National case study report #1

Belgian offshore wind: Innovation and investment

An ex-post analysis

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Abstract

This case study examines the development of offshore wind energy in Belgium between 2002 and 2022, with a focus on the period when the major offshore wind parks became operational (2009-2020). The case study maps the actors in Belgian offshore wind and assesses elements related to innovation and investment. It finds that Belgium's decision to be a first mover in offshore wind energy led to the development of an extensive business and innovation ecosystem related to the sector, with companies from other industries with related experience reoriented to offshore wind development. This shift was supported by long-term certainty provided by green certificates, Power Purchase Agreements, and investment provided by banks, especially the European Investment Bank. Several actors from this ecosystem are also exporting their know-how in this area to other growth markets, including the US and Japan.

Contents

List of tables

List of figures

Executive summary

Case study context and methodology

This case study looks at the development of offshore wind in Belgium between 2009 and 2020. The background of this case study is two-fold. In the first place it links to climate change mitigation goals and achieving net-zero emissions by 2050 via transformational policies. The second contextual element is 'industrial policy' aimed at the development of a homegrown clean-tech industry. Belgium and offshore wind were chosen as a case study because Belgium was one of the first countries in the world to develop offshore wind energy[1], in 2020 it was the 4th largest offshore wind energy country (based on capacity installed). Within the context of developing transformational climate policies and clean industrial strategies, the main research questions for this case study on the development of Belgian offshore wind are:

- Did a Belgian offshore wind energy ecosystem[2] emerge following offshore wind energy development in Belgium?
- Did the Belgian initiative to develop offshore wind induce technological innovation and business model innovation in Belgium?
- What are the main features of offshore wind investment in Belgium and what are elements that contributed to the successful development of offshore wind?

The methodology used in this case study consists of the following consecutive steps:

1. Understanding offshore wind energy development in Belgium
2. Identifying main data sources for actor mapping
3. Identifying main data points
4. Data acquisition
5. Streamlining data
6. Data analysis and interpretation
7. Deeper qualitative assessment of selection of actors identified

The approach starts with a literature study of Belgian offshore wind energy. This includes the development of the sector over time, policy initiatives and other information that was relevant for the mapping of actors (e.g., identification of coordination bodies or sector federations). Next the

[1] With Denmark the pioneer in offshore wind in the 1990s and the UK in the first years of the 21st century, Belgium and Germany were the next EU countries to commercially develop offshore wind starting in 2010.
[2] Industrial ecosystems encompass all players operating in a value chain: from the smallest start-ups to the largest companies from academia to research service providers to suppliers. See: https://clustercollaboration.eu/in-focus/industrial-ecosystems/definition

main data sources to enable the mapping of actors in Belgian offshore wind were identified. The main sources are the coordination bodies: the Belgian Offshore Platform, the Belgian Offshore Cluster, and the IBN Offshore Energy Cluster. Other sources used to identify actors included websites and project documents from major offshore wind developers in Belgium. Finally, all the websites of the actors identified were consulted to extract information on their main activities related to offshore wind, their location, and their international activities. Next the main data points for each actor were identified. These included the name of the company, a description of the main offshore wind energy related activities, identifiers of main activities, coordination body membership identifiers, a headquarter identifier (i.e., does the company have a Belgian headquarters) and does the company have offices in other countries outside of its main headquarters.

For an assessment of innovation related to Belgian offshore wind, additional data was added using the Google Patents Database.[3] This generated a list of patents published by the Belgian patent office between 2002 and 2022 and made it possible to link the patent holders with the actors in the overall mapping. For investment, additional data was added on shareholder and shareholder structure for the offshore wind parks in Belgium, together with data from the European Investment Bank on its participation in Belgian offshore wind energy projects. Next the data gathered on actors in the Belgian offshore wind ecosystem was streamlined by eliminating duplicates, refining the main activities linked to each actor and transcription error elimination. In addition, a qualitative assessment was added to the quantitative analysis. Using media reports and company websites, actors with innovative and/or international activities were identified. This qualitative information was used to demonstrate the presence of technological innovation, business model changes and investment related activities.

Offshore wind in Belgium

Planning for offshore wind power in Belgium started in the beginning of the 21st century. A first wind park was planned but due to protest (e.g., the fear of visual pollution) the permit was stuck down. Another site had to be chosen. The first park came online in 2009 (C-Power). At the time of C-Power’s design and engineering, building a far shore wind farm at 25 to 30 km from the coast was a first.

Between 2010 and 2020, eight additional wind farms went into operation in these designated zones. Together, these farms have 399 turbines and a total installed capacity of 2.26 gigawatts (GW). In 2020 Belgian offshore wind produced 6.7 terawatt hours (TWh) of electricity, almost 10% of Belgium’s annual gross electricity consumption. During the decade of offshore wind farm construction, technology and construction practices have changed dramatically. The changes include an evolution in foundation types (from gravity-based foundations and jackets to XL monopile wind turbines), an expansion of the construction area into more offshore waters and an

[3] The data was retrieved in January 2023 via patents.google.com on the search term “Offshore wind” for the period 1/1/2002 until 31/12/2022 and limited to the Belgian patent office.

increase in the size and capacity of wind turbines (from 3 megawatt turbines with a rotor diameter of 90 metres to 9.5 megawatt turbines with a rotor diameter of 164 metres). According to the Belgian Offshore Platform, offshore wind energy accounts for 14,000 jobs today.[4]

Case study findings

Between 2009 and 2020, a broad and diverse Belgian offshore wind ecosystem was created.

Over a period of 10-15 years, following the initiative of the Belgian government to develop offshore wind, at least 169 companies became active in the development and operation of this sector in Belgium. There are now 6 coordination bodies or sector federations representing the industry. There is one dedicated research lab and 11 other research institutes focussing on innovation. Out of the 169 companies active in offshore wind, 102 (or 60%) are Belgian, demonstrating a locally grown industry. The Belgian companies are active in all areas related to offshore wind (e.g., development, investing, maritime engineering, services and to a lesser extent turbines and components).

Belgium has become a global player in the construction of offshore wind parks and infrastructure.

The choice of the Belgian government to start developing offshore wind as one of the first countries has resulted in nurturing two companies that have become world leading in offshore wind construction (Jan De Nul and DEME). Both companies are active in the development of offshore wind in Europe e.g., France, UK, Germany. Furthermore, they were in pole position to secure contracts for the development of offshore wind in the US, Taiwan and Japan which are major future growth markets. Belgium has also become a global leader in modular offshore grid construction (via the company Smulders and its subcontractors) with around 40% of these substations being constructed in Belgium. The explanation for such large market shares for a small country links to two elements seen in this case study:

The early development of offshore wind in Belgium allowed large and multinational Belgian companies to start investing in technologies and techniques required for this sector. These larger companies both had the financial means and experience in the necessary area (i.e., maritime engineering) to be successful in changing or adapting their business models.

Innovation is the second element that was important, with maritime engineering companies investing in innovative offshore wind construction and maintenance ships (e.g., increasing size and capabilities). Maritime engineering companies also hold a large share of offshore wind related patents published by the Belgian patent office between 2002 and 2022. This continued innovation allowed these companies to engage in larger (and more complex) offshore wind construction outside of Belgium and Europe.

[4] Belgian Offshore Platform, 2022; Deme group, n.d.; FOD Economie, 2022

High-tech meets clean-tech.

Next to the high-profile activities by Belgian maritime engineering firms, a large services industry to the offshore wind industry in Belgium developed over the last two decades. These services cover a broad group of activities such as consulting, verification and accreditation, maintenance, surveying, safety and safety training, IT services and remote sensing. There is strong evidence for innovative entrepreneurial activities related to offshore wind in Belgium. There is evidence for specialisation in Belgian offshore wind services focusing on innovative software (e.g. use of AI), data monitoring and remote sensing relevant for the development and operations and maintenance for offshore wind (infrastructure).

Belgian offshore wind is Belgian owned with a large share of public sector ownership.

Most of the offshore wind capacity is owned by Belgian companies or public sector stakeholders. This contrasts with gas- and nuclear based power production, which currently is owned by foreign companies. Belgian ownership has the advantage that it increases the chances that revenues and profits of offshore wind are reinvested in the Belgian economy.

The public sector is an important shareholder in offshore wind in Belgium. Belgian municipalities in particular, play an important role through the investment vehicle Aspiravi representing 94 Belgian communes (through its shareholders). Aspiravi is an important shareholder in C-power and Otary. Elicio, the developer and main shareholder of one park, is owned by Nethys ,a company whose shareholders are the communes of the Walloon region in Belgium. C-power and Otary have other public sector related shareholders next to the ones mentioned above.

Multilateral development banks, policy support and power purchase agreements facilitated financial closure of investments.

It is not only the ownership of offshore wind in Belgium that is a mix of private and public actors. The capital made available (e.g. via loans) to make the investments possible is also a mix of public and private funds. Next to the commercial banking sector, national and international development banks provided a substantial amount of financing. The European Investment Bank (EIB) provided a substantial part of financing for all Belgian offshore wind parks. In total 33% of capital was provided via the EIB. Having large multilateral development banks such as the EIB involved helps these capital-intensive projects reach financial closure. This is important for emerging technologies that have additional amounts of project and technology risks.

In the case of Belgian offshore wind developments two elements helped to bring about long-term investment certainty: The long-term support via green energy certificates (17-20 years) and the use of Power Purchase Agreements (PPAs). PPAs often play an important role in project financing of renewable energy projects, including offshore wind. Having a PPA in place to secure the revenue stream for a renewable energy project over a long time is often a necessity to attract banks and other project financiers. Hence, PPAs facilitate the bankability of an offshore wind project. PPAs are commonly used in Belgian offshore wind. In some cases, energy companies (e.g., Engie, Eneco, Lampiris) act as an intermediary to conclude downstream PPAs with final consumers. This case study noted the involvement of major industrial companies such as Ineos, Borealis and Air Liquide with offshore wind PPAs contracted to production plants in Belgium. For industry, such PPAs can be advantageous because they are a long-term contract and hence provide a form of supply and pricing stability. Furthermore, such renewable energy PPAs allow for energy-intensive companies to green their production.

Recommendations for transformative climate policies

When it comes to lessons learned and policy recommendations, three main points can be highlighted resulting from this case study:

1. Early mover advantages emerge under certain conditions (incl. R&D support).
2. A local ecosystem can be the driver for higher government ambitions relating to that ecosystem. When this ecosystem relates to green technologies it can lead to higher green ambitions.
3. Securing investments is key, especially to support financial closure of projects.

Being among the first countries to develop offshore wind energy at scale has brought (early mover) advantages to Belgium. The most notable is the emergence of home-grown world leaders in installation of offshore wind parks and infrastructure. The (early) policy choice to develop offshore wind is a prime driver but it is not a sufficient condition for such developments. Three other elements are likely to have contributed. First, offshore wind energy built upon the strength and experience of companies in distinct but related industries. This was specifically the case for maritime engineering where Belgium, as a coastal country with large harbours and ports, had ample experience and the presence of Belgium headquartered (multinational) companies. Secondly, R&D support e.g., through the presence of coordination centres and R&D testing infrastructure, helped companies active in offshore wind innovate faster. Finally, when designing and developing the first offshore wind parks, Belgian offshore wind developers pushed the technological frontiers for offshore wind at that time. While introducing a higher level of (technology) risk, this has pushed companies to developed new techniques and hence create a know-how advantage compared to international competitors.

Belgium plans to almost triple its offshore wind capacity by 2030 (from 2.6 GW to almost 8 GW). It can be argued that the local industrial ecosystem that emerged from developing offshore wind in the period 2009–2020 enabled such a leap forward. First, there is little doubt that the industrial capacity and know how to expand offshore wind is present in Belgium. Second, having a domestically grown offshore wind industry created a pressure group with an interest in growing this industry. In Belgium this is visible through organizations representing the offshore wind industry such as the Belgian Offshore Platform and the Belgian Offshore Cluster.

Offshore wind energy remains a capital-intensive industry and achieving financial closure of offshore wind projects (i.e., securing the necessary capital) is an important challenge. Three elements from this case study helped achieve the necessary investments. First, the Belgian support system via green energy certificates generated a long-term (e.g., 17- to 20-year) secure revenue stream. Importantly, this system has been adjusted following lower costs of offshore wind energy by linking it to power prices. Soon, the system can take the form of a contract for difference (CfD). Support for infrastructure (e.g., offshore to onshore cables) also helped to bring about offshore wind projects. Second, multilateral development banks and in particular the European Investment Bank provided large shares of financing (loans) to offshore wind. The presence of such a large and secure lender facilitated capital from private banks. Third, securing revenue streams via (long-term) Power Purchase Agreements added another layer of investment security to these projects. Of interest is the symbiotic relation with energy-intensive industries where the latter benefit from offshore wind PPAs due to (depending on the contract) price stability and greening of the indirect greenhouse gas emissions.

1. Introduction

This case study examines the development of offshore wind in Belgium over the period 2009-2020. The background of this case study is two-fold. In the first place, the context links to climate change mitigation goals and achieving net-zero emissions by 2050 via transformational policies. The second contextual element is 'industrial policy' aimed at the development of a homegrown clean-tech industry.

Belgium and offshore wind were chosen as the case study because Belgium was one of the first countries in the world to develop offshore wind energy[5], in 2020 it was the 4th largest offshore wind energy country (based on capacity installed). There is also evidence of Belgian companies benefitting from this early action by exporting their locally gained know-how internationally.

The deployment of offshore wind energy is also at the core of delivering the European Green Deal. The installed offshore wind capacity in the EU was 14.6 GW in 2021. To ensure that offshore renewable energy can help reach the EU's ambitious energy and climate targets for 2030 and 2050, the Commission published a dedicated EU strategy on offshore renewable on 19 November 2020 which proposes concrete ways forward to support the long-term sustainable development of this sector. The strategy sets targets for an installed capacity of at least 60 GW of offshore wind and 1 GW of ocean energy[6] by 2030, and 300 GW and 40 GW, respectively, by 2050. Together with achieving 2030 and 2050 climate goals, elements of industrial policy featuring more in policy agenda. The most notable example is the recently adopted US Inflation Reduction Act (IRA) which sets goals for, amongst others, renewable energy and electric vehicle production in the US and by US-based companies. There are indications this is triggering a global clean-tech race with the European Commission responding to the US IRA with a Net Zero Industry Act.

The rest of the report is organised as follows. Chapter 2 presents the case study design. It starts by briefly sketching the background of the case study. Next the research questions, focusing on innovation and investment, are presented. This is followed by linking the context of the case study with the relevance for transformative climate policies. The next section outlines the methodology used, with focus on the actor-mapping approach.

In Chapter 3, the case study is introduced together with the results. The chapter starts by introducing the Belgian energy context and the development of offshore wind. Next the general results of the actor mapping are presented. This is followed by the analysis on innovation in Belgian offshore wind and next the investment context for offshore wind energy in Belgium.

Chapter 4 summarizes the results from this case study and a brief review of the methodology and elements for future research. The case study closes by generalizing the results towards recommendations for transformative climate policy.

[5] With Denmark the pioneer in Offshore wind in the 1990s and the UK in the first years of the 21st century, Belgium and Germany were the next EU countries to commercially develop offshore wind starting in 2010.

[6] A.o. wave and tidal energy

2. Case study design

2.1 Background

The background of this case study is two-fold. In the first place the context links to climate goals and achieving net-zero emissions by 2050 via transformational policies. The second contextual element is 'industrial policy' aimed at the development of a homegrown clean-tech industry for the country or economic region.

The EU aims to be the first climate neutral continent by 2050 and, as an interim target, to reach a 55% reduction in greenhouse gas emissions by 2030 compared to the year 1990. To achieve this goal, the European Commission proposed, as part of the European Green Deal (EGD), a set of legislative proposals on 14 July 2021. This package includes revisions (with increased ambition and targets) of several parts of the 'U's climate and energy legislation such as the EU Emissions Trading System and the Effort Sharing Regulation. A review of the Renewable Energy Directive, another part of the EGD, put forward a target of 40% renewable energy in the EU by 2030.[7]

Following the recent energy crisis, the European Commission proposed, under Repower EU, to increase the latter target to 45% with the goal to achieve lesser dependence on (imported) fossil fuels. This would bring the EU's total renewable energy generation capacities to 1236 GW by 2030, in comparison to 1067 GW by 2030 originally envisaged under the EGD for 2030. For wind energy, these targets imply an increase to 510 GW installed capacity by 2030 (compared to 469 under the 2030 Fit-for-55 proposals).[8] According to the European Commission, the energy production targets for offshore renewable energy in all the EU's sea basins are at least 60GW by 2030 and 340GW by 2050.[9]

Together with achieving 2030 and 2050 climate goals, elements of industrial policy are increasingly featuring on the policy agenda. The most notable example is the recently adopted US Inflation Reduction Act, which sets goals for, amongst others, renewable energy and electric vehicle production in the US and by US-based companies. There are indications this is triggering a global clean-tech race with the European Commission responding to the US Inflation Reduction Act (IRA)[10] with an EU green deal industrial plan for the net-zero age.[11]

[7] European Commission, 2019
[8] European Commission, 2022
[9] European Commission, 2020
[10] The White House, 2023
[11] European Commission, 2023

2.2 Research questions

This case study looks at the development of offshore wind in Belgium over the period 2009–2020. Within the context of developing transformational climate policies and clean industrial strategies, the main research questions for this case study on the development of Belgian offshore wind are:

- Did a Belgian offshore wind energy ecosystem[12] emerge following offshore wind energy development in Belgium?
- Did the Belgian initiative to develop offshore wind induce technological innovation and business model innovation in Belgium?
- What are the main features of offshore wind investment in Belgium and what are elements that contributed to the successful development of offshore wind?

The underlying hypothesis behind these research questions is that the Belgian offshore wind development can be seen as an industrial strategy and hence that important changes occurred in the industrial and economic sphere in Belgium because of this strategy. An industrial strategy can be defined as the purpose-driven coordination by the state of its 'supply side' economic policies – those relating to the productive capacity of the economy, and the market conditions in which investment and production occur.[13]

Belgium was one of the first movers in the development of offshore wind energy.[14] First movers often face higher risks (e.g., technology risks) and costs when testing and deploying new technologies. However, as a derivative of the above-mentioned industrial strategy hypothesis, there might also be benefits for Belgium being among the first movers globally when it comes to the development of offshore wind. These benefits can include the export of know-how gained during the development of offshore wind. Examples of these are explored in this case study.

2.3 Relevance for transformative climate policy

This case study examines offshore wind development in Belgium with a focus on innovation and investment. Therefore, the relevance for transformative climate policy of this case study comes from three angles:

- The relevance of offshore wind energy
- The relevance of the developments in Belgium
- The relevance of innovation and investment in this context

[12] Industrial ecosystems encompass all players operating in a value chain: from the smallest start-ups to the largest companies from academia to research service providers to suppliers. See: https://clustercollaboration.eu/in-focus/industrial-ecosystems/definition
[13] Jacob, M., et al., 2017
[14] After Denmark and the UK.

A recent study commissioned by Wind Europe estimated that offshore wind in Europe has a theorical potential to generate between 2,600 TWh and 6,000 TWh per year at a competitive cost (€65/MWh or below).[15] By 2030, 212 GW offshore wind could be deployed in the North Sea, 85 GW in the Atlantic (including the Irish Sea), 83 GW in the Baltic, and 70 GW in the Mediterranean and other Southern European waters.[16]

The deployment of offshore wind energy will play an important role in delivering the European Green Deal. The installed offshore wind capacity in the EU was 14.6 GW in 2021. To ensure that offshore renewable energy can help reach the EU's ambitious energy and climate targets for 2030 and 2050, the Commission published a dedicated EU strategy on offshore renewable on 19 November 2020 which proposes concrete ways forward to support the long-term sustainable development of this sector. The strategy sets targets for an installed capacity of at least 60 GW of offshore wind and 1 GW of ocean energy by 2030, and 300 GW and 40 GW, respectively, by 2050.[17] [18]

While offshore investments started in the EU, other parts of the world are following suit. China has seen major growth in offshore wind, the US is installing its first offshore wind parks with plans of major expansion over the coming years and Japan has plans for big investments in this area. As a result, offshore wind has now become a global industry with global installed capacity of 54 GW in 2021 and expected to grow to 187 GW by 2027.[19] The global weighted average levelised cost of electricity (LCOE) of newly commissioned offshore wind projects declined by 60% between 2010 and 2021.[20] Innovations, such as floating offshore wind turbines, will make larger areas of the sea accessible for this energy source both in Europe and the rest of the world.

Belgium is one of the pioneers in offshore wind in the EU and globally. The decision to develop offshore wind in Belgium was taken in the beginning of this century and the first offshore wind park became operational in 2009. Between 2009 and 2020, around 2.6 GW capacity has been installed. In 2020, Belgium was ranked 4th globally when it comes to installed offshore wind capacity (behind the UK, Germany, and China).[21] The fact that Belgium started early gives a timeframe of around 10 years to assess in this case study. Together with the important size of offshore wind investments, this should provide sufficient data to assess (industrial) ecosystem development, innovation, and investment impacts. It also provides insights on possible advantages of an early mover, such as Belgian companies capturing part of global market share in (more recent) offshore wind developments in the rest of the world.

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15 Wind Europe, 2017
16 Wind Europe, 2017
17 European Commissions, 2020a
18 In 2020 the total installed power generation capacity in the EU was 963 GW. See: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_and_heat_statistics#Installed_electrical_capacity
19 International Energy Agency, 2023
20 International Renewable Energy Agency, 2022
21 Flanders Investment and Trade, 2020

Innovation and investments are relevant for transformative climate policy because they touch upon broader challenges and opportunities beyond achieving renewable energy and climate goals such as[22] [23]:

- Industrial and employment dimensions
- The technological transfer of research projects from the laboratory into practice

Investments in offshore wind should lead to an industrial response. This can be the production of turbines, components, products, and infrastructure for offshore wind energy and/or services to this industry. This can lead to new industrial players emerging and/or existing companies changing their business model. Emerging and growing industries also offer important opportunities for innovation (e.g., to reduce costs) in new technologies, techniques and the general dissemination of know-how.

2.4 Methodology

The methodology used in this case study consists of the following consecutive steps:

- Understanding offshore wind energy development in Belgium
- Identifying main data sources for actor mapping
- Identifying main data points
- Data acquisition
- Streamlining data
- Data analysis and interpretation
- Deeper qualitative assessment of selection of actors identified

The approach starts with a literature study of Belgian offshore wind energy. This includes the development of the sector over time, policy initiatives and other information that was relevant for the mapping of actors (e.g., identification of coordination bodies or sector federations). The main sources are:

- Documents and information published by Belgian federal government and affiliated organisations such as the power and gas market regulator.
- Documents and information published by EU institutions relevant for renewable energy and climate policy in Belgium

[22] European Commission, 2020a
[23] European Commission, 2021

- Documents and information published by companies and other organisations involved in the development of offshore wind in Belgium
- Information from (specialised) media sources

Next the main data sources to enable the mapping of actors in Belgian offshore wind were identified. The main sources are the coordination bodies: the Belgian Offshore Platform, the Belgian Offshore Cluster, and the IBN Offshore Energy Cluster. Other sources used to identify actors included websites and project documents from the main offshore wind developers in Belgium. Finally, all the websites of the actors identified were consulted to extract information on their main activities related to offshore wind, their location, and their international activities. Next the main data points for each actor were identified. These include the name of the company, a description of the main offshore wind energy related activities, identifiers of main activities, coordination body membership identifiers, a headquarters identifier (i.e., does the company have a Belgian headquarters) and whether the company has offices in other countries outside of its main headquarters.

For innovation, additional data was added using the Google Patents Database.[24] This generated a list of patents published by the Belgian Patent Office between 2002 and 2022 and made it possible to link the patent holders with the actors identified in the overall mapping. For investment, additional data was added on shareholder and shareholder structure for the offshore wind parks in Belgium, together with data from the European Investment Bank on its participation in Belgian offshore wind energy projects. Next the data gathered on actors in the Belgian offshore wind ecosystem was streamlined by eliminating duplicates, refining the main activities linked to each actor, and transcription error elimination.

All data was entered into Excel worksheets. These were used for the quantitative analyses. The data sheet can be accessed via this link.[25] The validity of the data for its quantitative use was controlled by using multiple data sources (i.e., the coordination bodies) for the actor mapping and by accessing each of the identified actors' individual websites to corroborate the other data sources. In total, 185 actors in Belgian offshore wind were identified, mainly using the membership lists of the offshore wind coordination bodies. While it is likely that not all actors in Belgian offshore wind were identified, for the purposes of this case study this is likely an adequate set given the high overlap of membership of the different coordination bodies. However, it is still possible that some actors are active in the offshore wind ecosystem but did not see added value in joining a coordination group.

To the quantitative analysis, a more qualitative assessment was added. Using media reports and company websites, actors with innovative and/or international activities were identified. This

[24] The data was retrieved in January 2023 via patents.google.com on the search term "Offshore wind" for the period 1/1/2002 until 31/12/2022 and limited to the Belgian patent office.
[25] https://drive.google.com/file/d/1SJGcUDZt4tLv9y5gUAEQ6SH12COPTQ2i/view?usp=sharing

qualitative information was used to demonstrate the presence of technological innovation, business model changes and investment-related activities

3. Case study and results

3.1 Introduction to Belgian offshore wind

3.1.1 Energy use and production in Belgium

In 2020, the total primary energy use in Belgium was 510 TWh (43,883 ktoe[26]) and the final energy consumption was 361 TWh (31,092 ktoe). Out of this, 79 TWh (6,801 ktoe) is electricity use. The main electricity users in Belgium are industry (46%), commercial and public services (26%) and households (24%).[27]

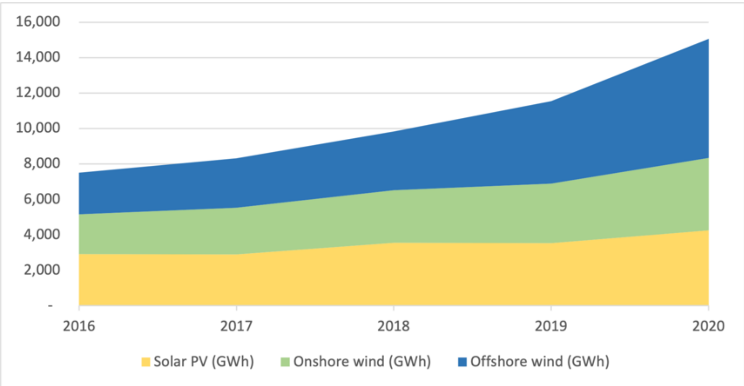

Figure 1: Evolution of renewable electricity in Belgium (2016–2020)
Includes solar PV, onshore and offshore wind production in Belgium (GWh). Source: Elia, 2021.

In 2020, the share of renewable energy in Belgian final energy consumption amounted to 12.01%. This is under the binding target of 13% as laid down in the Renewable Energy Directive. To make up for this deficit, various purchases of quantities of energy from renewable sources from other Member States (Finland, Denmark and Lithuania) were carried out. These purchases lead to an increased share of 13.00% of renewable energy in the final energy consumption.[28]

In its National Energy and Climate Plan as submitted to the European Commission, Belgium proposed an 18.3% share of energy from renewable sources in gross final consumption of energy in 2030 as a contribution to the EU renewable energy target for 2030.[29] According to the European Commission, this level of ambition is below the share of 25% by 2030 that would result from the

[26] Kilotonnes of oil equivalent
[27] Eurostat, 2022
[28] FOD Economie, 2022
[29] Federale Overheid België, 2020

ambition level calculated via a formula in the climate Governance Regulation (Annex II of the Governance Regulation).[30]

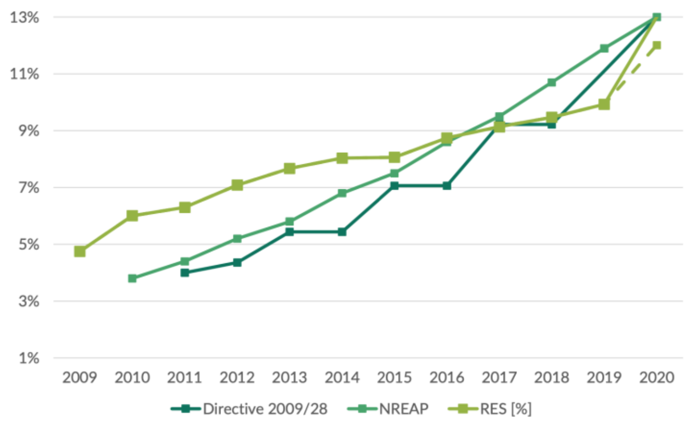

Figure 2: Renewable energy production in Belgium (2000–2020)
Percent of gross final energy consumption. Source: FOD Economie, 2022.

3.1.2 Energy governance in Belgium

Belgium is a federal state with powers divided between the regions (the Flemish and Walloon regions and the Brussels Capital Region) and the federal government. In Belgium the regions are responsible for policies regarding renewable energy, energy saving and the distribution of power and gas (DSO level). The Federal government is however responsible for the development of offshore (wind) energy in the North Sea, for nuclear safety and power production and transmission network regulation (> 70 kiloVolt).[31]

3.1.3 Brief history of offshore wind in Belgium

Planning for offshore wind power in Belgium started in the beginning of the 21th century. A first park was planned but due to protests (e.g. the fear of visual pollution) the permit was struck down. Another site had to be chosen. The first park came online in 2009 (C-Power). At the time of the design and engineering, building a far shore wind farm at 25 to 30 km from the coast was a first. The development of offshore wind farms led to a legal framework for the organisation of the planning of marine areas[32]:

- the modification of special areas of conservation of natural habitats and of wild fauna and flora) and special protection areas on the conservation of wild birds)

[30] European Commission, 2019a
[31] CMS, 2017
[32] CMS, 2017

- the creation of a dedicated advisory commission and the procedure for the adoption of the Marine Spatial plan
- the development of the Marine Spatial Plan (MSP)

The Marine Spatial Plan (MSP) designates the zones dedicated to the development and operation of offshore wind farms, in total covering up to 240 km² (equal to 7% of the Belgian North Sea), of which approximatively 190 km² are currently already occupied by existing projects. When taking adjacent security zones into account, the entire area designated by the development plan for offshore wind farms has already been granted to existing projects.[33]

Between 2010 and 2020, 8 additional wind farms came into operation in these designated zones. Together, these farms have 399 turbines and a total installed capacity of 2.26 GW. In 2020 Belgian offshore wind produced 6.7 TWh electricity, closing in on 10% of Belgium's annual gross electricity consumption. During the decade of offshore wind farm construction, technology and construction practices have changed dramatically. The changes include an evolution in foundation types (from gravity-based foundations and jackets to XL monopile wind turbines), an expansion of the construction area into more offshore waters and an increase in the size and capacity of wind turbines (from 3 MW turbines with a rotor diameter of 90 m to 9.5 MW turbines with a rotor diameter of 164 m). According to the Belgian Offshore Platform, offshore wind energy accounts for 14 000 jobs today.[34]

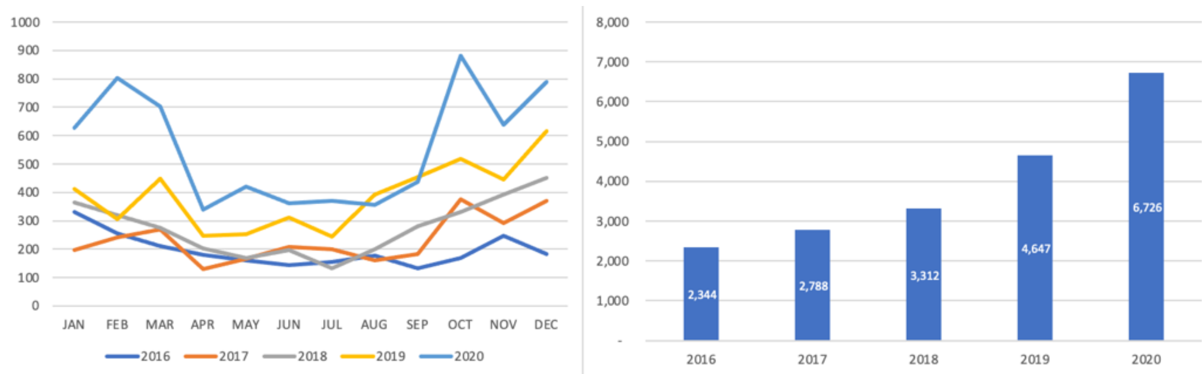

Figure 3: Monthly/yearly power production of offshore wind in Belgium (2016-2020)
The left panel shows monthly electricity production from offshore wind in gigawatt hours. The right panel shows total annual electricity production from offshore wind in gigawatt hours. Source: ELIA, 2021.

Table 1: Overview and key features of offshore wind parks in Belgium

Name	Capacity installed (MW)	Number of turbines	Sizes of turbines	Depth	Distance to shore (km)	Area (km2)	Became operational in

[33] CMS, 2017
[34] Belgian Offshore Platform, 2022; Deme group, n.d.; FOD Economie, 2022

C-POWER	325	54	6x5MW and 48x6.15 MW	14 to 28m	30	19.84	2009
BELWIND	171	56	55x3 MW and 1x6 MW	15 to 37m	49	17	2010
NORTHWIND	216	72	72x3 MW	16 to 29m	37	14.5	2014
NOBELWIND	165	50	50x3.3 MW	26 to 38m	47	19.8	2017
RENTEL	309	42	42x7 3.5 MW	22 to 36m	34	22.72	2018
NORTHER	370	44	44x8.4 MW	20 to 35m	23	44	2019
NORTHWESTER 2	219	23	23x9.5 MW	25 to 40m	51	12	2020
SEAMADE - ZONE MERMAID	235	28	28x8.4 MW	24.4 to 39.5m	54	16.7	2020
SEAMADE - ZONE SEASTAR	252	30	30x8.4 MW	22 to 38m	40	19.54	2020
Total	**2,262**	**399**				**186**	

Source: FOD, Economie, 2021

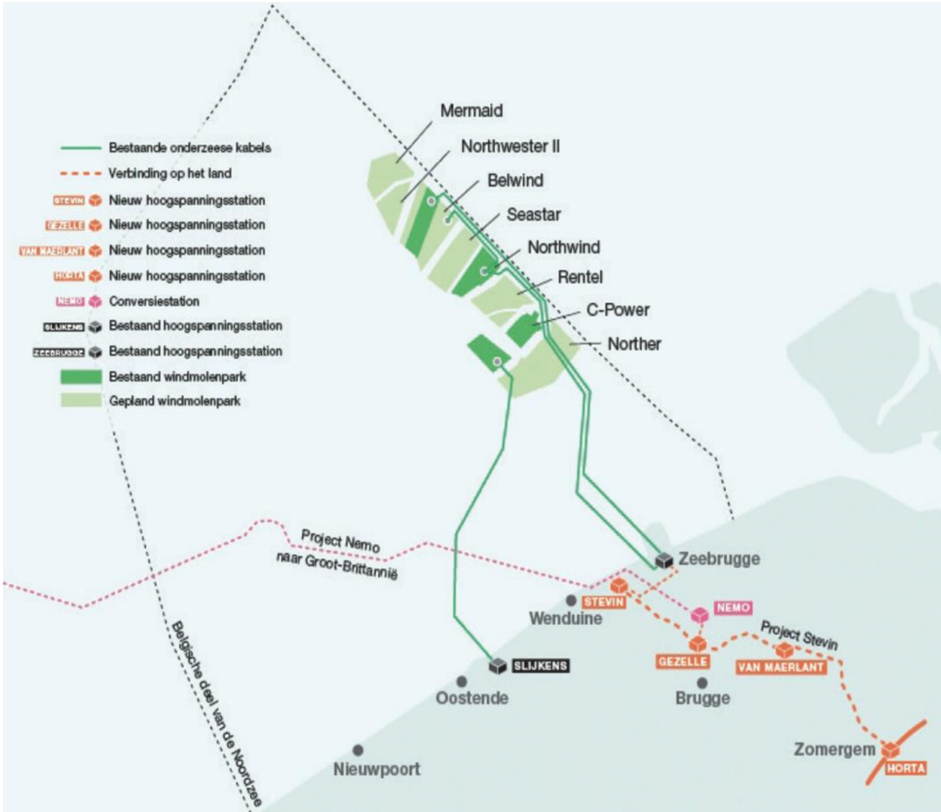

Figure 4: Location of Belgian offshore wind parks
Source: Belgian Offshore Platform.

3.1.4 The policy framework for offshore wind in Belgium

Next to the Marine Spatial Plan (as mentioned above) that designates the zones dedicated for the development and operation of offshore wind farms, the policy framework for offshore wind in Belgium consists of 3 parts[35]:

- Permitting and domain concessions
- Guarantees of origin
- Green certificates

The plots of sea-areas are assigned for offshore wind production via the marine spatial development plan. Offshore wind developers must put forward a permit request to get one of the domains assigned. In total three permits are required to develop an offshore wind park[36]:

- The permit to operate on the assigned plot;
- A maritime protection permit; and

[35] CREG, 2018
[36] CMS, 2017

- A permit for the cables connecting the offshore wind park to the electricity grid.

The wind park developer receives financial support for the transmission cable infrastructure. This subsidy happens through the transmission system operator (TSO) Elia and is limited to 1/3 of the cable cost and capped at 25 million EUR.[37]

The guarantees of origin are a system to prove to end consumers that the power produced originated from offshore wind production. This is essential for receiving green energy certificates. A federal guarantee of origin is an electronic document whose sole purpose is to prove to the final customer that a certain share or quantity of energy has been produced from offshore renewable sources. The authenticity of guarantees of origin is ensured by registration in a database for guarantees of origin centralised and managed by the Belgian federal regulator for electricity and gas markets (CREG). To qualify for guarantees of origin, producers of electricity generated from offshore renewable energy sources can address their application to the CREG.[38]

Financial support for offshore wind in Belgium happens via a system of green energy certificates. The CREG grants green energy certificates to producers holding a domain concession (for renewable electricity generated in the Belgian sea area) and a certificate of guarantee of origin. The Belgian electricity transmission system operator (Elia) is obliged to purchase the green energy certificates from the green electricity producer. The price of these certificates (between 90 and 107 EUR/MWh) was fixed in advance for the first four offshore wind farms in Belgium. The purchase obligation lasts for 20 years for the green energy certificates generated by these 4 wind farms. For the five other wind farms (Rentel, Norther, Mermaid, Seastar and Northwester 2), the minimum price per green certificate depends on the electricity price and is set by the CREG. The purchase obligation applies for 19 years for the Rentel and Norther wind farms and for 17 years for the Mermaid, Seastar and Northwester 2 wind farms.[39]

The cost of the purchase obligation by the transmission system operator is passed through to electricity consumers via a surcharge on transmission tariffs. However, the surcharge depends on the volume of electricity consumed. Large electricity consumers (e.g., industrial installations) are mostly shielded from this surcharge.[40]

3.1.5 Prospects for Belgian offshore wind energy

In the new Marine Spatial Plan (MRP) 2020-2026, the federal government decided to earmark an additional area in the Belgian North Sea of 285 km² (on the border with France) for the construction and operation of renewable electricity generation facilities. This comes in addition to the existing 225 km² area of the first (eastern) windmill zone. The new Princess Elisabeth Zone, as defined in the MRP 2020-2026, will consist of three zones designated for the construction and

[37] CREG, 2018
[38] Id.
[39] Id.
[40] Id.

operation of plants for the production and storage of renewable energy and transmission of electricity. The expansion of offshore wind energy via these new zones aims to raise the offshore wind production capacity in Belgium to 5.4-5.8 GW.[41]

In accordance with EU state aid rules, the new domain concessions for offshore wind will be allocated through competitive tendering. The winner of the competitive bidding procedure, to whom the domain concession is granted, obtains permission to use the relevant plots for the purpose of construction and private operation of offshore power generation facilities and automatically and immediately obtains all necessary permits.[42]

The support system for offshore wind will also be changed. It is likely that the current system that offers a minimum price per green energy certificate (depending on the energy prices) will be further changed into a system of contracts for difference (CfD). Future investments will also enable the use of (citizen) cooperative power purchase agreements next to the existing corporate power purchase agreements.[43]

It is also likely that the current offshore parks will (over time) be re-powered, where older existing turbines will be replaced by higher performing ones. This could bring Belgian's offshore wind production capacity to 8 GW, i.e., tripling the current capacity. Finally, the Belgium government is planning to construct an energy island. This island will be an electricity hub for Belgian offshore wind and if possible, offshore wind outside of Belgium.[44]

3.2 Case findings

This section will present and discuss the findings following the actor and ecosystem mapping of offshore wind energy in Belgium. It starts by looking at the general findings from the mapping. This gives a good overview of the types of actors and activities related to offshore wind energy in Belgium.

Next the mapping results focus on innovation by highlighting the actors and institutes deemed relevant in this area. It discusses examples of types of innovation taking place and if Belgian developed know how is being exported. Thirdly, the findings on the investment ecosystem are presented.

[41] FOD Economie, 2023
[42] Id.
[43] FOD Economie, 2022a
[44] Bolero, 2022

3.2.1 General findings on the offshore wind ecosystem in Belgium

In total, 185 actors in Belgian offshore wind were identified.[45] The following classifications were applied:

- Types of activities (see below)
- The headquarter of the actors (Belgium/Foreign)
- Does the actor have multinational presence (Y/N)

The types of activities identified are: coordination function, investment, maritime engineering and infrastructure, turbines and components, R&D and education, energy producers, developers and operators and services to offshore wind.

The coordination function is carried out by actors that represent groups of actors in offshore wind, sector federations and that implement or facilitate coordinated R&D actions. Investment covers shareholders of offshore wind parks, commercial banks and investment banks. Consultancies facilitating the financing of offshore wind have been included under services. Maritime engineering and infrastructure imply the construction of offshore wind parks and related infrastructure (excl. surveying which is covered by services). Turbines and components cover the actual wind turbines, parts thereof and products needed for operation (e.g., lubricants and anti-corrosion coatings). R&D and education are actors that have a primary focus on research and/or offer education and training in offshore wind energy. Energy producers are companies that supply power to consumers. Some of these companies are also shareholders in Belgian offshore wind parks. Developers and operators cover the main developers and operators of offshore wind in Belgium. Maintenance is covered by the category services. Services cover a broad range of activities such as:

- Maintenance
- Maritime and geological surveying
- Disposal of legacy explosives
- Consulting (incl. financial consulting and engineering consulting)
- Accreditation and verification
- Safety, including safety training (e.g. rope services)
- Helicopter services

[45] Data sheet with collected data for this case study https://drive.google.com/file/d/1SJGcUDZt4tLv9y5gUAEQ6SH12COPTQ2i/view?usp=sharing

- IT services incl. (remote) sensing, monitoring (e.g. via drones) and optimisation of operations
- Harbour services

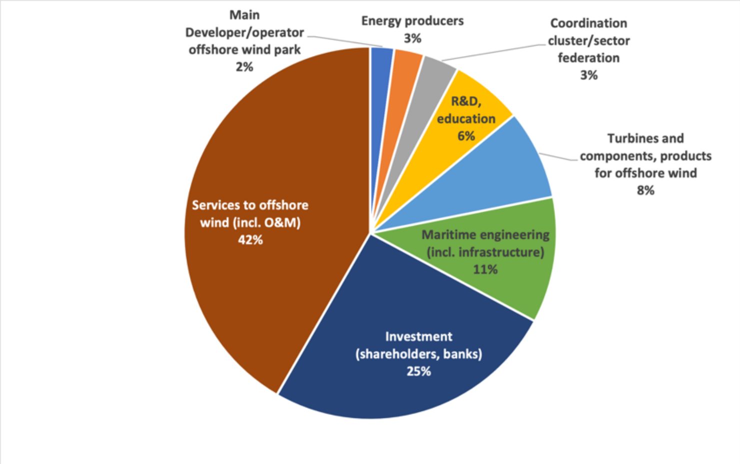

Figure 5: Share of actors' types of activities in Belgian offshore wind

Out of the 185 entities identified as active in Belgian offshore wind, 80 (or 42%) are delivering services to or related to offshore wind, 49 (or 25%) are involved in investing, 21 (11%) deal with maritime engineering and infrastructure, 15 (8%) are companies making turbines or components, there are 12 (6%) R&D and education entities, 6 coordination bodies (3%), 5 energy companies (3%) and 4 lead developers of offshore wind (2%). The total number of the actors in these activities is higher than the overall number of entities mapped because some have a dual role (e.g., energy company or maritime engineering and investor).

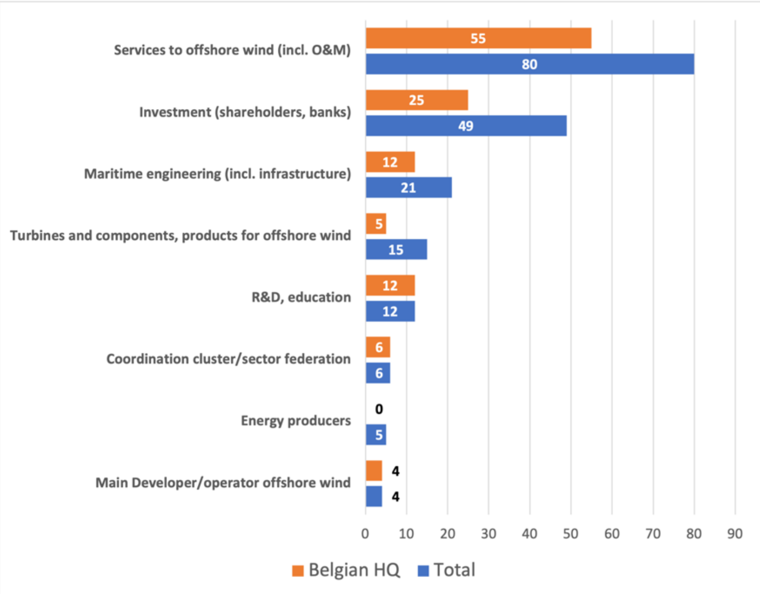

Figure 6: Activities of actors in Belgian offshore wind (total and with Belgian headquarters)

To see if a regional industry with activities in offshore wind emerged in Belgium, one can look at the (relative) number of actors with headquarters in Belgium. This shows that out of the 192 actors, 119 or 62% are headquartered in Belgium. If the comparison is restricted to companies (e.g., excluding universities and public R&D centres) this results in 102 Belgian companies out of the 169 total or 60%. All the main developer and operators of offshore wind parks are Belgian (or with majority of Belgian shareholders) as well as all R&D actors and cluster coordination bodies. Belgium has no wind turbine manufacturers but a few companies making components or products for turbines (e.g., gearboxes, paints and coatings).

Belgium has important actors in maritime engineering and the majority of the companies active in Belgian offshore wind are Belgian. Also, half of the companies active in investment are Belgian. Services, the largest and most diverse identifier, sees a presence of almost 70% Belgian headquartered companies. While the service activity is broad, it is worth pointing out that there seems to be a specialisation happening in Belgium with a focus on surveys, remote sensing and IT for monitoring and optimising offshore wind (e.g., using AI).

While a complete survey of the individual companies is beyond the scope of this case study, there is evidence of new (Belgian) companies being established following the development of offshore wind and with a clear focus on this industry. This includes two spin-out companies of the OWI-lab. Out of 102 Belgian-headquartered companies active in offshore wind, 28 (or 27%) have multinational activities (i.e., defined as companies with offices outside of Belgium), indicating possibilities of export of know-how developed in Belgium. Furthermore, it is likely that Belgian companies without offices outside of Belgium are also exporting products and services.

The mapping shows that a large (industrial) offshore wind ecosystem has established itself in Belgium over a period of 10-15 years. While Belgium is dependent on foreign companies for its offshore wind turbines, most of the other activities are largely fulfilled by Belgian actors. Belgian companies have developed diverse activities related to the construction of offshore wind, and especially related to the services to this industry. There are indications of high-tech specialisation in these services in Belgium (e.g., IT and remote sensing).[46] An important subset of Belgian companies involved in offshore wind is also active outside of Belgium, indicating the potential for export of know-how developed in Belgium (see also 3.2.3 below).

3.2.2 Innovation – key findings

Regarding innovation, this case study looks at the presence of actors that play a role in an innovation ecosystem, the presence of innovative activities and development of know-how (e.g.,

[46] Out of the 55 companies with Belgian headquarters that are active in services to offshore wind, 22 are specialized in remote sensing, monitoring and IT (incl. energy modelling) applications: e-bo, Marlinks, Hypertechnics, 24Sea, 3E, Kapernikov, Prophesea, Sentea, UX solutions, Zensor, Future services, Aerobot, Fluves, Com&sens, nCentric, Elsyca, Phoenix contact, Space applications, CTS, Crescent, Aetos, Magics.

via patents), the evolution of companies' business models, and whether know-how developed in the Belgian offshore wind ecosystem has been exported.

The key findings on innovation related to offshore wind development in Belgium are that:

- There is an (emerging) innovation ecosystem consisting of actors from the private sector, public sector, and research organisations;
- There is a strong correlation between the development of offshore wind and related patents by Belgium companies;
- There is strong evidence of innovative entrepreneurial activities;
- There is evidence of companies changing or adapting their business model; and
- There is evidence of Belgian developed know-how being exported.

3.2.3 The emergence of an innovation offshore wind ecosystem in Belgium

Through the mapping of the Belgian offshore wind ecosystem, actors that are relevant to innovation have been identified. These include coordination organisations, research bodies and entrepreneurial activities.

Coordination organizations are entities that represent, coordinate, and support a group of companies and other (R&D linked) actors with the goal to facilitate cooperation, support and know-how development on innovation in offshore wind (and related or similar activities). Three coordination organisations with activities related or focussed on innovation have been identified:

- De Blauwe Cluster (The Blue Cluster) originated in 2017 as a partnership of companies active in the economic development of the Belgian North Sea. It later became an innovation focused 'spearhead' (speerpunt) cluster as part of the Flemish innovation and entrepreneurship agenda. The cluster links Flemish research and research institutes with the economic and R&D activities of its company members. The cluster is supported by scientific and societal advisory boards.[47]
- 'Fabrieken voor de toekomst (factories for the future) – Blue energy' is an initiative of the Belgian province West-Vlaanderen and aims to assist companies active in offshore energy with international cooperation, skills and piloting and testing of floating energy installation at sea.[48]
- IBN offshore energy cluster, established by the Flemish agency for innovation and entrepreneurship (VLAIO), is a network of Flemish companies innovating in the field of

[47] Blauwe cluster, n.d.
[48] POM West-Vlaanderen, 2023

offshore energy (offshore wind, floating wind, wave & tidal). The activities of the IBN Offshore Energy are oriented towards facilitating innovation in this area, the mission of the support team is to support the process from back-of-the-envelope idea towards a project plan for an innovative product or service ready to be executed. The technology knowledge centre Sirris coordinates the cluster activities in cooperation with the university of Ghent (UGent), the Vrije Universiteit Brussel (VUB) and Agoria, the sector federation for high tech and non-ferrous metals in Belgium.[49]

These coordination bodies are facilitating R&D and innovation for companies involved in offshore wind energy in Belgium. This happens through enabling connections to other companies (e.g., exchange of know-how), research institutes and/or (EU) innovation funding and assistance in testing or piloting new technologies.

Most of the Belgian universities and research institutes are involved in R&D and educational activities related to offshore wind. UGENT, VUB, UAntwerpen (University of Antwerp) and the VIVES high school are part of the above-mentioned IBN offshore energy cluster.[50] The universities UGent and KULeuven (Catholic University of Leuven) offer training courses on offshore wind energy.[51]

Belgium also has two dedicated research and testing centres for offshore wind energy: OWI-lab and the Coastal & Ocean Basin (COB) research facility. OWI-Lab supports the full Belgian wind energy value chain (from development to decommissioning phase) as an expertise consortium with national and international 'industry driven' Research, Development & Innovation actions to further build-up Belgium's leading role in the worldwide wind energy sector. The technological knowledge centre Sirris and the universities of Brussels and Ghent coordinate multidisciplinary projects there. With support from the Flemish government, OWI-Lab developed innovative applications in offshore wind energy, from which two spin-offs emerged.[52] The Coastal & Ocean Basin (COB) research facility is located in the Ostend Science Park, which houses companies active in the Blue Economy with special attention to Research and Development (e.g., E-bo and GEOxyz).[53]

The mapping of the offshore wind ecosystem in Belgium demonstrates a high level of entrepreneurial activity. While this case study could not assess the innovation activities of each of these companies, there is evidence of a concentration of service activities in high-tech areas such as remote sensing and advanced application of IT technologies in offshore wind. A selection of important examples is given in section 3.2.3.3 below.

[49] IBN offshore Energy, n.d.
[50] Id.
[51] See: https://www.kuleuven.be/onderwijs/levenslangleren/permanentevorming/Docs/windenergie and https://www.ugain.ugent.be/opleidingen/aanbod/offshorewindenergy2020/offshorewindenergy2020.pdf
[52] OWI-lab, n.d.
[53] Ostend Science Park

3.2.3.1 Patents

To see if offshore wind development triggered innovation the publication of related patents can be used as a proxy. Here we consider the patents published in Belgium given that these are mostly owned by Belgian companies. It is of course possible that Belgian companies also registered their patents in other countries. There are 110 patents published by the Belgian patent authority mentioning 'offshore wind' covering a period of 20 years (2002-2022).[54]

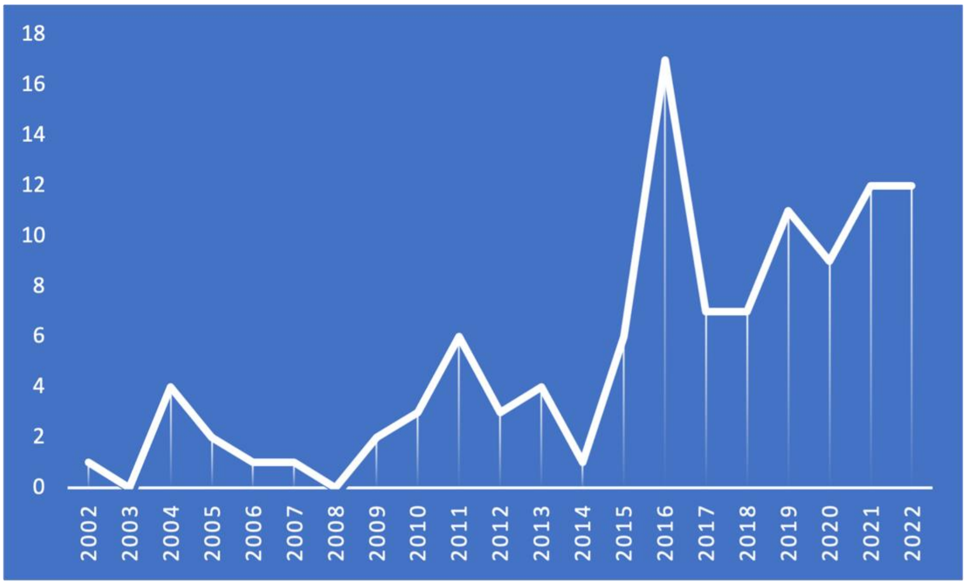

Figure 7: Annual number of Belgian patents mentioning 'offshore wind' (2002–2022)
Source: Belgian Patent Authority (data acquired via Google Patents).

The patent data shows a clear increase in published patents referring to offshore wind after 2009, with sustained higher numbers as from 2015. This matches the development of offshore wind in Belgium, with the first offshore wind farm coming online in 2010 and accelerated deployment after 2014. While this correlation seems clear, it is not proof that companies involved in offshore wind development in Belgium engaged in innovation leading to patent registration. However, scanning the actual patents shows major activity by important actors in offshore wind in Belgium. Out of the 110 patents published between 2002 and 2022, 56 are owned by 6 companies (51%). These companies are Geosea (24 patents), DEME (20 patents), High Wind (6 patents), DECO (4 patents), Jan De Nul (4 patents) and Zensor (2 patents). All of these companies are very active in the development of offshore wind in Belgium, hence establishing a causal link between the patent evolution and offshore wind evolution in Belgium, especially because the majority of these patents were awarded after the first development of offshore wind in Belgium.

[54] The data was retrieved in January 2023 via patents.google.com on the search term "Offshore wind" for the period 1/1/2002 until 31/12/2022 and limited to the Belgian patent office.

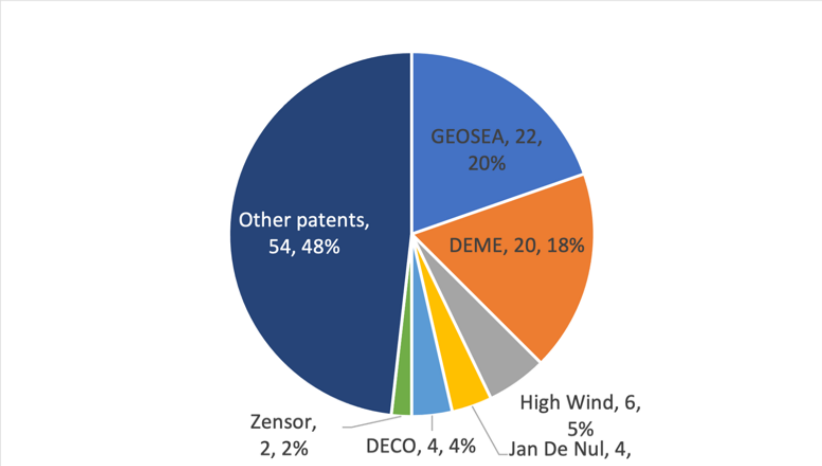

Figure 8: Belgian offshore wind patents by company (2002–2022)
Source: Belgian Patent Authority (data acquired via Google Patents).

One of the possible drivers behind the patent developments in Belgium was the local technological challenges of developing offshore wind in Belgium. In particular, the early offshore wind projects in Belgium were characterised by elements which at that time were considered technologically challenging. These include: [55]

- The size of turbines (6.15 MW for the first park, at the time the largest offshore turbines);
- The high number of planned wind turbines (54 in the first offshore wind park);
- The distance from the coast (24 to 54 km from shore); and
- The considerable depth required to lay the foundations for the towers (up to 40m).

These projects were therefore very ambitious and innovative projects at the time they were designed and built.

3.2.3.2 Innovative entrepreneurial activities

This case study could not research the innovations realized by all companies mapped in the Belgian offshore wind eco-system. However, by looking at important actors and sampling activities of other companies, two important elements come forward. First, Belgian companies are innovative frontrunners in the construction of offshore wind farms. Second, there is evidence of innovation and specialisation in software applications and remote sensing related to offshore wind energy operations. Finally, companies active in offshore wind are looking ahead towards raising the value of offshore wind electricity by connecting it to hydrogen production.

When it comes to the construction of offshore wind farms, major innovative investments happened regarding offshore installation vessels. The Belgian maritime engineering and dredging

[55] FOD Economie, 2021

firms DEME[56] and Jan De Nul[57] the leaders in this field, now own the most modern fleets of such vessels. These specially developed ships for offshore wind construction improve access and safety to development sites and help shorten construction time, hence reducing costs. Newly constructed vessels are ready for the next generation of (large) offshore wind turbines.

While Belgium does not have wind turbine manufacturers, it has an industry-leading wind energy gearbox company (ZF Power). This company now owns a state-of-the-art test and prototype centre, it develops industry leading gearbox technologies and moved further into digitization (e.g., via life cycle monitoring) to reduce operational costs of wind turbines.[58]

Next to companies involved in construction of offshore wind there seems to be a specialization in Belgium focusing on innovative software, data monitoring and remote sensing relevant for the development and operations and maintenance for offshore wind (infrastructure):[59]

- GEOxyz, a surveyor company, specialised in maritime soil investigation and support services such as cable inspection, transport of maintenance teams and even accommodation at sea of large maintenance teams in hotel ships.
- The company e-BO became a leader in the development of software for the operations of offshore wind farms. All Belgian wind farms use its software platform e-Wind to manage their operations.
- Marlinks, a start-up, developed a software solution to preventively detect problems with cables, based on data coming directly from the fibres in the cables. Based on this, an algorithm calculates the depth at which it is buried in the seabed.
- Hypertechnics is another SME specialising in subsea infrastructure. The seven-year-old company builds underwater sensors to specific applications, such as measuring vibrations but also production line of underwater connectors. These connectors are a kind of plugs for at sea. Until recently these had to be imported.
- Flidar makes floating measuring buoys that map conditions at a particular spot at sea, providing data to optimise the efficiency of turbines.
- 24SEA, a spinout from OWI-labs and the VUB, builds sensor systems to monitor the health of offshore foundations.[60]

[56] For example, see: https://www.deme-group.com/technologies/innovation
[57] For example see: https://kanaalz.knack.be/nieuws/jan-de-nul-laat-schip-zo-hoog-als-eiffeltoren-te-water/video-normal-1829047.html
[58] Z.F. power, n.d.
[59] De Preter, W., 2021
[60] See: https://www.owi-lab.be/24sea

- ZENSOR a spinoff of the VUB has introduced a smart, multi-sensor monitoring solution to have a continuous view on the offshore wind farm foundation's state of health together with its evolution.[61]
- 3E, an environmental consultant and research company is an industrial frontrunner in the development of digital platforms for the development, operational asset management and analytics of renewable energy projects, including offshore wind.[62]
- While not commercialized yet, there is ongoing research by the VUB Artificial Intelligence Lab and OWI-lab to introduce AI into the management of offshore wind. The goal is to minimise production losses at offshore wind farms.[63]
- The IT company Prophesea creates custom predictive software. These predictive models can be data-driven, building upon state-of-the-art machine learning technology, or by solving mathematical equations and are used in areas such as predictive maintenance.[64]

Finally, looking beyond the current framework of offshore wind production, companies involved in offshore wind in Belgium have started to investigate the valorisation of offshore wind produced electricity into Hydrogen production. A public private consortium including DEME and Ostend Port have started to develop pilot and later demonstration projects in this area.[65]

3.2.3.3 Business model innovation

Next to assessing the technological innovations mentioned before it is interesting to see if the development of offshore wind has led to incumbent companies changing or innovating their business models.

Again, DEME and Jan De Nul are important examples. These two Belgian-headquartered multinational companies have a long history in dredging and engineering in a maritime environment. They were amongst the first to reorient (part of) their business model towards the development of offshore wind. In the case of DEME this went beyond development of offshore wind and included significant investments in offshore dedicated technology (e.g., installation and maintenance ships) towards becoming an important shareholder in 3 offshore wind parks in Belgium.

The steelworks company Smulders is another example of where offshore wind contributed to a turn around. The company flirted with bankruptcy in 2011, but due to restructuring and refocusing its business model on energy projects in the North Sea, including offshore wind, the company managed to turn profitable and is now a European leader in supporting construction for offshore wind. The company, with its Belgian consortium partner Equans is also one of the few global

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[61] See: https://vubtechtransfer.be/en/zensor
[62] See: https://3e.eu/our-platform
[63] VUB, 2021
[64] See: https://www.prophesea.eu
[65] Durakovic, A., 2020

constructors of modular offshore grids (MOGs).[66] 40% of all offshore wind energy platforms are constructed in Belgium.[67] In a similar way the steelworks company John Cockerill has shifted part of its business model towards offshore wind maintenance and repairs.[68]

Finally, there is Belgian retail group Colruyt that moved into the energy business via its investment arm Virya energy and is now the lead developer (under the name Parkwind) and (co-)owner of 4 of the offshore wind parks in Belgium.

Next to these more visible examples of business model changes there are many other companies active in offshore wind in Belgium that have shifted from incumbent markets to offshore wind. These include accreditation and verification organisations, (legal) consultants and companies that were already active in a maritime environment (e.g., engineering, safety training and helicopter chartering).

3.2.3.4 Exporting Belgian know-how on offshore wind

The early action of Belgium in developing offshore wind has resulted in nurturing two companies that have become world leading in offshore wind construction: Jan De Nul and DEME.

Both companies are active in the development of offshore wind in the EU, e.g., in France, UK, Germany. Furthermore, they were in pole position to secure contracts for the development of offshore wind in major future growth markets such as the US, Taiwan and Japan.[69]

Next to the advantage of having experience with offshore wind development in Belgium, these companies secured global leadership by investing in innovative offshore wind installation technologies, in particular the scaling up of deployment and maintenance vessels. As such, the Belgian offshore wind policy helped advance the global deployment of offshore wind.

While the development of offshore wind in Belgium can be seen as a necessary condition for these companies to grow into global leaders in offshore wind construction, it is not the only or sufficient condition. These companies were already operating at a global scale in related maritime engineering and operations (incl. in the energy sector). Hence, they had the know-how and (financial) means to invest and operate in the nascent offshore wind business.

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[66] Brockmans, H., 2015
[67] van den Buijs, D., 2023
[68] See: https://johncockerill.com/en/services/energy/services-to-wind-energy/
[69] A selection of international projects of these major maritime engineering companies: DEME group, 2019. DEME group, 2020. DEME group, 2021. DEME group, 2021a. Jan de Nul, 2020. Jan De Nul, 2022. Jan De Nul, 2022a.

3.2.4 Mapping Belgian offshore wind investment

3.2.4.1 Key findings

Overall, 49 actors directly involved in investment in offshore wind energy in Belgium were identified. These represent major shareholders of offshore wind parks, commercial and investment banks. In total an estimated €7.5 billion has been invested in offshore wind in Belgium between 2009-2020.[70]

Key findings on investment are:

- Majority of offshore wind is Belgian-owned, with large share of public sector ownership;
- Investment banks, and in particular the European Investment Bank, played an important role in financing Belgian offshore wind to achieve financial closure;
- Long-term financial certainty via the support mechanism and Power Purchase Agreements (PPAs) was important in securing investments in Belgian offshore wind. PPAs frequently link to industrial end consumers; and
- The cost per MW installed has come down between 2009 and 2020.

3.2.4.2 Ownership of offshore wind

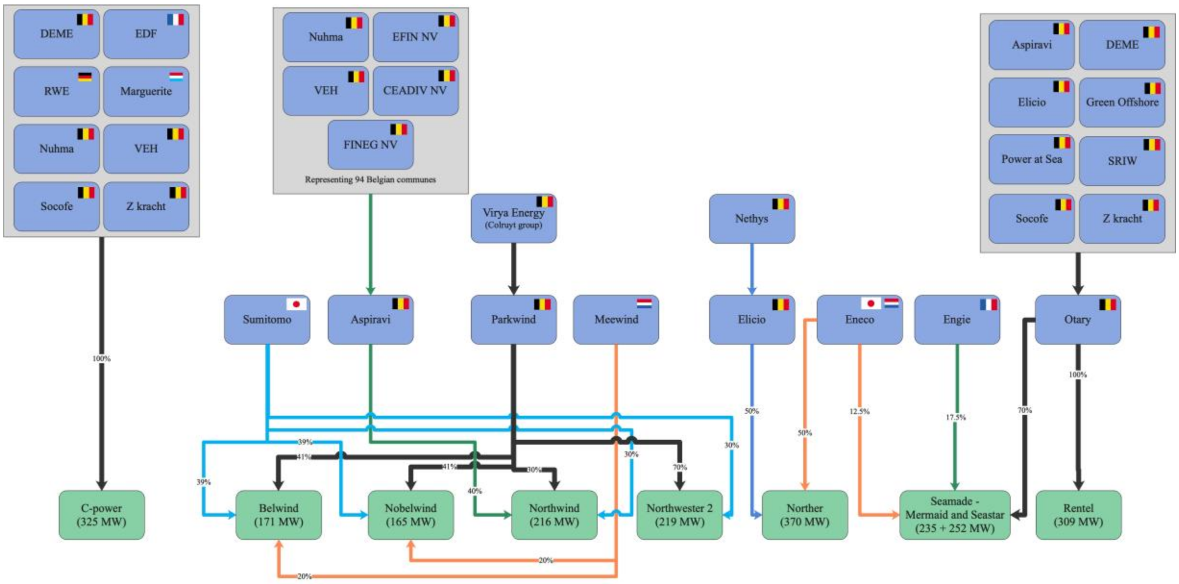

Figure 9: Shareholders in Belgian offshore wind and countries of origin
Sources: Belgian Offshore Platform, Norther (Elicio), C-Power, Parkwind and Otary)

[70] Figure has been calculated using the EIB project financing press releases on the 8 Belgian offshore wind parks.

There are four major developers of offshore wind in Belgium: C-power, Parkwind, Elicio and Otary. These companies own, often with other (minority) shareholders, the 8 offshore wind parks in Belgium. Other important shareholders in Belgium offshore wind parks are the Japanese company Sumitomo (shares in 4 parks), the Dutch investment company Meewind (with shares in 2 parks), Dutch/Japanese Eneco (with shares in 2 parks) and Engie (with shares in 1 park) and the young Belgian energy company Elicio (with a 50% share in 1 park and shares in Otary)

Overall, most of the offshore wind capacity is owned by Belgian companies or public sector stakeholders (see Figure 9).[71] This contrasts with gas- and nuclear-based power production, which currently is owned by foreign companies. Belgian ownership has the advantage that it increases the chances that revenues and profits of offshore wind are reinvested in the Belgian economy, hence creating a dividend for the Belgian economy. One possible explanation for the high level of Belgian ownership is that it is often companies or public sector stakeholders with experience in onshore wind development (e.g. Aspiravi, Elicio and Virya energy) or Belgian companies with an important stake in the construction of offshore wind energy (e.g. DEME).

From the private sector two actors are noteworthy and have been mentioned before in the section on (business model) innovation. First, the dredging and maritime engineering group DEME is a shareholder in both C-power and Otary. Secondly, Parkwind is an investment vehicle owned by Virya Energy, the latter is a part of the Belgian retail group Colruyt.

The public sector is an important shareholder in offshore wind in Belgium. Belgian communes in particular play a key role with the investment vehicle Aspiravi representing Belgian 94 communes (through its shareholders). Aspiravi is an important shareholder in C-power and Otary. Elicio the developer and main shareholder of one park is owned by Nethys a company who' s shareholders are the communes of the Walloon region in Belgium. C-power and Otary have other public sector related shareholders next to the ones mentioned before.

3.2.4.3 Investment banks and financing

The ownership of offshore wind is not the only key aspect that features a mix of private and public involvement. The capital made available (e.g., via loans) to make the investments possible is also a mix of public and private funds. Private sector capital was made available via at least 15 major national and international banks.[72] Next to the commercial banking sector, national and international development banks provided an important amount of financing. These are the Flemish investment bank Participatiemaatschappij Vlaanderen (PMV), the Danish foreign investment fund (EKF), the German KfW and finally the EU's European Investment Bank (EIB).

[71] Citizens can also (indirectly) invest in Belgian offshore wind. Currently via the ECO2050 vehicle by Aspiravi/Nuhma and in the future via other cooperative organisations that are currently being established to participate in future offshore wind tenders.
[72] Including: Dexia, Rabobank, BNP Paribas, Fortis, ASN AMRO, Belfius, BMTU, SMCB, Societe Generale, Santander, Bank of China, Commerzbank, ING, KBC, MUFG, Siemens Bank and Triodos

The later provided an important part of financing for all Belgian offshore wind parks. In total 33% of capital was provided via the EIB.

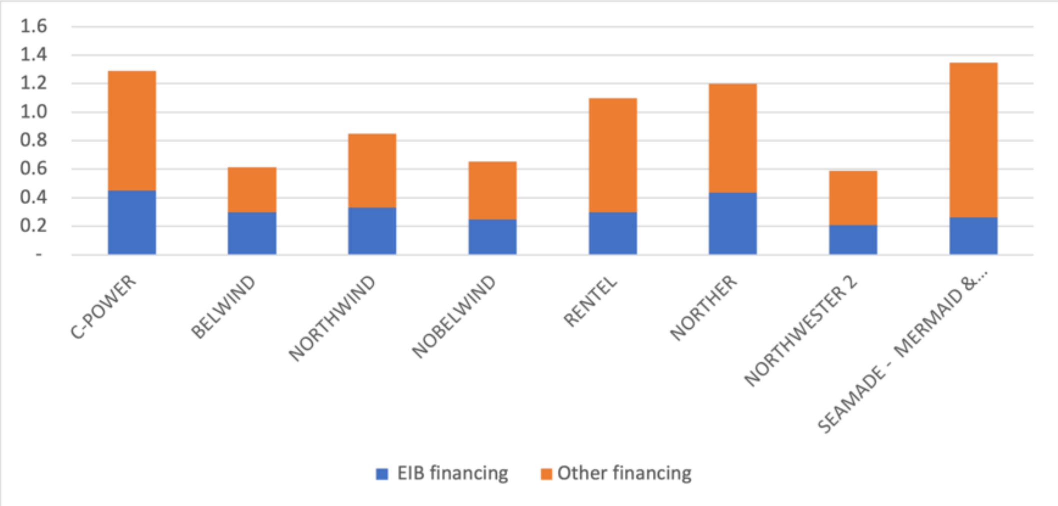

Figure 10: European Investment Bank contribution to offshore windfarms in Belgium
In billion Euros. Sources: Parkwind, Otary, C-power and EIB.

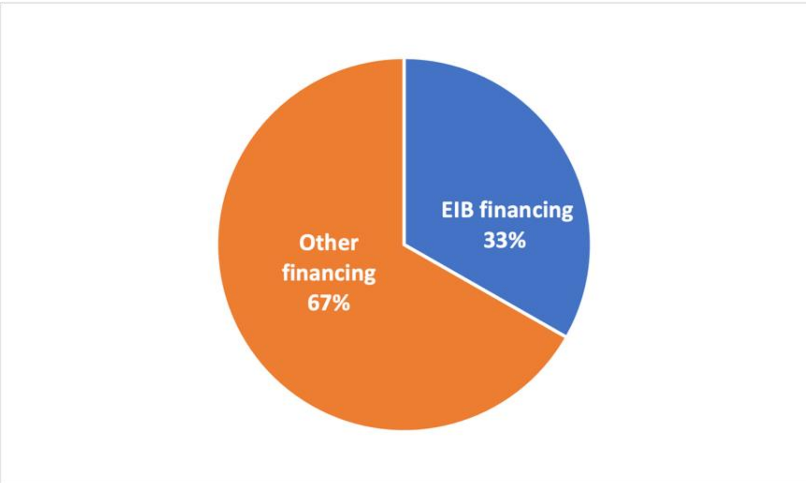

Figure 11: Total European Investment Bank contribution to offshore windfarms in Belgium
In billion Euros. Sources: Parkwind, Otary, C-power and EIB.

Having large multilateral development banks such as the EIB involved helps these capital-intensive projects reach financial closure. This is important for emerging technologies that still can have a high amount of project and technology risks.[73]

[73] Norther, n.d.

3.2.4.4 Long-term certainty, policy support, and Power Purchase Agreements

Green investments benefit from long-term (regulatory) certainty e.g., via a secure revenue stream and/or a stable policy.[74] In the case of Belgian offshore wind developments two elements helped to bring this about. The long-term support via green energy certificates (17-20 years)[75] and the use of Power Purchase Agreements (PPAs).

Power purchase agreements often play an important role in project financing of renewable energy projects, including offshore wind. PPAs are Performance-Based Contracts (PBCs) that aim to create a "fair" and risk-controlled agreement for the purchase and sale of energy between a utility (the Buyer) and a generator (the Seller).[76]

Having a PPA in place to secure the revenue stream for a renewable energy project over a long time period is often a necessity to attract banks and other project financiers. Hence, PPAs facilitate the bankability of an offshore wind project.[77]

PPAs are also commonly used in Belgian offshore wind. Examples are PPAs of the Northwester 2 offshore windfarm with RWE, Belwind farm with Engie, Seamade with Eneco, Rentel with Lampiris, C-power with Essent and Eneco, and Norther with Eneco. In some cases, the energy companies (e.g., Engie, Eneco, Lampiris) act as an intermediary to conclude downstream PPAs. Here we noted the involvement of major industrial companies such as Ineos, Borealis and Air Liquide with offshore wind PPAs contracted to production plants in Belgium. For industry, such PPAs can be advantageous because they are a long-term contract and hence can include a form of supply and pricing stability. Furthermore, such renewable energy PPAs are a way for energy intensive companies to green their production.

3.2.4.5 Evolution of investment costs

With over 10 years of investments in offshore wind in Belgium it is possible to evaluate the evolution of the investment cost per MW installed capacity. While all the offshore parks are not exact copies of each other (e.g., different types of turbines, size, distance from shore and construction depth) a clear evolution in costs is visible. C-power, the first offshore wind farm to be completed (2009) had a total investment cost of 3.97 million EUR per MW installed.[78] Northwester 2 and Seamade, two farms completed in 2020 had a respective cost of 2.69 and 2.76 MEUR/MW. Using the average investment cost of 2020 (2.74 MEUR/MW) leads to an estimated investment cost reduction of 31% over a period of 11 years.

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[74] Blyth, W., et al., 2007
[75] Bolero, 2022
[76] Bruck, M., et al., 2018
[77] Nilsen, J. N., 2021
[78] Calculated by dividing the capital investment (million EUR) by the installed capacity (MW). The capital investment data was retrieved from the EIB press releases announcing the project support for the 8 offshore wind parks in Belgium.

Table 2: Evolution of capital expenditure per megawatt installed
Sources: FOD Economie, 2023 and EIB

Name	Operational (year)	MEUR/MW installed
C-POWER	2009	3.97
BELWIND	2010	3.59
NORTHWIND	2014	3.94
NOBELWIND	2017	3.97
RENTEL	2018	3.56
NORTHER	2019	3.24
NORTHWESTER 2	2020	2.69
SEAMADE (MERMAID+SEASTAR)	2020	2.76

4. Conclusions and future work

4.1 Conclusions of the case study

This section provides an overview of the main findings of the actors mapping together with characteristics of Belgian offshore wind.

4.1.1 A broad and diverse Belgian offshore wind ecosystem

Over a period of 10-15 years, following the initiative of the Belgian government to develop offshore wind, at least 169 companies became active in the development and operation of this sector in Belgium. There are now 6 coordination bodies or sector federations representing the industry. There is one dedicated research lab and 11 other research institutes focussing on innovation. Out of the 169 companies active in offshore wind 102 (or 60%) are Belgian, demonstrating a locally grown industry. The Belgian companies are active in all areas related to offshore wind (e.g., development, investing, maritime engineering, services and to lesser extent turbines and components).

4.1.2 Belgium is a global player in offshore wind

The choice of the Belgian government to start developing offshore wind as one of the first countries has resulted in nurturing two companies that have become world leading in offshore wind construction (Jan De Nul and DEME). Both companies are active in the development of offshore wind in the EU, e.g., in France, UK, Germany. Furthermore, they were in pole position to secure contracts for the development of offshore wind in the US, Taiwan and Japan, which are major future growth markets. Belgium has also become a global leader in modular offshore grid construction (via the company Smulders and its subcontractors) with around 40% of these substations being constructed in Belgium.

The explanation for such large market shares for a small country links to two elements seen in this case study:

- The early development of offshore wind in Belgium allowed large, multinational Belgian companies to start investing in the technologies and techniques required for this sector. These larger companies had the financial means and experience in the necessary area (i.e. maritime engineering) to be successful in changing or adapting their business models.
- Innovation is the second element that was important, with maritime engineering companies investing in innovative offshore wind construction and maintenance ships (e.g., increasing size and capabilities). Maritime engineering companies also hold a large share

of offshore wind related patents published by the Belgian Patent Office between 2002 and 2022. This continued innovation allowed these companies to engage in larger (and more complex) offshore wind construction outside of Belgium and Europe.

4.1.3 High tech meets clean tech

Next to the high-profile activities by Belgian maritime engineering firms, a large services industry to the offshore wind industry in Belgium developed over the last two decades. These services cover a broad group of activities such as consulting, verification and accreditation, maintenance, surveying, safety and safety training, IT services and remote sensing. There is strong evidence for innovative entrepreneurial activities related to offshore wind in Belgium. There is evidence for specialisation in Belgian offshore wind services focusing on innovative software (e.g., the use of AI), data monitoring and remote sensing relevant for the development and operations and maintenance for offshore wind (infrastructure).

4.1.4 Belgian offshore wind is Belgian owned with significant public sector ownership

Most of the offshore wind capacity is owned by Belgian companies or public sector stakeholders. This contrasts with gas- and nuclear-based power production, which currently is owned by foreign companies. Belgian ownership has the advantage that it increases the chances that revenues and profits of offshore wind are reinvested in the Belgian economy.

The public sector is an important shareholder in offshore wind in Belgium. Belgian municipalities in particular, play an important role with the investment vehicle Aspiravi representing 94 Belgian communes (through its shareholders). Aspiravi is an important shareholder in C-power and Otary. Elicio, the developer and main shareholder of one park, is owned by Nethys a company who' s shareholders are the communes of the Walloon region in Belgium. C-power and Otary have other public sector related shareholders next to the ones mentioned before.

4.1.5 Multilateral banks, policy support and PPAs facilitated financial closure

The ownership of offshore wind is not the only key aspect that features a mix of private and public involvement. The capital made available (e.g., via loans) to make the investments possible is also a mix of public and private funds. Next to the commercial banking sector, national and international development banks provided a substantial amount of financing. The European Investment Bank (EIB) provided a substantial part of financing for all Belgian offshore wind parks. In total 33% of capital was provided via the EIB. Having large multilateral development banks such as the EIB involved helps these capital-intensive projects reach financial closure. This is important for emerging technologies that have additional amounts of project and technology risks.

In the case of Belgian offshore wind developments, two elements helped to bring about long-term investment certainty: The long-term support via green energy certificates (17-20 years) and the use of Power Purchase Agreements (PPAs). Power purchase agreements (PPAs) often play an important role in project financing of renewable energy projects, including offshore wind. Having a PPA in place to secure the revenue stream for a renewable energy project over a long time is often a necessity to attract banks and other project financiers. Hence, PPAs facilitate the bankability of an offshore wind project. PPAs are commonly used in Belgian offshore wind. In some cases, energy companies (e.g., Engie, Eneco, Lampiris) act as an intermediary to conclude downstream PPA's with final consumers. This case study noted the involvement of major industrial companies such as Ineos, Borealis and Air Liquide with offshore wind PPAs contracted to production plants in Belgium. For industry, such PPAs can be advantageous because they are a long-term contract and hence provide a form of supply and pricing stability. Furthermore, such renewable energy PPAs allow for energy intensive companies to green their production.

4.1.6 Conclusions on the methodology

The combination of literature reviews and mapping of actors in offshore wind achieved a decent understanding of the Belgian offshore wind ecosystem. More in-depth knowledge, however, was gained by linking the mapping data with other data sources such as patent databases, shareholder lists and data on investments for each offshore wind park. The actor mapping in itself does not offer an explanatory framework for why certain features were observed (e.g., export of know-how). This required additional information, often found via company websites or media reports and where available links to theories on industrial policy.

It is important to note that the conclusions of this case study apply to Belgian offshore wind specifically. Extrapolating these conclusions to other countries and sectors is hence not straightforward. Therefore, the recommendations for transformative policies (see next section) are kept more general and pay attention to local circumstances. Replicating this mapping for other countries with offshore wind (e.g., over a similar time period) can allow for a comparative analysis and hence more generalized conclusions and recommendations. This is however beyond the scope of this case study.

Further research based on this case study can include such comparative analysis. This case study can also form the basis of an innovation system analysis, given that such analysis requires mapping of actors in the innovation system.

4.2 Recommendations for transformative climate policies

When it comes to lessons learned and policy recommendations, three main points can be highlighted resulting from this case study:

- Early mover advantages emerge under certain conditions (incl. R&D support).

- A local ecosystem can be the driver for higher government ambitions relating to that ecosystem. When this ecosystem relates to green technologies it can lead to higher green ambitions.
- Ingredients to secure investments, in particular financial closure of projects.

Being among the first countries to develop offshore wind energy at scale has brought (early mover) advantages to Belgium. The most notable is the emergence of home-grown world leaders in installation of offshore wind parks and infrastructure. The (early) policy choice to develop offshore wind is a prime driver but it is not a sufficient condition for such developments. Three other elements are likely to have contributed. First, offshore wind energy built upon the strength and experience of companies in other, related industries. This was specifically the case for maritime engineering where Belgium, as a coastal country with large harbours and ports, had ample experience and the presence of Belgian-headquartered (multinational) companies. Secondly, R&D support e.g., through the presence of coordination centres and R&D testing infrastructure helped companies active in offshore wind innovate faster. Finally, when designing and developing the first offshore wind parks, Belgian offshore wind developers pushed the technological frontiers for offshore wind at that time. While introducing a higher level of (technology) risk, this has pushed companies to develop new techniques and hence create a know-how advantage compared to international competitors.

Belgium plans to almost triple its offshore wind capacity by 2030 (from 2.6 GW to almost 8 GW). It can be argued that the local industrial ecosystem that emerged from developing offshore wind in the period 2009-2020 enabled such a leap forward. First, there is little doubt that the industrial capacity and know how to expand offshore wind is present in Belgium. Second, having a domestically developed offshore wind industry created a pressure group with an interest in growing this industry. In Belgium this is visible through organizations representing the offshore wind industry such as the Belgian Offshore Platform and the Belgian Offshore Cluster.

Offshore wind energy remains a capital-intensive industry and achieving financial closure of offshore wind projects (i.e., securing the necessary capital) is an important challenge. Three elements from this case study helped achieve the necessary investments. First, the Belgian support system via green energy certificates generated a long-term and secure revenue stream. Importantly, this system has been adjusted following lower costs of offshore wind energy by linking it to power prices. Soon, the system can take the form of a contract for difference (CfD). Support for infrastructure (e.g., offshore-to-onshore cables) also helped to bring about offshore wind projects. Second, multilateral development banks and in particular the European Investment Bank provided large shares of financing (loans) to offshore wind. The presence of such a big and secure lender facilitated capital from private banks. Third, securing revenue streams via (long-term) Power Purchase Agreements added another layer of investment security to these projects. Of interest is the symbiotic relation with energy intensive industries where the latter benefit from offshore wind PPAs due to (depending on the contract) price stability and greening of the indirect greenhouse gas emissions.

Concluding recommendations for transformative climate policies:

- Use and/or nurture local industrial (and know-how) strengths;
- Build R&D coordination and support infrastructure;
- Push technological frontiers (risk taking) if needed and/or possible given that this will trigger innovation and development of (local) know-how that can be exported;
- Use a flexible support system which offers long-term revenue certainty. Think of supporting flanking infrastructure;
- Engage with multilateral development banks, especially for capital-intensive projects; and
- Stimulate the use of Power Purchase Agreements and facilitate the link with energy intensive industries.

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About the project

4i-TRACTION – innovation, investment, infrastructure and sector integration:
TRAnsformative policies for a ClimaTe-neutral European UnION

To achieve climate neutrality by 2050, EU policy will have to be reoriented – from incremental towards structural change. As expressed in the European Green Deal, the challenge is to initiate the necessary transformation to climate neutrality in the coming years, while enhancing competitiveness, productivity, employment.

To mobilise the creative, financial and political resources, the EU also needs a governance framework that facilitates cross-sectoral policy integration and that allows citizens, public and private stakeholders to participate in the process and to own the results. The 4i-TRACTION project analyses how this can be done.

Project partners

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