present in the North Sea, is favorable to be repurposed for hydrogen transport, including the several gas depleted fields.

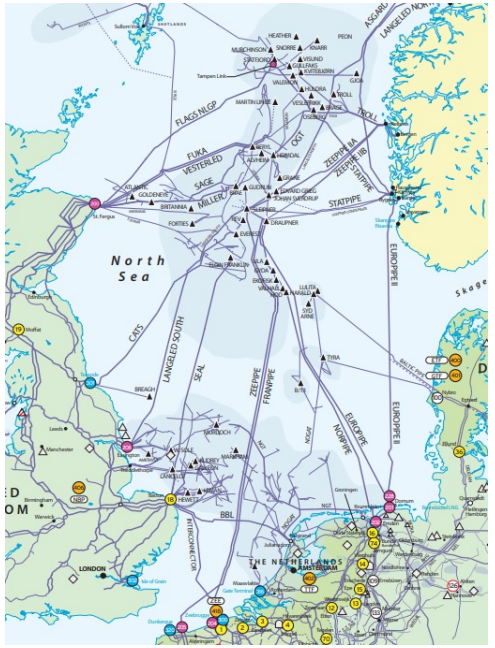
Different configurations for hydrogen production using offshore wind can be considered and modeled:

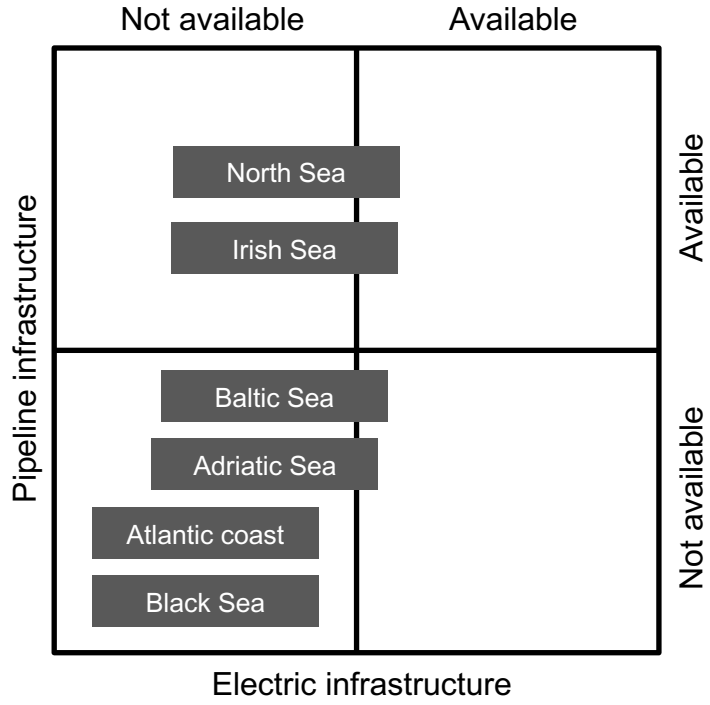


Hydrogen is produced directly at each wind turbine. Hydrogen is collected via an array of small pipelines connected to a larger pipeline.

Hydrogen is produced via large-scale electrolysis on a central platform and sent to onshore. Wind turbines are connected to the central platform via an electric collection grid.

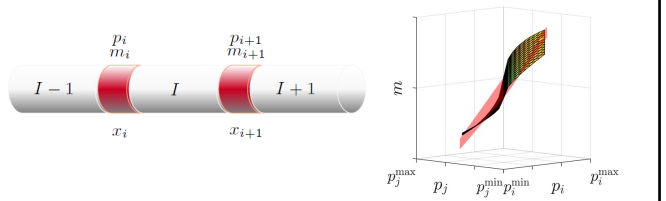
Hydrogen is produced via large-scale onshore electrolysis. Wind farm is connected to shore via HV cable(s).





When modeling hydrogen transport it is important to consider the gas fluid dynamics.

It is a non-linear model that needs to be linearized into the model formulation.



Source: ENTSO-G

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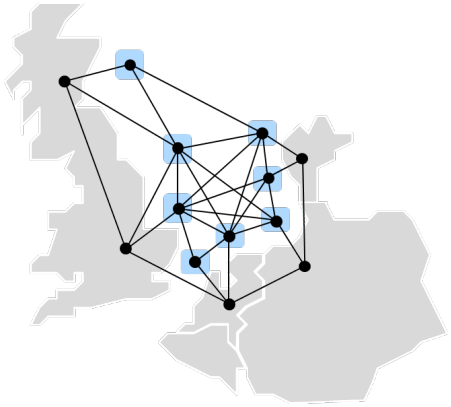
Outlook

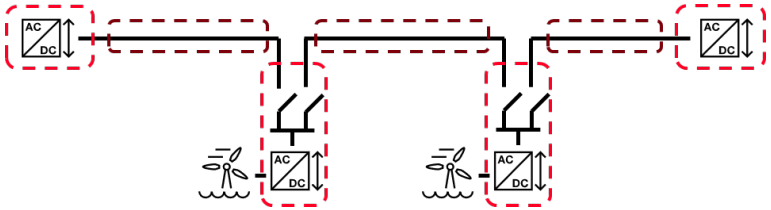
Granularity

How to define the granularity of the model? Finding the optimal ratio of zones and required computational power.



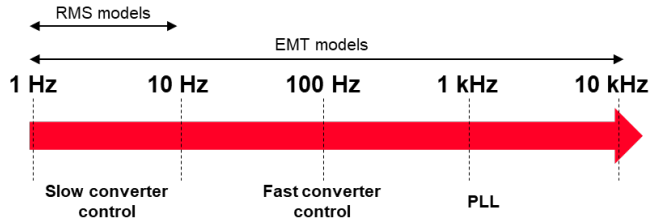
Grid configuration

What is the best approach for automatically selecting the optimal configuration of the offshore grid?



System stability

It is necessary to introduce the analysis of the dynamics of the system.

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