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TNO report

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System Integration Offshore Energy: Innovation Project North Sea Energy

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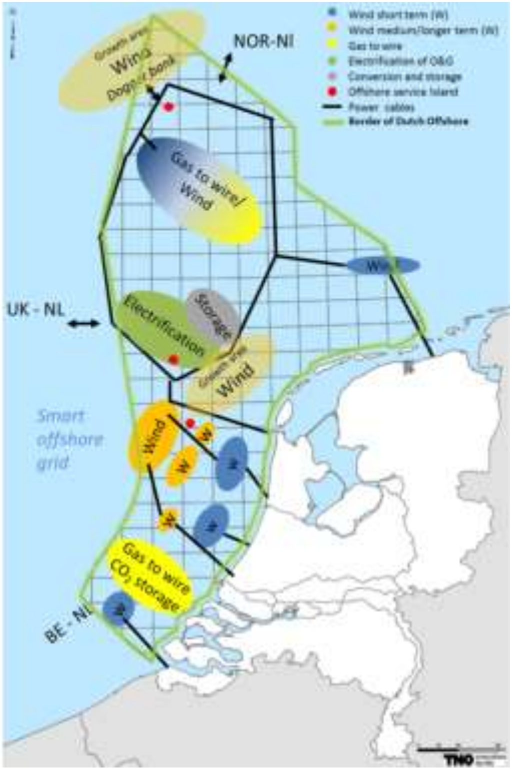
Executive Summary: North Sea Energy Innovation Project

Background

The international community faces an important challenge to implement the Paris agreement (UN 2015), substantially reduce CO_2 emissions and limit global temperature increase to 1.5°C or lower. A fast transition to a new, low carbon energy system is therefore required. The Dutch North Sea is an area where this energy transition actually materializes, with the current strong ramp-up of wind energy construction. Parallel, the cessation and decommissioning of current gas production activities will start in the upcoming years. Next to these activities, the North Sea hosts several other important (economic) activities, including fishing, sand and shell extraction, shipping, military use, nature reserves and recreational activities. Given the many uses and the limited space available in the Dutch sector of the North Sea, this requires that synergies between different uses must be found and optimized.



An offshore system integration concept for 2030+

Motivation

In the current situation, the main players in the offshore energy domain, the gas sector on one hand and the wind energy sector on the other hand, are largely operating in rather separate worlds. Overall operational efficiency, economics and environmental performance could be significantly improved by (partly) sharing infrastructure, offshore services, human capital, products and knowledge. Such an integrated energy system would allow for optimizing the efficiency of the system and make it more robust regarding security of supply, as well as more flexible in coping with fluctuations in supply and demand. For these reason, system integration in the offshore energy domain is unavoidable. Successful system integration can only be achieved if common drivers of the stakeholders can be identified. The report identifies these drivers and outlines a broad innovation project on System Integration Offshore Energy, including innovation themes that are relevant for offshore energy system integration in which a joint effort by stakeholders can tackle challenges and create opportunities in the pre-competitive domain. The innovation project furthermore contains a set of key performance indicators to ensure that research and innovation within the program is transparent, verifiable, relevant, and impactful. In short, the report presents a common vision for the North Sea as a clean energy source for the Netherlands

Drivers for system integration
The most important offshore energy challenges and drivers for system integration from the perspective of offshore wind sector, offshore gas sector and society concern the following categories: *Policy and regulation, Optimisation for lowest social (system) cost, Geographic limitations, Short and long term grid integration, Public and environmental impacts, Shortage of human capital*.

For the wind energy community, the most important driver is lowering the cost of wind energy. This can be achieved by cost reduction through synergies in construction, operation and maintenance, and the optimal use of space through strategic planning. A jointly developed offshore grid including offshore demand for electricity can lower the costs of the investments required to transport power from windfarms.

For the gas community the most important driver is maintaining a security of supply with as little emissions as possible. This can be achieved through electrification of platforms, which could potentially reduce the GHG emissions, increase energy efficiency lower the operational costs of E&P installations. Infrastructure lifetime extension would mean more time to explore opportunities for the reuse of installations and reservoirs for innovations like system integration, CO_2 storage, power to gas and balancing of the offshore energy grid.

For society at large, the main driver is a transition to clean energy at acceptable cost for society while moving towards a low-carbon system that remains at least as reliable as our current energy system.

Innovation themes
The report identifies four innovation themes with their key aim as follows:

- **Strategic spatial planning** “To balance competing commercial, ecological and societal interests and open opportunities for smart coupling of infrastructure”.
- **Society and Governance** “To understand and mitigate public perception issues, regulatory hurdles and human capital shortages”.
- **Physical network** “To achieve an integrated energy network in the Dutch North Sea.”
- **Health, Safety and Environment ”**To maintain and strengthen the trust that offshore activities can be performed safely and with care for the environment.”

For potential specific topics of research the reader is referred to the full report.

Per project, a thorough analysis of benefits is required concerning all stakeholders. The report identifies the following key performance indicators per project: Economics & Finance, Strategic Spatial Planning, Technology & Innovation, Legislation, Organisation & Stakeholders, Public Engagement, Environmental Performance.

North Sea Energy (NSE) project
The NSE program will run for at least 5 years and members can change their membership status annually. Under a 50% co-funding scheme the program will receive at least € 500,000 of co-financing from TKI Gas and TKI Offshore Wind (WoZ), and organize four general NSE meetings per year for knowledge transfer. There is a 50% discount available for SME. Interested parties can join the offshore energy system integration program to become part of the North Sea Energy Community by contacting TNO: rene.peters@tno.nl.

1 Introduction

System Integration in the Offshore Energy domain: What is there to gain?

The international community faces an important challenge to implement the Paris agreement (UN 2015), substantially reduce CO2 emissions and limit global temperature increase to 1.5°C or lower. A fast transition to a new, low carbon energy system is therefore required. This means shifting towards a larger contribution of renewable energy in the energy mix and improving efficient and responsible use of fossil fuels with reduced carbon emissions. The Dutch Agreement on Energy for Sustainable Growth (“EnergieAkkoord”) aims at realizing a share of 14% of renewable energy in the Netherlands by 2020, increasing towards 16% in 2023.

The North Sea is an area where this energy transition actually materializes. The Netherlands is currently experiencing a strong ramp-up of wind energy construction activities in the North Sea. Parallel, the cessation and decommissioning of current oil and gas production activities will start in the upcoming years as well. Next to these activities, the North Sea hosts several other important (economic) activities, including fishing, sand and shell extraction, shipping, military use, nature reserves and recreational activities. The North Sea area thus has a very important economic and environmental function for the Netherlands. Given the many uses and the limited space available in the Dutch sector of the North Sea, this requires that synergies between different uses have to be found and optimized.

In the current situation, the main players in the offshore energy domain, the oil and gas sector on one hand and the wind energy sector on the other hand, are still working as rather separate worlds. Overall operational efficiency and economics and environmental performance could significantly improve by sharing (part of) their infrastructure(s), offshore services, human capital, products and knowledge. Such an integrated energy system would also be beneficial to optimize the efficiency of the system and make it more robust concerning security of supply as well as more flexible to cope with fluctuations in supply and demand. For that reason, system integration in the offshore energy domain is a must.

The need for an Innovation Program North Sea Energy

To take steps towards a successful and sustainable offshore energy system, it is required to identify and develop shared benefits and drivers across all stakeholders, create a common vision for the future of the North Sea as a source of clean energy, initiate a cross-sector collaborative approach and start joint efforts in tackling the challenges and grasping opportunities ahead.

The first objective of this report is to find common drivers of the stakeholders in the offshore energy domain to establish the common ground for shared innovative actions to facilitate the energy transition, improve efficiencies and create buffers for imbalances.

Secondly, another objective of this report is to sketch the contours of a common vision for the North Sea as a clean energy source for the Netherlands, both in terms of impact that system integration could have on the energy system as well as in terms of outlook towards the year 2030 and beyond with spatial planning for different integrated energy functions in the North Sea area.

The third and final aim is to develop the outline of a broad innovation project on System Integration Offshore Energy. This program will be set up under the umbrella of the Top Consortiums for Knowledge and Innovation for Gas and Offshore Wind and will have connections to other market segments, like the maritime sector and the infrastructure sector, and to new developments for renewable energy, like tidal, wave and blue energy.

The outline will propose innovation themes that are relevant for offshore energy system integration for which a joint effort by stakeholders can tackle challenges and create opportunities in the pre-competitive domain. The innovation program outline will also contain a set of key performance indicators to ensure that research and innovation within the program is transparent, verifiable, relevant, and impactful.

What is the scope of this study?
The report includes the synthesis of current viewpoints on offshore system integration taken from literature and stakeholder discussions. It sets a framework in which innovation actions could be executed to realise an integrated energy system. It describes options or exemplifies opportunities that may arise when innovative efforts are accelerated in the Dutch offshore energy domain. As such, this report should be considered as a discussion or working paper. As a starting point, this report only considers the Dutch part of the North Sea. Logically, in the long term, international connection and integration in the offshore sector is desirable, if not vital.

What will be the next steps?
The next steps encompass the further development of an Innovation Program North Sea Energy and the creation of a community of participating companies (from SME to large companies) and research organisations, which are all active within the offshore domain.

Reading guide
Chapter 2 sketches the needs and societal trends of moving towards a clean and reliable offshore energy system. It discusses the most important offshore energy challenges and drivers for system integration from the perspective of offshore wind sector, offshore oil and gas sector and society.

Chapter 3 provides a vision on how system integration in the offshore energy domain could have an impact on society, environment and economy.

Chapter 4 gives insight into which energy functions in the North Sea (area) could be integrated, which quick-wins are possible towards 2020, as well as a longer-term outlook towards 2030.

Chapter 5 and 6 report on the follow-up of this study. In chapter 5, the outline of the Innovation Project North Sea Energy is explained, discussing innovation themes and key performance indicators. In chapter 6 more detail is presented on the participation conditions, governance structure and the positioning of the project in relation to other existing or emerging initiatives in this domain.
Chapter 7 gives insight into how the stakeholder involvement was organized and what input was gained.

2 Towards a clean and reliable offshore energy system

The Dutch government and society – although not uniquely – is facing a changing energy system which is moving from a centralized and fossil-fuel-dominated energy system to a complex, more variable energy supply system. A transition driven by an increasing urgency which is caused by cumulative concentrations of CO_2 in the atmosphere, decreasing public acceptance of fossil fuels and an increasing awareness of anthropogenic stress on the environment. A transition to move towards a clean, affordable and reliable production of energy. This transition should be realised while making optimal use of the existing energy infrastructure and thereby minimising loss of capital, human capital and public investment.

In order to give direction to this transition, there is a need to find innovative, long-term solutions to meet the world energy demand. Various factors have accelerated the need to re-think the way in which our energy system is organised, including declining fossil fuel reserves and international climate pledges. The push towards a reliable, sustainable energy system has become a priority.

2.1 Motivation for new energy system

The fossil-fuel-dominant energy mix that has been established over the last century will need to change inherent to the imposed targets for reduction in greenhouse gas emissions (see Figure 2-1). The Paris Agreement (UN 2015) seeks to reinforce the ambition to reduce climate change by pursuing efforts to limit the temperature increase to 1.5 degrees Celsius.

These agreements provide focus for a transition to a clean energy system, but do not appear sufficient by themselves to realise the targets (IEA 2015). The so-called Dutch Agreement on Energy for Sustainable Growth, henceforth EnergieAkkoord (SER 2013), aims at 14% of renewable energy by 2020 in the Netherlands, with a further increase towards 16% in 2023. The Netherlands are currently just above 5%. Climate pledges are thus an excellent basis from which to build ambition, but they have not yet been proven to be extensive enough to achieve their climate goals (see Figure 2-1).

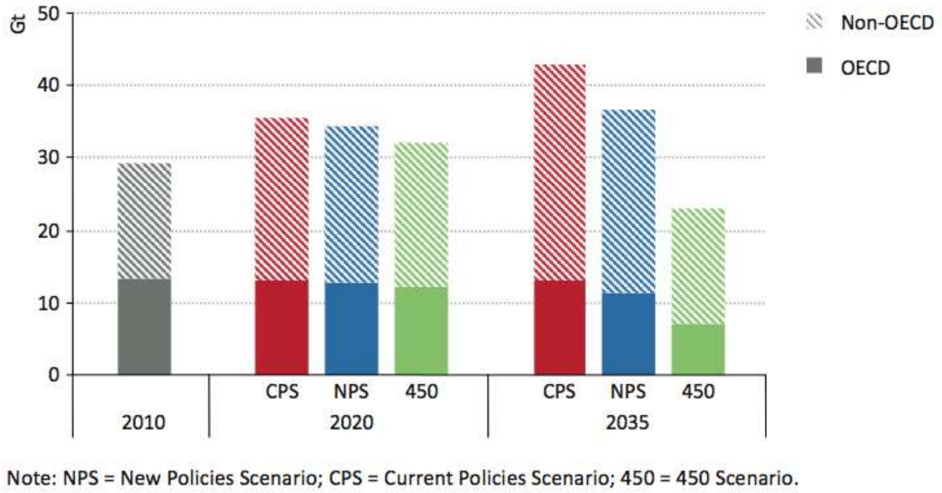


Figure 2-1 Global energy-related CO_2 emissions by scenario (IEA, 2015). The 450 scenario (corresponding to 450 ppm CO_2) sets out an energy pathway consistent with the goal of limiting the global increase in temperature to 2°C [currently adjusted to a 1.5°C limit]. As can be seen, new policies scenarios alone do not enable reaching this goal.

Governmental support (in the form of funds and subsidies) is a way to guide the development of new technologies until these have become sufficiently mature and economically competitive. An example is SDE+ (the subsidy program Stimulation of Sustainable Energy Production) as a feed-in tariff for electricity or heat generated by sustainable energy technologies. It should be noted that even though overall cost of sustainable energy technologies is decreasing, governmental support is often still needed for renewable energy generation.

Close collaboration on an integrated system is essential to have a resilient, reliable and clean energy system which consists of multiple (fluctuating/variable) sources of energy (heat, electricity and various renewable energy carriers) in the future. It is essential to have a well-organised infrastructure and control architecture by virtue of a close collaboration among the stakeholders. This system consists of a complete set of sources, sinks, buffers and back-ups with a focus on a strong decrease in anthropogenic stress on the environment (e.g. a strong decline in atmospheric emissions such as CO_2 and NO_x) and a reliable, guaranteed supply of energy.

The offshore domain of the Dutch territory provides an opportunity for such collaboration, whilst the development of natural gas sources is declining and offshore wind is growing fast. Combining the challenges, opportunities and benefits for all offshore actors in order to accelerate the gains for the society and environment will be the basis for successful system integration of offshore energy.

2.2 Strive towards win-win-win

An energy transition has started in the Netherlands by the increase in sustainable energy supply (notably wind energy) and increased awareness of reduction of energy consumption. This shift in energy sources, energy consumption and energy distribution involves an enormous effort and cooperation between various parties.

To meet the ambitious targets, all energy suppliers, consumers and product developers have to cooperate; system integration is crucial. In order to achieve a successful transition to an integrated (offshore) multimodal energy system, the added value of this transition has to be readily understood and made explicit for all stakeholders. System integration in a complex, multimodal energy system might require win-win-win scenarios to accelerate the sustainable energy transition in which the societal challenges are tackled, the opportunities for offshore wind seized and the challenges for offshore natural gas turned into opportunities.

Three main observations endorse the implementation of system integration in the North Sea (see also Figure 2-2):

1 <u>There is a need and urgency for an accelerated energy transition</u>

This is a need which consists both of a decreasing stress on the environment and the challenge of coping with an increasingly complex multimodal energy mix. An increased awareness of environmental issues and its relation with human factors has created a push from within society to convert to a sustainable energy system. Although the development of a system is expected to be realised in the long term, it requires an immediate focus on ideas and concepts.

2 <u>In the transition there is a need for security of supply at lowest emissions as possible</u>

Considering the current use/consumption of natural gas and the penetration rate of renewables in this market, there is a need for a clear and acknowledged role of all offshore actors in the energy system in the next 25 years. This means that the system should strive to decrease their emissions to the lowest point as possible, but that there will be an explicit right to play for domestic gas to ensure security of supply.

3 <u>To shape the sustainable energy production, strive for cost-effective development of wind energy</u>

Integrating activities in the offshore energy sector provides a basis for a cost-effective OPEX strategy for the post-SDE subsidy era of the offshore wind sector (after 15 years of operation).

This will create opportunities for cost-effective large and far offshore wind farms by close cooperation, optimised operations, maintenance and developments. Smart geographical planning of licensed areas, by linking to other nodes in the network, will optimise the system. In due time, this will include future energy generation types, storage and conversion technologies.

Figure 2-2 System integration offshore energy combines the strengths and challenges from society, offshore wind and offshore gas.

2.3 Drivers for offshore actors

2.3.1 Offshore Wind

With the Agreement on Energy for Sustainable Growth, many Dutch companies have committed themselves to working towards reducing energy consumption and increasing the share of renewable energy in the total Dutch energy production to 14% by 2020 and 16% by 2023.

Offshore wind will contribute the majority of the expansion in renewable energy. An additional 3500 MW of installed offshore wind energy capacity is envisaged by 2023. At the same time, the agreement aims for a levelized cost of energy (LCOE) reduction of 40% with regard to the 2008-price level for wind energy (SER 2013).

This means that the Netherlands is currently experiencing a strong ramp-up of wind energy construction activities in the North Sea. The companies involved are driven by competition to install large windfarm capacity within a relatively short time while lowering costs. From the perspective of the offshore wind sector, system integration offers the potential to mitigate some of the challenges that are currently faced (e.g. public support for wind energy and potential shortages in educated and qualified offshore personnel). A main driver, however, is the need for cost reduction in order to remain competitive; system integration offers chances for the wind sector to reduce both capital and operational expenses. During the planning and construction of a wind farm, the potential conversion of electricity or the use of existing infrastructure could enable improved business cases. Next, synergies in terms of monitoring, inspections and maintenance of the offshore installations and infrastructure arise. Lastly, a robust inclusion of offshore wind parks in the national energy grid is fundamental.

With the construction and development of an increasing number of wind farms, the offshore wind sector faces a challenge to provide sufficient and well trained personnel. According to TKI Wind op Zee, there were ~2150 jobs in the offshore wind sector in 2014 (see Figure 2-3, (de Jager et al. 2014)). This is a growth of 12%

compared to the prior year. The expectation is that this will grow towards 10,000 jobs in 2020.

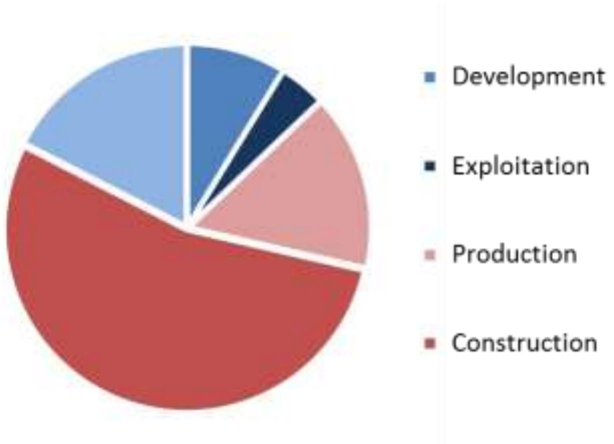


Figure 2-3 Jobs per phase of the offshore wind value chain, according to TKI Wind op Zee (website www.tki-windopzee.nl, visited Jun 2016).

Within the Netherlands, the companies and the knowledge they have built have the opportunity to play a key role in developing, operating and maintaining offshore windfarms. The Netherlands already has a strong position based on the knowledge and experience gained in the offshore natural gas sector and in the dredging and maritime industry. If optimal use is made of existing and new synergies – both technical and best practices – by a strengthened collaboration between offshore wind and offshore gas, it would be possible to develop offshore system integration as an international growth business for the Netherlands.

In the long term (from 2020 to 2030 and beyond), a strategic cooperation with other sectors in the North Sea is essential because:

1. Space is limited. The wind energy sector is competing for space with other sectors such as the fishing industry, shipping lanes, areas restricted for military use, nature reserves and the oil and gas industry. Long-term strategic planning therefore is crucial to support a safe and efficient use of the (Dutch) North Sea.
2. The joint development of an offshore energy grid could contribute to the reduction of the levelized cost of energy of offshore wind farms, since up to 15% of the LCOE originates from the electrical infrastructure, like transformer stations and export cables (Westwood 2010; IRENA 2012).
3. A balanced supply-and-demand network at sea could offer optimization capabilities and reduce transport losses. Such a network not only involves new regulation, but also stimulates actual demand for electrical energy offshore, e.g. through the electrification of oil and gas infrastructure. These factors jointly contribute to making remote and large offshore wind energy parks both cost competitive with other renewable energy sources and an attractive business case by itself. In addition, as offshore wind infrastructure expands towards the boundaries of the Dutch North Sea, a vision on international cooperation for the development of interconnected, international offshore wind farms is required.

2.3.2 Offshore Gas

During the mid-1970s, the development of natural gas moved for the first time offshore in The Netherlands. Since then, more than 270 gas fields have been explored and developed with more than 850 wells from which gas is produced. In 2015 almost 150 gas fields were producing from about 400 wells.

Although gas production from offshore gas fields has been declining since 2008 (see Figure 2-4), the Dutch continental shelf still holds a vast supply of natural gas resources (source: focus on Dutch gas 2016 – EBN). Key to the development of these resources is the availability of the offshore infrastructure to transport the gas to shore. The existing offshore infrastructure is developed at the time when still large fields could be found and developed. These large fields required large new infrastructure and could carry the related investments. The existing offshore infrastructure contains over 150 platforms and three main trunk lines (see Figure 2-5). The remaining gas resources require this infrastructure in order to be developed in an economically feasible manner. However in case the costs of maintenance and operation of the infrastructure is foreseen to be higher than the benefits of to be developed fields than the infrastructure will be gradually but definitely decommissioned. The latter can be accelerated by the current low gas price environment. The decommissioning of an installation not only has impact on the surrounding fields but also on the economics of the connected installations as the same costs have to be carried by less volume. This can result in a domino effect (reference: https://www.gov.uk/government/publications/call-to-action-the-oil-and-gas-authority-commission-2015, p11).

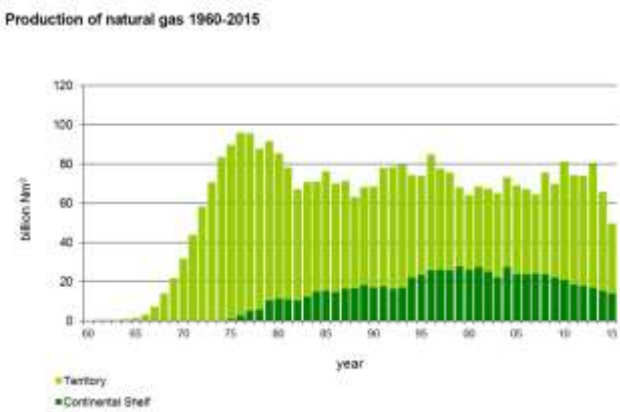


Figure 2-4 Production of Dutch gas fields (Ministerie van Economische Zaken 2016).

Based on a scenario of the production of existing and to be developed fields the lifetime of offshore installations is estimated as shown in Figure 2-5. As can be seen some areas can still offer long term opportunities for gas production and therefore also for system integration.

To produce a gas field economically, gas compression is necessary on the offshore production platforms. The energy used for the compression is generated on the offshore production platforms using a relative small amount of the gas produced. Figure 2-5 shows a potential scenario regarding the energy consumption of production platforms until 2050. This energy could potentially be supplied by nearby offshore wind generation, which could potentially reduce the GHG emissions, increase energy efficiency, lower the costs of the investments required to transport power from windfarms and lower the operational costs of E&P installations. The latter could extend the effective utilization of the E&P installations, the extension of production of offshore domestic gas and cause related societal benefits as security of supply and State profits. Finally extension of the lifetime of the infrastructure brings more time to explore opportunities for the reuse of installations and reservoirs for innovations like system integration, CO_2 storage, power to gas and balancing of the offshore energy grid.

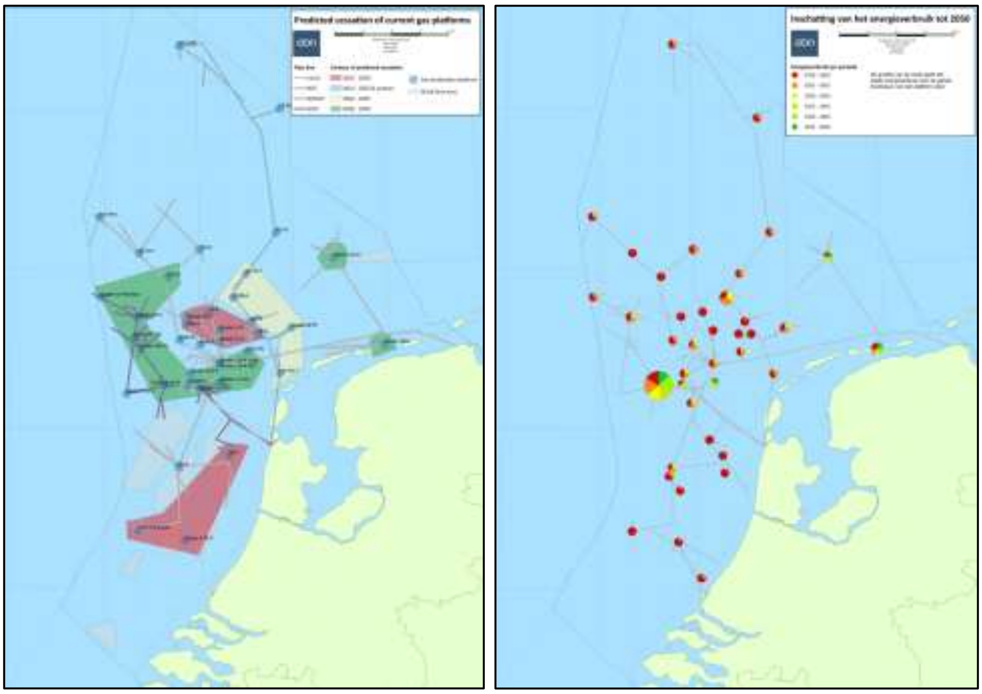


Figure 2-5 Potential scenario regarding cessation of current gas platforms (left) and potential power consumption of platforms until 2050 (right) (EBN – InfraSim 2016, for detailed map see Appendix 1)).

For illustration purpose: Based on the assumption that ten of the forty gas production platforms, which consume the most energy through its life cycle, are possible to connect to a wind farm than the above scenario reveals an average electricity consumption during the coming decade of up to 1.4 TWh annually. This represents a wind farm with a 40% capacity factor of 400MW and an average CO_2 reduction of the offshore production platforms of up to 1 million ton CO_2 each year.

From the industry itself, there is also the drive to improve. This is for example captured in the MJA3: a multi-year agreement on energy efficiency between government and industry. The MJA3 runs from 2001 till 2020 and aims at an efficiency improvement of 30% with respect to 2005 (see: http://www.e-mjv.nl/onderwerpen/mja/ (Dutch only)). This continuous effort by the gas sector to reduce emissions is required to ensure a transition that is as clean as possible.

Emissions have been slightly increasing over the past couple of years due to factors like the decrease in production of gas from the Groningen gas field and the fact that depleting gas reservoirs require additional compression. (Figure 2-6; Sustainability report 2016, EBN). Nonetheless Dutch domestically produced natural gas has a far lower carbon footprint than natural gas imported from other countries. (reference:

https://www.ebn.nl/wp-content/uploads/2014/11/ebn_focus_on_dutch_oil_gas_2014.pdf, page 14 and 15)

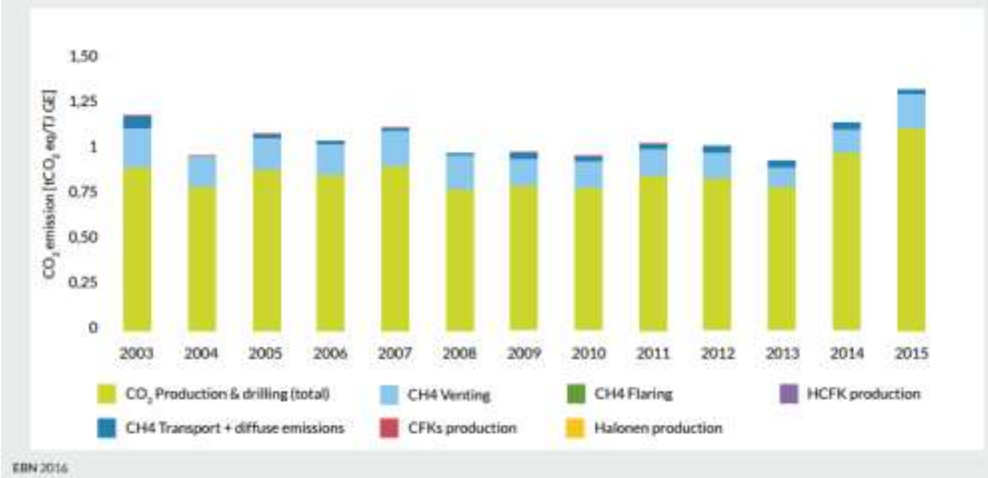


Figure 2-6 Specific greenhouse gas (CO2 eq.) footprint for average NL gas (EBN 2016).

Based on the above potential system integration scenario one may conclude that the CO_2 footprint of domestically produced gas is comparatively low, but can be further decreased through system integration.

2.3.3 *Society*

The international society faces an important challenge to execute the Paris agreement (UN 2015) and substantially reduce CO_2 emissions to limit global temperature increase. An additional driver to reduce CO_2 emissions in the Netherlands in the short term comes from the so-called Urgenda case (Rechtbank Den Haag 2015). The District court has ruled that the State has to ensure that the Dutch CO_2 emissions in the year 2020 will be at least 25% lower than those in 1990.

An important driver for system integration in the Dutch North Sea is to ensure that this transition is achieved at acceptable cost for society while moving towards a low-carbon system that remains as reliable as our current energy system. Costs and benefits of this transition are proportionally distributed across the actors. Society should be the monitor of this principle.

System integration can increase the return on investment as it provides options to reuse existing infrastructure or share cost for new infrastructure. For example, existing infrastructure (platforms, cables, pipelines) and (near) empty oil and gas reservoirs can serve new purposes, such as renewable offshore energy production, CO_2 storage, energy storage or as artificial sanctuary for maritime ecosystems. This can be done efficiently, provided that offshore structures are equipped with sustainable infrastructure. For example, in case an existing platform is used for an innovative application, although limited, generation is still required. So the electrification of platforms is the next move to drastically increase the efficiency and decrease the emission of carbon dioxide.

Society has an important role to play in offshore system integration. Societal benefits, including non-monetary benefits for the environment and long-term (economic) benefits are key drivers for societal actors (government, public, NGO's) to participate in system integration. It is the role of society to ensure that these elements are anchored in the decision-making processes.

2.3.4 Summary of drivers

The opportunities for system integration for offshore energy are shaped by combining the operations of two offshore actors, where three or more actors would be preferred. A summary of the drivers from the three main actors in the offshore energy domain – offshore wind, offshore gas and society – is given. The opportunities for system integration for offshore energy may be further shaped by combining these with drivers of the other actors, such as fishery, shipping, defence, etc.

The drivers can be categorized in 6 different topics:

1. Policy and regulation
2. Need for cost reduction/optimisation for lowest social (system) cost
3. Geographic limitations which stress the importance for spatial planning
4. Need for grid integration, both in the short and long term
5. Public or environmental impacts
6. The shortage of human capital

	OFFSHORE WIND	SOCIETY	OFFSHORE NATURAL GAS
POLICY	– Implementation of the target defined in the EnergieAkkoord (3,5 GW in 2023)	– Accelerate the transition to reach the climate goals (max. 1.5°C climatic temperature increase)	– Reduction of emissions which meet the societal challenges and regulations (BEMS) – ETS CO_2 trading influences the reduction of CO_2 emissions – With the MJA3 pact the gas sector committed themselves to increase the energy efficiency with 30% by 2020 in comparison to the 2005 levels.
COST REDUCTION	– Reduction of costs of 40% in 2020 (w.r.t. level of cost in 2008) – Far-offshore cost competitive with other sources of sustainable energy and commercially attractive	– Optimalization of the energy transition from the perspective of emissions, costs and benefits (e.g. Domestic gas is cleaner than imported gas)	– Reduction of the operational (OPEX) and abandonment costs (ABEX)
SPATIAL PLANNING	– Strategic Spatial planning which goes hand in hand with developments in the North Sea domain (e.g. phasing out of O&G, fishery, transport, etc.) – Save and effective spatial planning in combination with other functions at the North Sea – Large scale offshore wind farms which are developed in an international vision and collaboration	– Shared vision on a robust supply of energy – Fair distribution of burdens and benefits for all offshore actors and stakeholders – Upfront strategic planned positioning of offshore structures and operations to have a smart and effective organization with optimized revenues	– Smart combination of functions provides opportunities in strategic spatial planning – Development in line with the international planning and development to upscale the North Sea energy planning across the Dutch border
GRID INTEGRATION	– Robust implementation of offshore wind farms in a (inter-) national grid	– Control over the implementation of an (inter-) national offshore network – Opening of opportunities for other possible sources (sustainable energy, bio-materials, etc.)	– Responsible and sustainable realization of supply for (increasing) energy demand (e.g. increasing compression at last phase of production) – Offer opportunities for balancing and storage – Reliable energy supply – Reduction of OPEX due to reduction of maintenance operational costs – Future offshore electricity supply point for new offshore activities.
ENVIRON-MENTAL IMPACT	– Public support for offshore wind farms	– Increase of biodiversity – Decrease impact on the environment (sea and atmosphere)	– Limiting the impact on the environment: scale of operations, activities, weight, etc. – Biodiversity at current structures.
HUMAN CAPITAL	– Sufficient and well-trained personnel to meet the increasing demand	– Increase of employment – Preserve jobs and expertise – Training and education locations	– Sufficient qualified personnel; both now and in the future – Workforce which is employable for both offshore wind and gas

Figure 2-7 Summary of the drivers, organised within 6 different topics.

3 Vision for North Sea Energy

When the key drivers of offshore wind, offshore gas and society are aligned in an integrated system, the envisioned result will be a clean, resilient and reliable source of offshore energy for the Netherlands

Combining the key drivers from Offshore Wind and Offshore Natural Gas and striving towards contributions which benefit the society as a whole to accelerate the sustainable energy transition.

Synergies through system integration in the offshore energy domain could:

- **Reduce GHG emissions** to the atmosphere to – virtually – zero through electrification of platforms,
- **Reduce the costs of wind farms** (and grids) by combining maintenance staff, connecting to other structures in the North Sea and decreasing installation and transportation distances,
- **Provide a future infrastructure** for far offshore wind farms,
- **Increase biodiversity** in the North Sea by lowering the environmental impact and creating new biotopes,
- **Maximize economic revenues of subsurface natural gas resources** by smart development within the window of opportunity and longer tail end production (e.g. through gas to power at lower gas pressures),

- **Maintain a strong workforce for offshore operations** by integrating activities and requirements from the experienced offshore natural gas workforce with the potentially understaffed offshore wind workforce,
- **Minimize the negative externalities of a changing energy system**, e.g. increasing public participation and guaranteeing energy supply levels
- **Provide gas operators a future license to operate**, by, for example, reducing OPEX and ABEX (abandonment costs),
- **Provide energy storage and balancing options** (offshore UGS, P2G, CAES, H2) for a resilient and robust energy grid,
- **Providing offshore feed in locations for future energy generation options** (off-shore algae, tidal, wave, non-platform wind, etc.),
- **Optimise the implementation of innovative technologies**, e.g. offshore (or subsea) Wi-Fi, the use of robotics and drones and unmanned, autonomous ships.

4 North Sea Energy

There is a demonstrated profit and urgency for an accelerated energy transition, and the main actors in this field could benefit from system integration. This process can be accelerated by a joint search for synergy and congruency (win-win situations) in future and existing infrastructures. System integration offers opportunities for offshore wind, offshore gas, and society, as mentioned in the previous chapter.

4.1 Potential for system integration

4.1.1 The first step towards 2020

In the next years, communication between the stakeholders will be key: a perspective shift is needed, from individual optimisation of limited use cases towards a common awareness of potential synergies that optimise the North Sea energy region as a whole. Short-term solutions that create a lock-in effect are to be avoided.

Electrification of platforms is seen as the prime example for step one towards 2020. This has the potential to contribute to reduction of emissions . Lowering the emission of platforms can be achieved by expensive upgrades while , however, choosing to electrify the same platforms might require comparable initial investments yet result in lower future emissions and costs. Therefore, situations like this require a joint analysis from all stakeholders, including the governing bodies to speed up developments in this field.

However, to ensure a positive outlook towards 2030 and beyond, the development of new ideas and concepts that enable system integration (e.g. offshore conversion of synthetic energy carriers and storage practices like CO_2 and geothermal energy storage) needs to be accelerated from today on.

4.1.2 Outlook towards 2030 and beyond

4.1.2.1 Target areas for optimal impact of system integration

A common vision amongst stakeholders on the possibilities and limitations for offshore system integration is key in creating a foundation for progress towards such an integrated energy system. In several workshops, input from stakeholders was gathered to create a potential view of how different energy functions could be integrated in the North Sea in the year 2030. (see Figure 4-1). One should not underestimate the complexity of setting up detailed plans for system integration due the large variety of possible functions and large amount of scenarios. However, stakeholders from different backgrounds see a lot of opportunities for synergy between different functions in the North Sea.

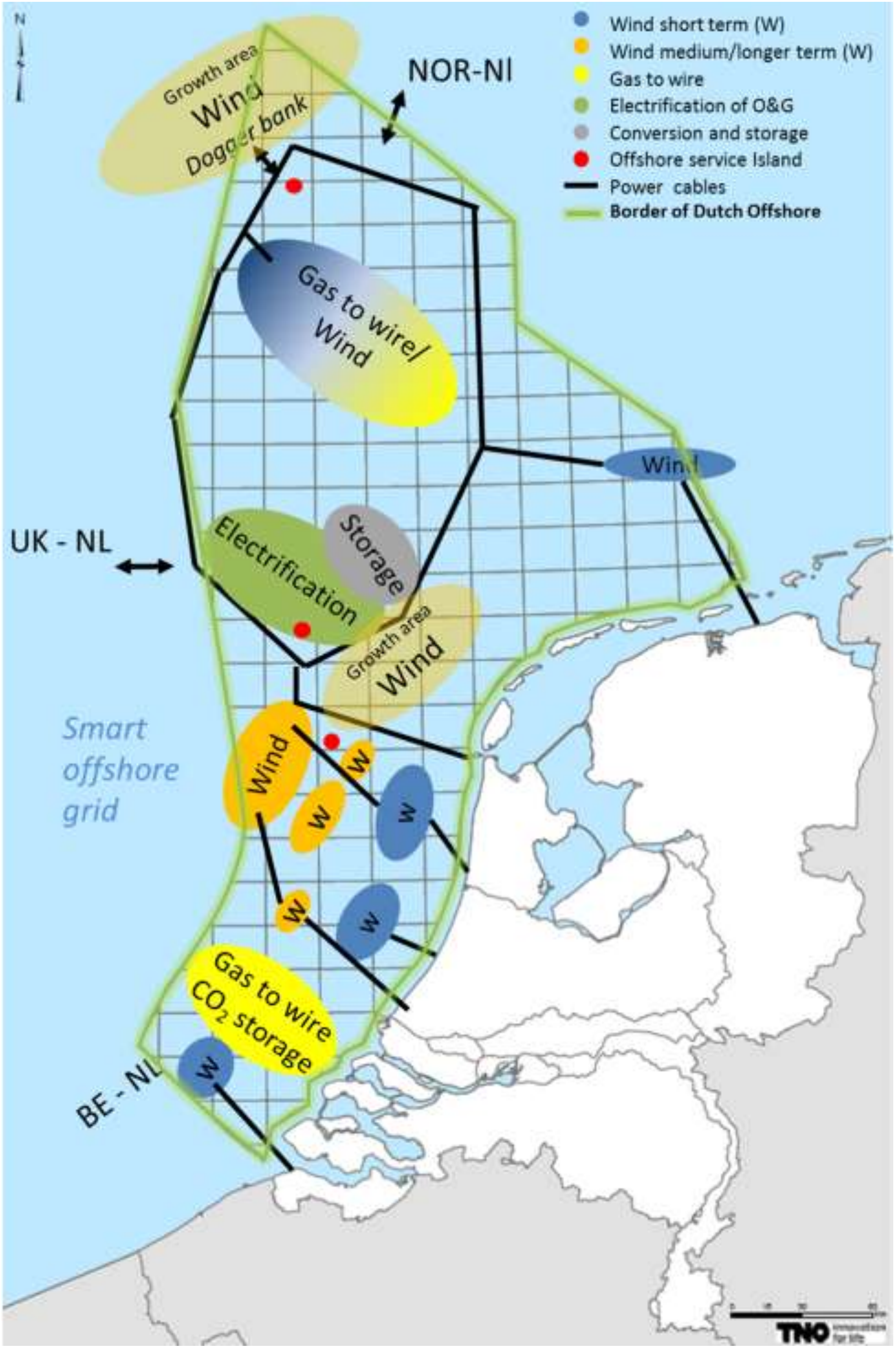


Figure 4-1 An offshore system integration concept for 2030+, developed during stakeholder workshops.

Offshore areas designated for wind energy can serve as a stepping stone for system integration. Examples of interesting target locations are the Gemini windfarm (North of Groningen) and the western part of the North Sea (orange coloured areas in Figure 4-1), where new wind capacity is likely to be implemented before 2030. These regions create an opportunity to establish connections between

offshore gas infrastructure and offshore windfarms. Even more as offshore gas production platforms in that area have a need for (electrical) energy.
This idea of system integration could be further extended to other parts of the Dutch part of the North Sea. This may also improve possibilities for international grid interconnection, for example with Norway, Belgium, the United Kingdom, Germany and Denmark.

Such a future would offer several opportunities:
- Making more efficient use of energy infrastructure and with lower transport cost of electricity to unlock the far offshore energy potential and lower grid connection costs.
- Offering flexibility services to the onshore as peak supply from renewable energy production could be shaved by offshore energy supply and demand, but also by energy storage technologies that could be deployed offshore.
- International cooperation on developing large windfarms or other large scale renewable energy technologies offering maximum potential for economies of scale and the returns of infrastructure.
- Lower operational costs through combined operation and maintenance infrastructure (e.g. offshore service islands), vessels and processes (see 3.3.2.).
- Increased availability of skilled personnel through integration of education and training programmes for different sectors.
- Storage and buffering to make the system robust, reduce losses and stabilize price development.

4.1.2.2 Flexibility of offshore energy

Due to the increasing intended contribution of renewable energy sources to the energy mix, offshore energy needs to be flexible enough to compensate for cover for fluctuations in energy supply. System integration can accelerate this flexibility. The offshore sector can offer different trends or services that are foreseen to play a role in offshore system integration towards 2030 :
- Grid (discussed above)
- Supply
- Demand
- Storage
- Conversion of synthetic energy carriers

When combined properly, these characteristics of the energy system can result in a high degree of flexibility of the energy system such that it allows integration of renewable energy sources.

Energy supply
For energy supply, several new technologies can be considered:

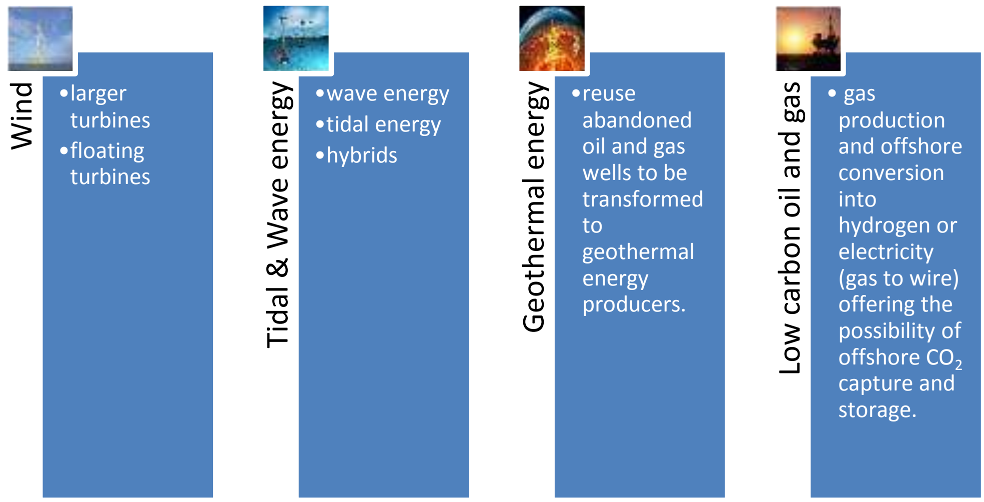


Figure 4-2 Inventory based on feedback received from workshops

Energy demand
The offshore energy demand can provide and eventually increase flexibility services to the whole integrated energy system. For example, the offshore gas sector could peak shave the characteristic fluctuations in energy supplied by offshore wind farms.

The current demand (peak) for compression and operations could be expanded if additional conversion and storage technologies were developed and implemented offshore. Examples are the conversion of electricity to synthetic natural gas (power to gas: also including offshore LNG production and loading facilities), the conversion of electricity to hydrogen and mixing with natural gas, and even power to heat.

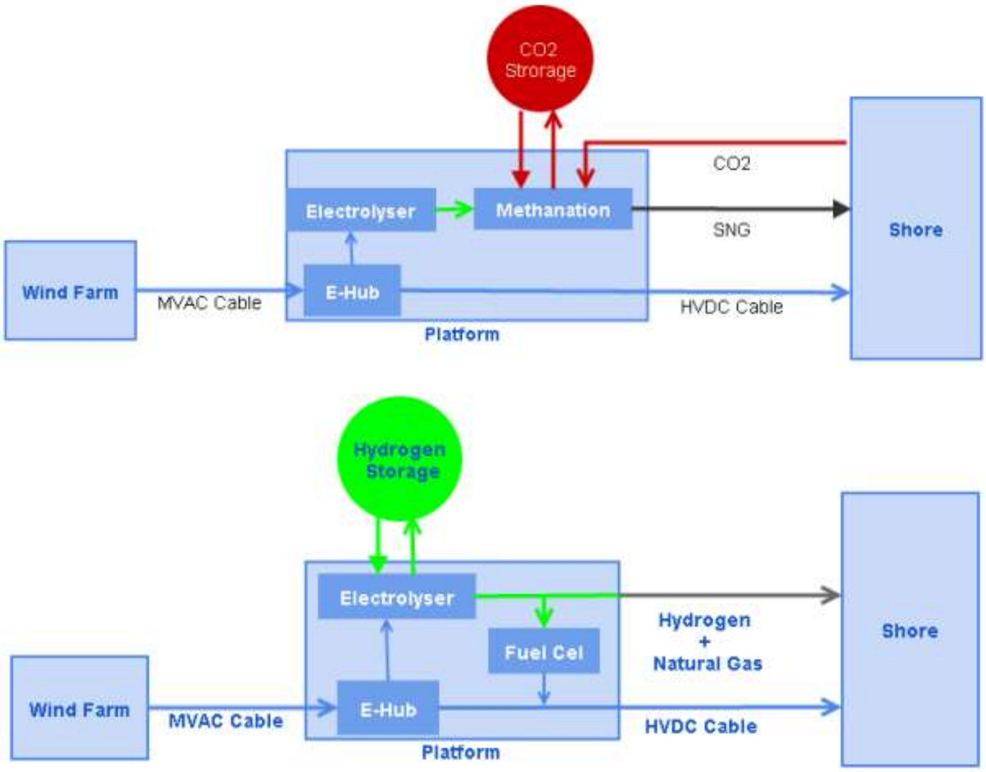


Figure 4-3 Power to gas options offshore. Source: (Jepma et al. 2015)

Storage

Both the storage of energy and CO_2 are considered to be important services that could be delivered by the North Sea region. Studies have been performed on the business case of various energy conversion and storage technologies linked with offshore wind production, e.g. power to gas using hydrogen and/or CO_2 storage (Jepma et al. 2015). Furthermore, electricity could be stored offshore in the form of electricity or other carriers.

Gas can be stored on offshore platforms at the small scale or in depleted gas fields or aquifers in the subsurface at the large scale. Depleted gas fields and offshore aquifers are also potentially suitable for storage of CO_2, either for buffering to provide for a source of CO_2 for SNG production or for long-term CO_2 storage. The latter offers CO_2 reduction opportunities for the onshore carbon-intensive industries and electricity generation in the Netherlands and neighboring countries. These storage options offer the potential for reusing existing assets (gas reservoirs, gas infrastructure) and lower system cost.

Offshore conversion of synthetic energy carriers

The offshore options to store CO_2 and availability of (surplus) electricity created the opportunities to produce synthetic energy carriers next to SNG (short for Substitute (or Synthetic) Natural Gas). These carriers could replace conventional energy carriers by synthesis of commodities and fuels with the use of electricity as the primary energy source (ECN & TNO 2016). The upside of this conversion is that it is possible to supplement the decreasing load of natural gas in the existing pipeline infrastructure and to make optimal use of the pipeline capacity. This prevents the decommissioning of this asset and – at least – postpones a possible lock-in.

Too little use of the gas pipeline will have a negative effect on the allowed capacity of merged hydrogen (in the case of a standstill, the gas will concentrate in the top parts of the pipeline) or it will lead to a negative business case, after which decommissioning will follow. Since the majority of the gas pipelines reach the shore in the northern parts of the Netherlands, this part of the network is sensitive to these developments. When these connections are gone, it will close opportunities for a vast majority of the northern gas activities, preventing system integration options.

Another big question for the development of the offshore energy landscape is whether conversion – as buffer functionality at times of electricity overproduction – will take place offshore or on land. In case of conversion on land, there will be a stronger emphasis on electrification offshore. Conversion offshore can prolong the use of offshore infrastructure and open the possibility for SNG applications which extend beyond the platforms, e.g. offshore SNG/LNG gas stations for shipping.

Benefits of the Energy Transition
For all cases and scenarios, it is worthwhile to get insight in the monetary, environmental and social benefits. Only this will give the framework and tools for strategic decisions. In Box 2 below, you can read more about our view on the quantification of benefits.

The economic value of the transition is underlined in the report on costs and opportunities of the energy transition by McKinsey & Company (Speelman et al. 2016), even though they do not account for the positive impact of innovation, research and development on the economy and the changes in level of investments across particular sectors. They see that the energy transition will lead to a decrease of imported gas (gradually from 67% in 2016 to eventually less than 50%). They also conclude that energy prices will drop and result in a net benefit of 8 billion Euro (increase GDP by ~1%). Aside from monetary benefits, the transition will lead to 45,000 more jobs in the short to medium term. Of course, these numbers account for the whole of the Netherlands, but the contribution of the offshore domain can be significant.

BOX 2. Quantification of benefits

An integrated approach is not only a technical challenge; it also complicates interactions in the existing value web, and most likely introduces new players in this web. Therefore it is suggested not only to investigate the costs and benefits for the platform operator, but to widen the scope to entail this complete value web. By investigating the relations between all players, a thorough assessment of the value of SIOE is possible.

For instance, electrification of platforms does not necessarily imply that more oil and gas is mined, rather more oil and gas is transferred to shore for utilization in more efficient processes. On the other hand, this unfortunately results in a reduced amount of green (wind) energy that is transferred to shore for sale and use. This is an interesting balance that requires a more in-depth investigation. It is currently unclear whether the reduction of inefficient gas use on the platform compensates for the reduction of available green energy on shore regarding greenhouse emissions. Apart from the ecological effects, there is also the matter of economics, which again is very much a question for the complete value web. The platform operator will be able to sell more gas but will need to buy electricity from a wind farm operator. Additionally, the transport costs in total could be lower because it is more efficient to transport gas than electricity. For the wind farm operator and the network operator (Tennet), there is also an economical decision to be made: what are the costs required to connect the platform to the wind farm, what should be the price for the electricity for the gas platform and will this offset the lost revenues from selling the electricity at shore?

In order to quantify the impact of SIOE, the approach below is suggested. It would be beneficial to perform this assessment in close cooperation with a party like EBN, combined with good representation from the offshore stakeholder network.

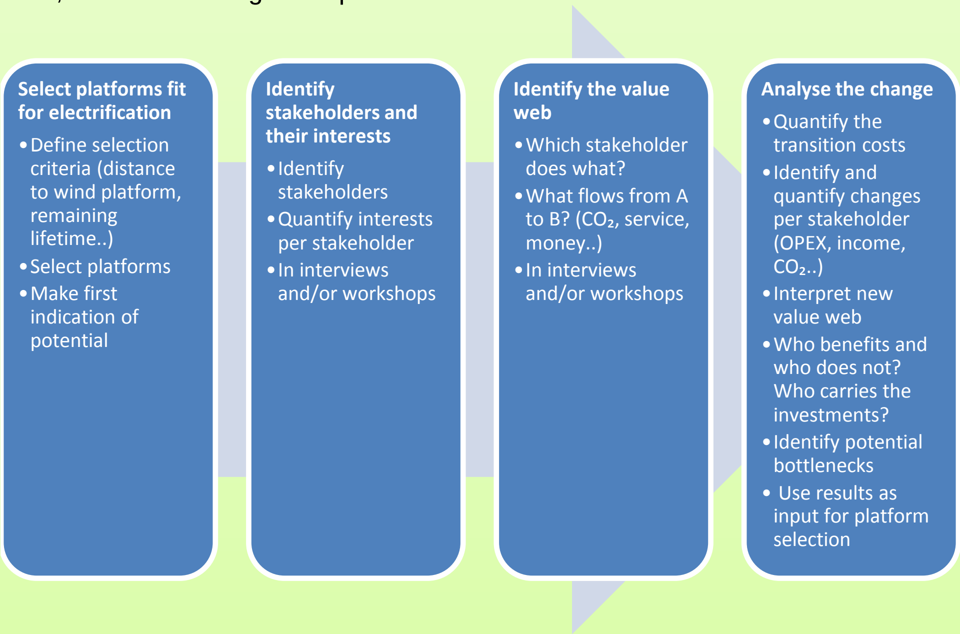


Figure 4-4. Suggested approach to quantify the impact of SIOE.

4.1.2.3 Strategic spatial planning

The international aspect of system integration and the role of societal actors therein is also of high relevance. In June of 2016 several Northwest European countries (Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway and Sweden) signed a declaration for more intensive energy cooperation between them (EU Energy Council 2016). Alignment of spatial planning, electricity grids, offshore infrastructure needs and sharing best practices are key drivers for cooperation across these countries.

Since this study focusses on the first outlook for opportunities in the near future and the paving the way for probable benefits and strategic positioning in the longer term for the Dutch part of the offshore, the international context is not part of this analysis. But the importance of developing strategies in close collaboration with the neighbouring countries is crucial to make the implementation resilient and robust.

In investigating opportunities for the Dutch offshore, the current offshore spatial planning was taken as a baseline (see also the map from RDW: Figure 4-5) and new ideas and plans were added for the various activities. Figure 4-6 shows the maps which are used. High resolution images of these maps are enclosed in appendix 1.

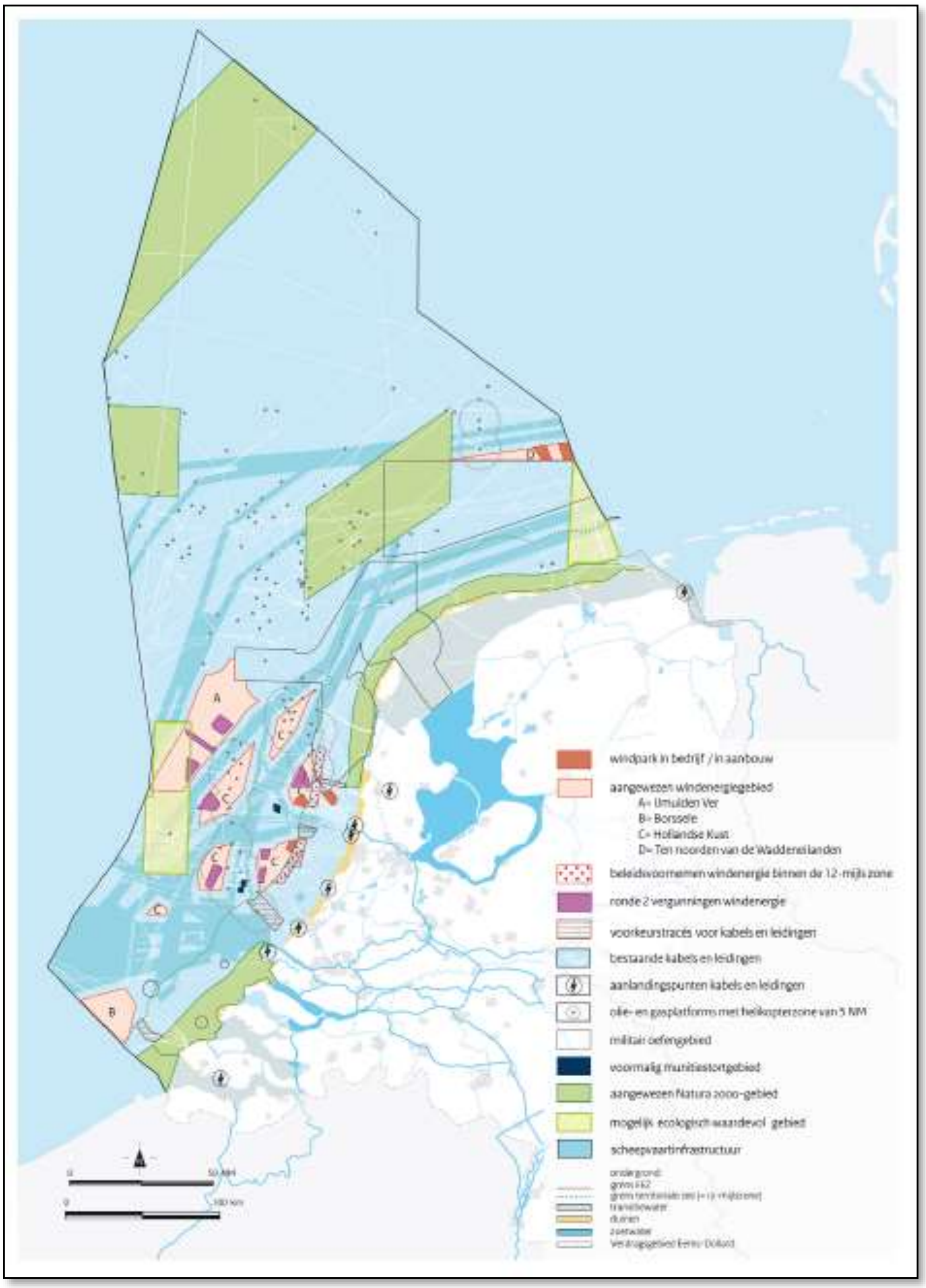


Figure 4-5 Spatial planning at the North Sea: the map shows the activities and reserved areas (RDW, 2015).

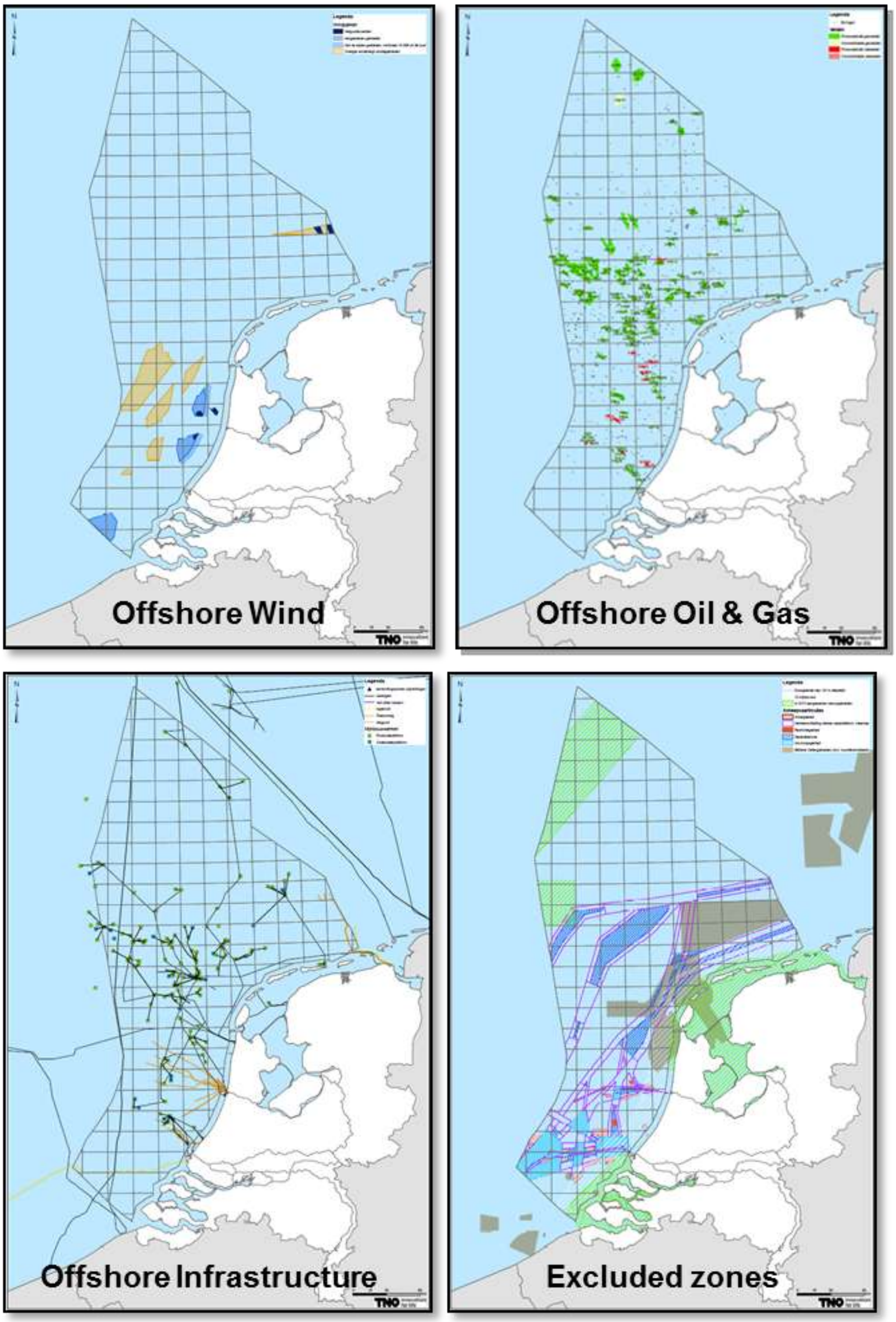


Figure 4-6 Examples of current and planned use functions for the North Sea (for high resolution versions of these maps, please refer to the appendix).

4.2 Key elements for the system integration process

To take steps towards a successful and sustainable offshore energy system, we require shared benefits, a common vision, a cross-sector collaborative approach and a joint effort in tackling the challenges ahead. All with the shared ambition to create and accelerate a transition as clean as possible which is robust, cost efficient and beneficial for the stakeholders involved.

To reach the proposed ambition/target, multiple topics arise which require attention. These topics will have to be tackled for the offshore sector as a whole to guide the ambition and open the way for the realization of the ambition. This can occur within the sector by jointly share costs and risks, but also from the society, by providing authorities with the input they require. A shared innovative effort is needed to address these challenges because a technology needs to be developed or financial models need to be analysed and reshaped, and this process requires a multi-disciplinary and broad scope as well as a long-term approach.

Information that can help to accelerate the sustainable energy transition needs to be shared among all stakeholders; doing so will not only integrate operational aspects, but will help to unify the sector as a whole.

Requirements on innovative proposals have to be defined to ensure that all joint activities are aimed to benefit the system as a whole.

A crucial part of a system is also how it will interact with, or affect its surroundings. For example, the high amount of power generated by offshore wind farms will have an effect on the onshore power transport and distribution network. The current onshore power transport and distribution systems are probably not suited for the high amount of generated power. New investments of the onshore power supply are necessary to avoid overcapacity of the offshore wind farms.

The optimum solution is to be determined when the energy consumption per source (e.g. platforms, offshore wind parks, etc.) is known. A scenario analysis of the energy demand during the energy transition is necessary to be able to make plans, in such a way that the integrated system can be tuned to this energy demand.

How all these key elements and complexities can be enabled, defined and formalized for a successful system integration of offshore energy is described in chapter 5.

5 Innovation Program North Sea Energy

As set out in chapter 1, a successful system integration for offshore energy consists of three elements. The innovation themes (5.1) to which a joint effort can tackle challenges and open opportunities, especially those in the pre-competitive domain, the topics of common interest (5.2) which benefit the offshore sector as a whole and a set of key performance indicators (5.3) to ensure that developments impact (or consider the impact on) the system as a whole. The sections below describe the topics in more detail.

5.1 Innovation Themes

From the analysis of the drivers for offshore wind, society and offshore natural gas (see chapter 2.3), combined with an inventory of the main challenges and opportunities (see chapter 4.1), the required innovation can be categorized in four themes (see Figure 5-1): strategic spatial planning (chapter 5.1.1), society and governance (chapter 5.1.2), physical networks (chapter 5.1.3) and health, safety and environment (chapter 5.1.4). Please find below a description of the topics and aims within these innovation themes:

Figure 5-1 The four innovation themes which are the building blocks for system integration offshore energy. Please note that buffering and conversion are part of a reliable physical network.

5.1.1 Strategic Spatial Planning

The North Sea is spatially dominated by either offshore activities or restricted areas. A large variety of offshore resources have their claim on the North Sea domain, like fisheries, offshore wind and offshore gas. Large shipping routes cross through the area and there is always a delicate balance with restricted areas for environmental protection or safety (defence area).

By use of a progressive and strategic spatial planning, this balance between competing commercial and also ecological and societal interests can be optimised and can even open opportunities for new, sustainable actors in the offshore energy system. By smart coupling of (infra-) structure, uses and knowledge, the offshore energy system can benefit from each other.

Also in the longer term, innovation creates a larger degree of freedom within a system which is spatially under pressure. By extending e.g. the offshore data network (offshore and subsea Wi-Fi), the spatial planning of the North Sea can become more effective. For example with dedicated developments for smart offshore mobility, we can move to adaptive shipping routes which are tailored to currents, water depths as well as migration of fish or other sea life or even couple maintenance of wind turbines to the migration of birds.

5.1.2 Society and Governance

Society and governance related to offshore energy systems provide highly relevant drivers and barriers of offshore energy system integration. Experience with public perception challenges for large-scale energy solutions (e.g. CCS and wind energy) suggest that careful planning of communication/engagement actions is needed to facilitate deployment. Lessons learned indicate that engagement of public actors is needed from a consortium of stakeholders; single source information provision on these subjects is inadvisable. The message should further contain balanced and understandable information about positive and negative aspects of offshore energy production and system integration. Concerns raised by public actors or other relevant actors should be taken into account, preferably early in the development process of offshore system integration.

A strong pillar in the society and governance innovation theme is the human capital agenda. IRO reports that the offshore sector currently employs 44,000 people. The challenge is the current and foreseen mismatch in demand and supply for human capital, with opposite trends for offshore wind and offshore hydrocarbon production. As described in chapter 2.3.1, the demand for human capital in all parts of the offshore wind value chain is growing fast towards 10,000 jobs in 2020. This is not a challenge four years from now, but should require smart solutions for training or re-design of the work in the short term. In the offshore oil and gas sector, another trend is expected. Because of declining offshore activity over the next decades, the demand for human capital will decrease. Creating better insight into the human capital agenda for the offshore sector and finding smart solutions to curb the challenges into an opportunity will be an essential part of the Innovation Programme.

Next to the potential advantages of deploying a physical infrastructure for energy transport and connection, the stakeholders also highlighted other benefits.

There could be important synergy in the operation and maintenance programmes for the offshore infrastructure. The skillset of offshore personnel could be developed in such a way that it can be used in several sectors by the year 2030. Operation and maintenance programmes could be merged or tuned and operation and maintenance vessels could serve multiple sectors lowering the overall cost. It was mentioned that dedicated offshore service islands could be realised, lowering the cost of offshore construction, operation and abandonment.

The employment perspective is of huge interest for the Dutch society, just as the potential to create additional added value for the Dutch economy. Developing smart solutions for system integration for offshore energy can create valuable knowledge and technological assets which can be exported and create additional value to the Dutch offshore sector. Innovation efforts should not solely focus on small scale implementations, but can also deal with the topic of upscaling, international design in collaboration with neighbouring countries and international standardization of requirements. In addition, a good understanding is needed of the commercial potential and key economic benefit of offshore energy system integration options.

The Dutch North Sea is a hotbed of economic activity and thus subject to a widely scoped regulatory framework , including some important laws governing use of the Dutch North Sea: the Water Act (Waterwet), the Shipping Traffic Act (Scheepvaartverkeerwet), EU Common Fisheries Policy (Gemeenschappelijk Visserijbeleid), the Mining Act (Mijnbouwet), the Flora and Fauna Act (Flora- en faunawet), The Nature Conservation Act (Natuurbeschermingswet) and the Earth Removal Act (Ontgrondingenwet) (Dutch North Sea Office, 2016).

The regulatory framework as it exists today provides important drivers and barriers for system integration. Some examples are listed here:

- Renewable energy subsidy is a very important driver for offshore renewable energy deployment.
- The offshore O&G sector faces, for example, strengthened environmental regulation to improve environmental performance.
- Spatial reservation for offshore installations provides barriers for spatial synergies (i.e. obstacle-free zones for helicopter landing).

It is thus of high value to map the regulatory framework to better understand where it provides barriers and drivers for system integration.

5.1.3 *Physical Network*

To achieve an integrated energy network in the Dutch North Sea, various technological challenges will have to be addressed. Among the potential topics for research are the following:

- Electrification of offshore gas platforms.
- Storage and energy transformation options (buffering and storage including potential use of empty gas fields, creation of hydrogen as an additive to methane gas, creation and transport of different energy forms such as electricity, LNG, NH_4, H_2).
- Re-use and retrofitting of existing network infrastructure, e.g., using the hundreds of kilometers of pipeline in the Dutch North Sea for data/electricity cables.
- Effect of existing physical network on CAPEX for the construction of offshore renewable sources other than wind network optimisation (load management, demand prediction).
- Reduction in OPEX through shared (integrated) condition monitoring and predictive maintenance of adjacent network infrastructure.
- Reduction of maintenance bottlenecks through capacity sharing (heavy lift vessels, jack-up rigs, pipe lay barges, existing offshore accommodation facilities), cable laying and crew vessels.
- Usage of existing accommodations from oil & gas infrastructure for maintenance of wind parks.
- Extending the offshore power grid with power connections on offshore platforms for future offshore power consumers.
- A stable, predictable offshore energy demand, demand management for oil and gas infrastructure.

- The optimisation of the design of an energy network, including optimisation of offshore HV stations, multi-nodal AC and/or DC infrastructures and cross-border connections (BE, UK, D, DK & NO).
- Development of remote monitoring and control of offshore (hybrid) energy grids.
- Development of compression/expansion systems for offshore energy and H_2/CO_2 injection.
- Instrumentation for measuring chemical components and energy fluxes.
- Offshore (LNG, GTL or Hydrogen) charging/refueling stations for ships.

5.1.4 Health, Safety and Environment

The social license to operate for the offshore energy sectors and industries is currently under debate by the public and politicians. The sector faces the challenge of regaining and strengthening the trust that the sector can operate safely and with care for the environment. Important here is that the sector strengthens trust in being a reliable partner in decision making processes regarding the energy transition together with public stakeholders. For example, the offshore oil and gas sector faces a stricter environmental regulation to improve environmental performance related to emissions to air and water, and reduce the use of energy and resources.

Improving health, safety and environmental performance in the offshore domain is thus a critical innovation area. Innovative solutions are already proposed to improve HSE performance by creating synergy through system integration.

Examples are:

- Synergy in HSE compliance between the offshore energy sectors. HSE requirements in the offshore wind sector are not equal to those in the offshore O&G sector. Lessons can be learned from both sectors and best practices in both sectors can be joined to develop improved and perhaps more standardised regulations, manuals, risk analysis and environmental impact assessment methodologies etc.

- Synergy by electrification of O&G platforms using an offshore energy grid allows for extensive CO_2, SO_x and NOx emission reductions. Taking into account the reliability and maintenance turndown, also CH_4 emission reduction by less venting might be considered as an upside. Current offshore energy conversion efficiency on gas platforms is about 30%. Electrification results in efficiencies around 98% and much higher reliability and longer maintenance intervals for the offshore installation. An offshore energy grid can improve the business case for electrification to a very large extent.

- Construction technologies minimising noise emissions and environmental impacts can be either developed or improved so that all offshore energy sectors could benefit from lessons learned from developments in the wind sector and offshore O&G sector.

- Artificial reefs are designed and constructed for the management of fisheries, coastal protection and preservation and rehabilitation of marine habitats (Langhamer et al. 2009). Langhamer notes that many artificial submerged structures do not have the primary function of reefs but will inevitably be colonised by organisms. Offshore infrastructure could, if well designed, thus serve as artificial reef that improves biodiversity and coastal protection, next to its primary service in the energy domain. New concepts could be developed that maximise these positive effects on the environment. A good example posed by (Langhamer 2012) is a: " *multifunctional area that includes mussel farming or seaweed cultivation appears to be one of the most straightforward economic opportunities within existing offshore parks*."

– A more general point of attention in this innovation theme is to deploy or, if not available, develop assessment methodologies that could evaluate the positive HSE effects of system integration in comparison with the environmental and/or economic trade-offs. A system or life cycle perspective is needed to avoid neglecting potential trade-offs elsewhere in the system or value chain.

5.2 Common Interest

For successful implementation of system integration in the North Sea, there are many issues and barriers that affect the entire sector and thereby serve the public interest, but do not per se fit into a joint innovation effort of the industry. Examples of aspects of public interest which we have established in cooperation with the sector are

1. Sharing knowledge (beyond the boundaries of the different groups involved).
2. The opening and / or sharing of knowledge, experiences and data (e.g. IP).
3. The sharing of risks (precompetitive research, shared investments, etc.).
4. (Innovative) business and financial models.
5. Involving governments for awareness of opportunities, activating stimuli and remedying obstacles.

5.3 Key Performance Indicators

System integration is about the role of each actor, each activity as being part of a larger part and the creation of synergies. Therefore, the indication of the relevance and impact of each project on the system as a whole is required. To give a clear indication of these elements, the following key performance indicators have been defined (Figure 5-2).

Figure 5-2 Key Performance Indicators for TKI North Sea Energy.

Economics & Finance
The project initiator describes if and how the project assesses the economics and financing of system integration and makes the financial impact of it explicit (quantitative, if possible). If the project contains new financial models, for example, this could be mentioned here.

Strategic Spatial Planning
The project initiator describes how the project has impact on strategic spatial planning in North Sea region. This could be targeting on the surface but also subsurface domain (e.g. planning for subsurface reservoir re-use) on different time scales and different geographical scopes.

Technology & Innovation
The project initiator describes whether the project incorporates the development and deployment of new products or services (or both). The Technology Readiness Level of the proposed product or service should be mentioned here.

Legislation
The project initiator describes whether the project will be significantly affected by existing (or foreseen) legislation. A project could also be targeted on reviewing and or improving regulatory framework that is critical for system integration.

Organisation & Stakeholders
The project initiator describes the key stakeholders and whether the project will rely on the alignment of stakeholders in order to be a success. A project could also be targeted at understanding how the roles of stakeholders should/could optimally be organised to streamline system integration.

Public Engagement
Related to the former KPI, the project initiator describes how the public is to be engaged within the project.

Environmental Performance
The project initiator describes briefly (in one or two sentences) what the environmental impacts (benefits and trade-offs) of the project are.

The concept entails that all research and development projects within the Innovation Program score themselves on each of these KPIs to ensure that projects:
- Are transparent in what they want to achieve and in which domain,
- Create impact and it is possible to monitor this,
- Ensure a uniform standard to make comparisons between projects in the Innovation Program possible and clear, and
- Enable communication about projects in the Innovation Program.

–

6 The Innovation Project

6.1 Membership

Joining the offshore energy system integration project means that you will become part of the North Sea Energy Community which extends beyond the boundaries of the project.

Being part of the North Sea Energy Community is possible in a variety of levels. The important distinction is threefold:

1. Participation as full member in the innovation program and an associated seat in the North Sea Energy Steering Committee.
2. Participation as an associate member where you can join in the knowledge sharing events and contribute directly to the common interest of North Sea Energy.
3. Participation as an executive research party.

The North Sea Energy program is envisioned to run for at least 5 years.

Alongside of membership, you can stay up to date through the working group of the TNO, Shell and Siemens Oil & Gas Reinvented Community (oil-and-gas-reinvented.com).

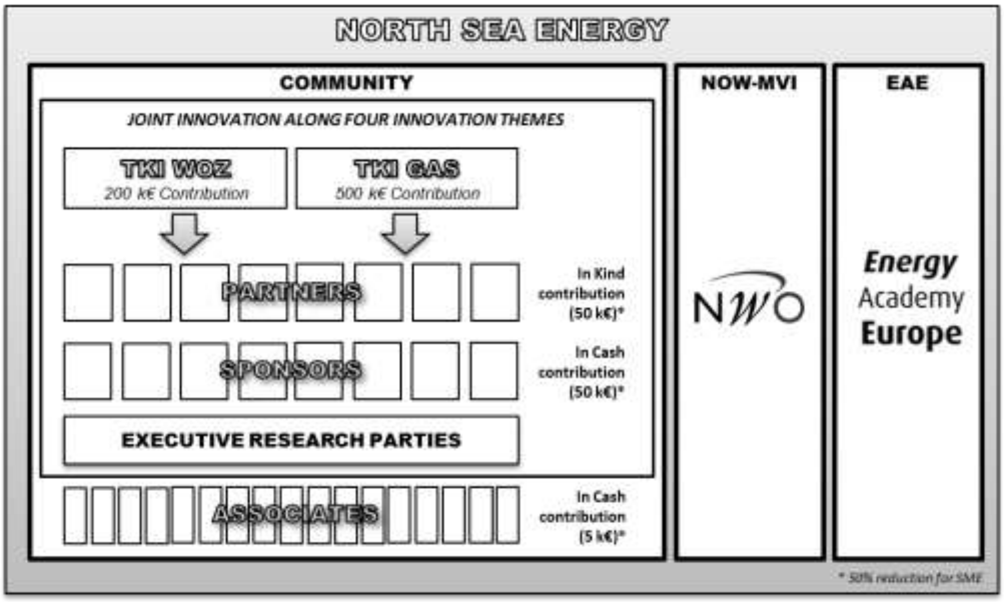


Figure 6-1 North Sea Energy Memberships

6.1.1 *Full Membership*

In case you want to participate in the North Sea Energy Initiative as a full member, you can either choose for the partnership or the sponsorship. Both memberships entitle you to the same rights and obligations, but they differ in the ways you contribute:

– **Partnership**: you contribute in kind (e.g. dedicated hours from senior experts in your organisation, data, models or equipment to the innovation projects). The monetary value of your annual contribution is € 50,000. The contribution is valued according to RVO definitions. You are an active member in research projects of the program.

- **Sponsorship**: you contribute in cash to the innovation projects. You sponsor the joint effort with an annual contribution of € 50,000. You are a non-active member of the program, but will receive all results of the projects and full access to meetings and events.

Every year a re-evaluation of your full membership is possible. In both memberships, the associate membership is included.

6.1.2 Associate Membership

In case your organisation may benefit from the North Sea sector and would like to contribute to knowledge sharing and/or is open to shared collaborations in the North Sea domain, you can opt for the associate membership. The cost for an associate membership is € 5,000 per year. You are not an active member of the innovation projects and receive limited access to results of the program. However, you will have access to knowledge-sharing events and will be regularly updated from progress of the innovation program without receiving access to the detailed results. You will be associate member of the North Sea Energy Community, with access to information via a website.

6.1.3 Participation for SME

For any small or medium sized enterprise it is possible to join with a 50% discount. This discount can apply for both the full and associate membership.

6.1.4 Annual fee

NSE program will run for at least 5 years; members can change their membership status annually.

6.1.5 Benefits of participation

- 50% co-funding scheme: at least € 500,000 co-financing from TKI Gas and TKI Offshore Wind (WoZ)
- Four general NSE meetings per year for knowledge transfer

6.2 Governance Structure

The North Sea Energy Community is coordinated by TNO. The evaluation, deviations and adjustments of the program are done by the NSE Steering Committee with representatives from all full members (both sponsors and partners).

The individual innovation themes are chaired by a representative from the industry.

- SC = Convenant Partners consisting of the full members (>50 keuro/yr)
- Industry representatives are innovation theme directors
- TNO = coordinator
- Executive parties are research institutes and universities (to be decided, potentially TNO, ECN, EAE and universities RUG and TUD)

6.3 Position of North Sea Energy in other Dutch initiatives

Currently, several innovation projects are ongoing related to the theme of System Integration for Offshore Energy, such as:
- System Integration Offshore Energy (TNO, EBN, Shell, Siemens),
- Smart Sustainable Solutions in the North Sea (RUG, ECN),
- North Sea Energy Infrastructures (EAE, TNO, ECN),
- North Sea Energy Innovation Challenge (TNO, KPMG, Siemens, Shell),
- MVI North Sea Energy pilot (Martine Verweij, Frans van Loo) and
- World Energy Council The Netherlands

Industry partners currently involved in these programs either as a participant or member of the steering board are:
- EBN,
- Siemens,
- Shell,
- TenneT,
- ENGIE,
- Gasunie,
- NAM,
- KPMG and
- ENECO.

Sector organisations involved in the program are:
- NOGEPA,
- NWEA and
- IRO.

All ongoing projects will be concluded in Q4 2016. The proposed innovation program will combine efforts of the research institutes currently involved in the topic of system integration in offshore energy and combine the strengths of:
- TNO: oil and gas design, installation, maintenance and operation, subsurface activities
- ECN: offshore wind, design and operation
- EAE: system integration, economics, energy law
- RUG: energy economics
- TUD: energy system modelling (TBM), offshore wind (DUT)

The program will be public/private funding with a combination of Top Sector funding (TKI Gas and TKI Wind op Zee), basic funding from knowledge institutes (ECN, TNO, EAE) and industry support.

7 Stakeholder involvement

For this project it was of great importance to collect as much as possible information, insights and knowledge from companies, institutes and NGO's which have a lot of experience in their offshore domain and which can think across sectoral borders. The knowledge and insights were collected over the course of multiple workshops and events:

Table 1 Workshops held as part of this project

Title	Date	Location	Aim
First brainstorm for opportunities with the offshore sector	July 2015	TNO Delft	To share the concept and ambition and innovation themes inventory
Workshop opportunities to concrete ideas with the offshore sector	Sept 2015	TNO Delft	Intensification of previous workshop results
Workshop case study Gemini	April 26	Rotterdam	To analyse and discuss business case for connecting offshore GEMINI wind farm with oil and nearby gas production platforms
Workshop Vision 2030	May 17 2016	Utrecht	To create a sketch of how different energy functions could be integrated in the North Sea in the year 2030
Workshop Sounding board	May 30 2016	Utrecht	Sharing intermediate results and gathering feedback from extended stakeholder group
Q-Meeting (Offshore Wind Meeting)	Jun 6 2016	Rotterdam (Van Oord)	Inform the offshore wind sector about the scope and aim of this initiative
Oil and Gas Re-invented Community	June 23 2016	Oil and Gas Re-invented Community, The Hague	Sharing intermediate results and gathering feedback from Oil and Gas Re-invented Community

8 Acknowledgement

We want to express our gratitude to all participants and listeners during the workshops and presentations over the course of this project. They have provided the insights to make this initiative extend over sector boundaries and clarify the benefits for all stakeholders.

In particular, we want the express our appreciation for the participants of the three main workshops which sequentially shaped the project: the case study at the IABR in Rotterdam, the formulation of a vision towards 2030 and beyond at the TNO office in Utrecht and the sounding board meeting with representatives from the whole offshore value chain (see next page):

Table 2. Overview of parties actively involved in one of more workshops/events (in alphabetical order)

All participants who have contributed to more than one workshop and/or have actively provided support outside the project team	All participants who have provided input during the first brainstorms (2015) and/or during the sounding board meeting (2016)	All participants which have actively contributed on behalf of one of the project partners
ENGIE NWEA Tennet Wintershall	Berenschot Bluewater Damen DGTA ECN Fugro Heerema Group Huisman IRO IV Oil&Gas Keppel Verolme Marin Natuur en Milieu Netherlands Maritime Technology (NMT) NoGePa ONE Royal IHC SBM Offshore St. De Noordzee TKI Gas TKI Wind op Zee Tocardo Tidal Power Total Van Oord	EBN NAM Shell Siemens TNO

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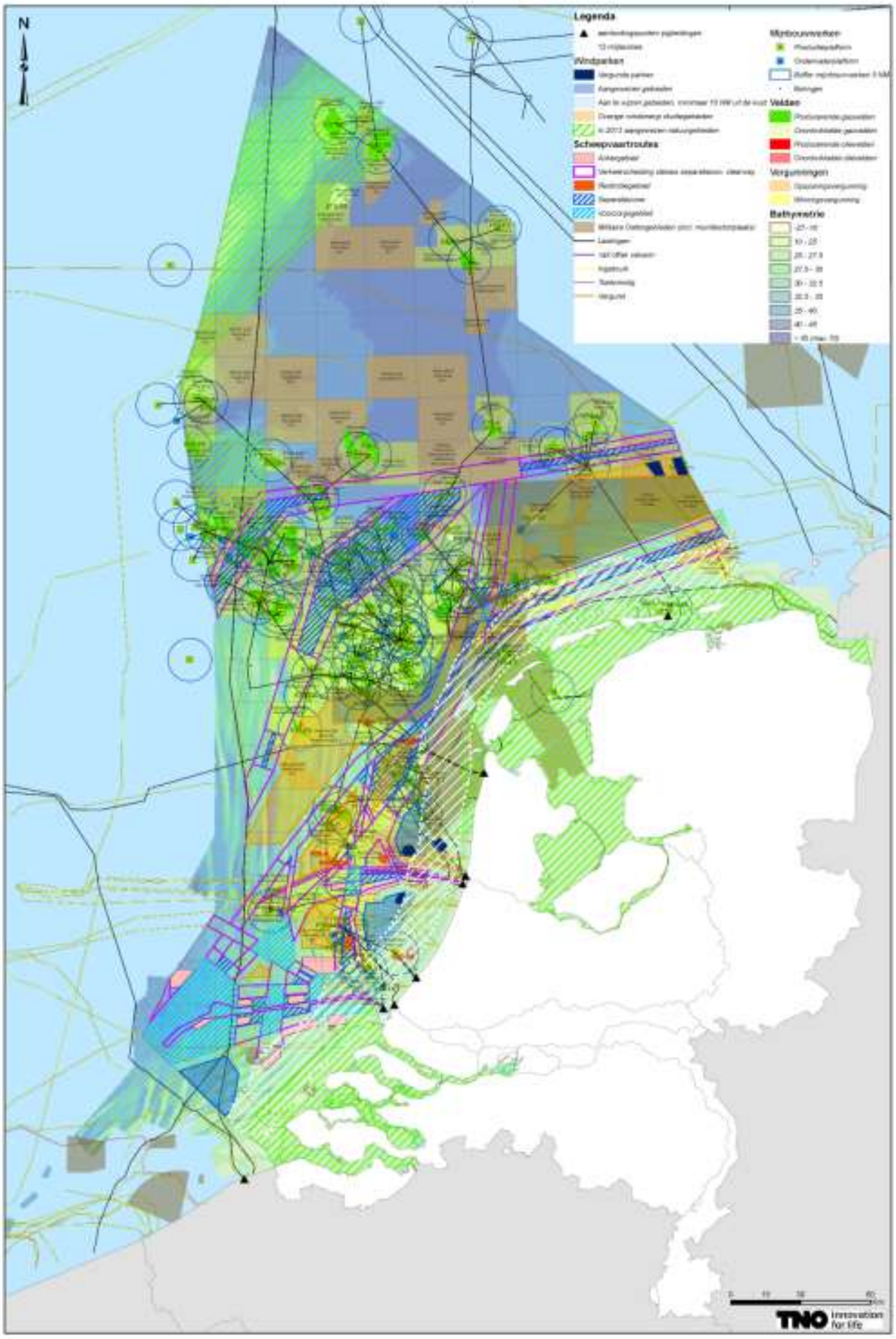
10 Appendix 1: Maps

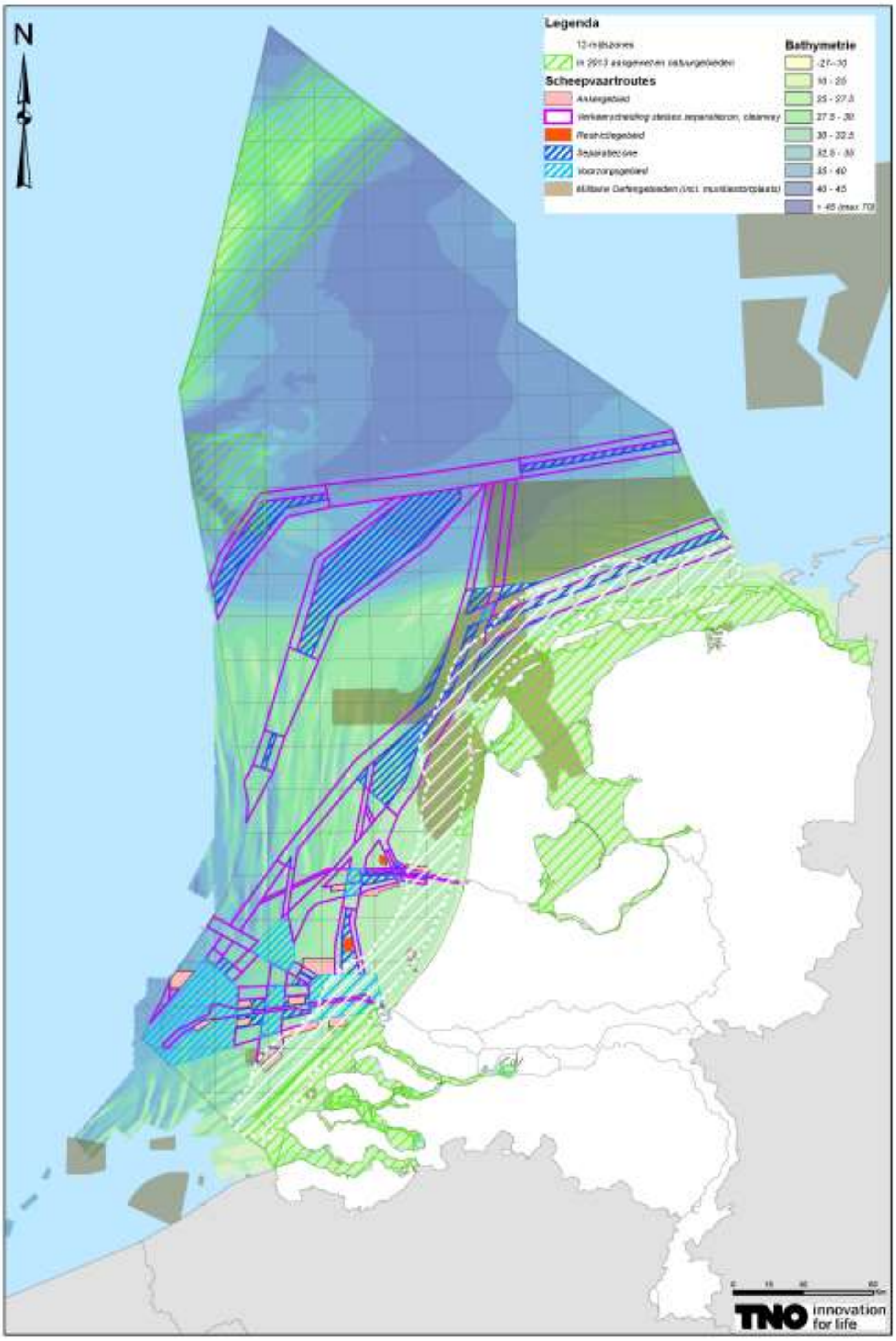
Map showing current state of spatial planning at the North Sea

The map below shows all current activities at the North Sea, plotted on the bathymetry map which represents the water depth.



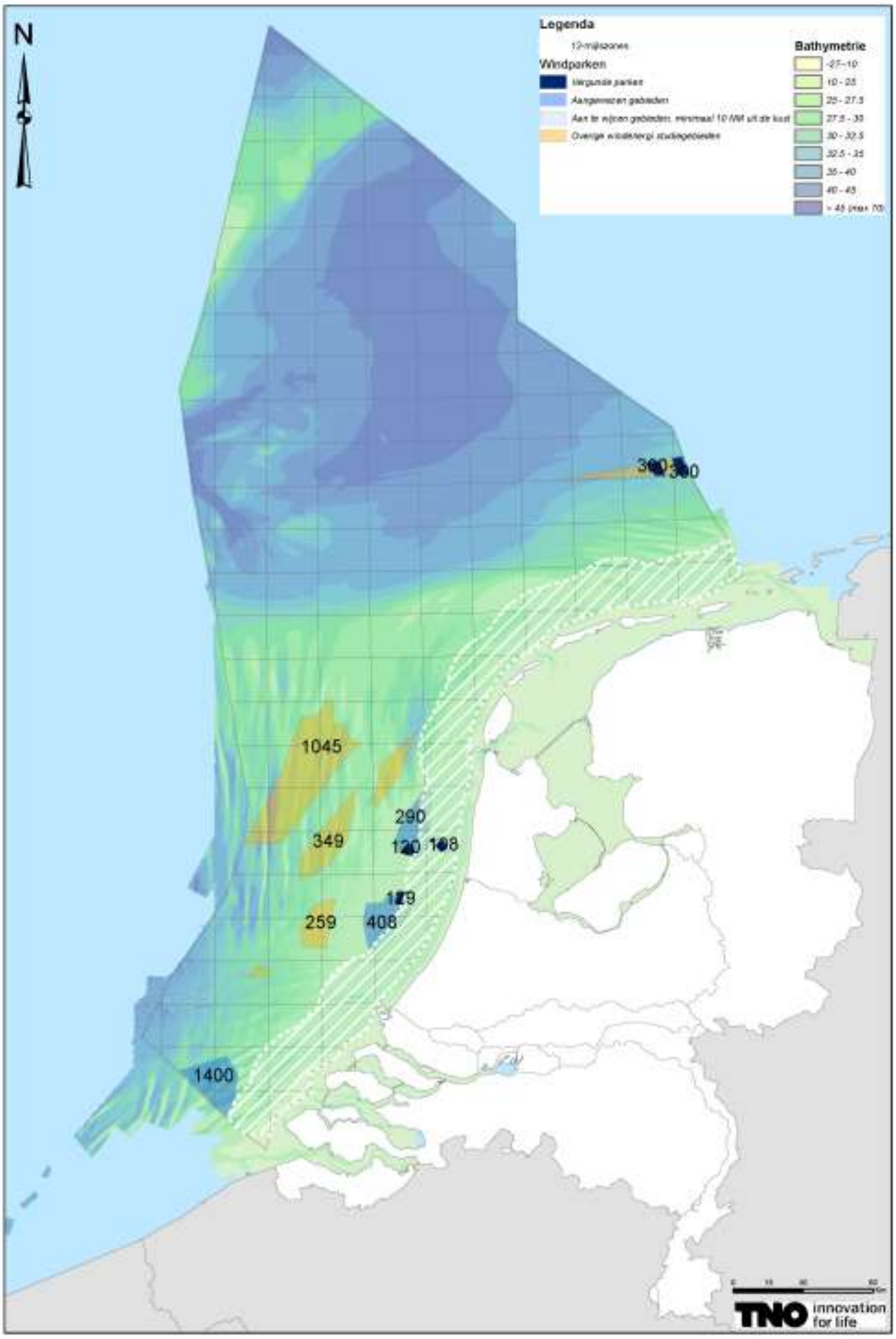
Excluded areas

At the North Sea there are large parts excluded from any activities, because of the ecological wealth, restricted areas for defence and transportation routes.



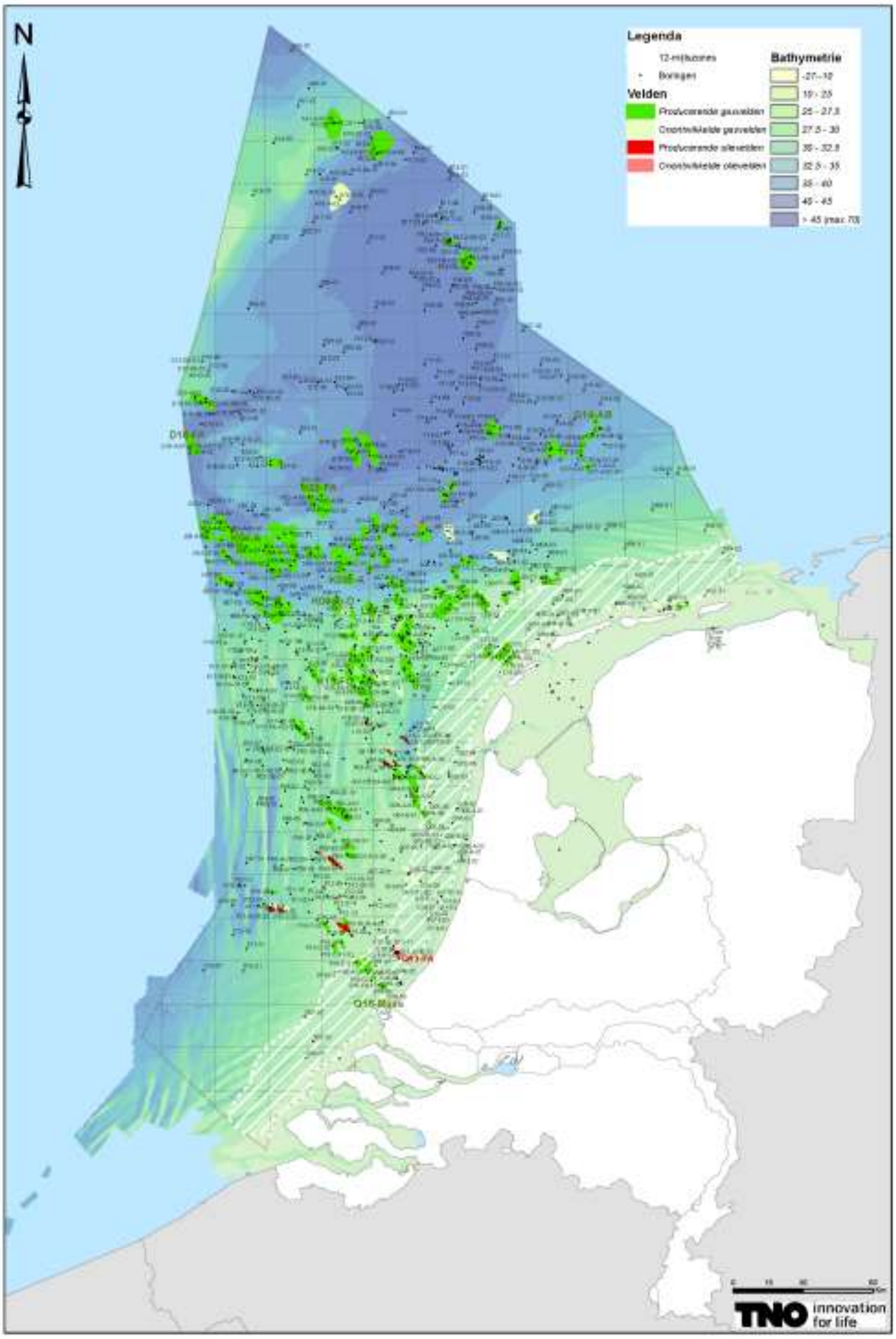
Wind energy at the North Sea

Installed wind farms and reserved areas for future wind farms



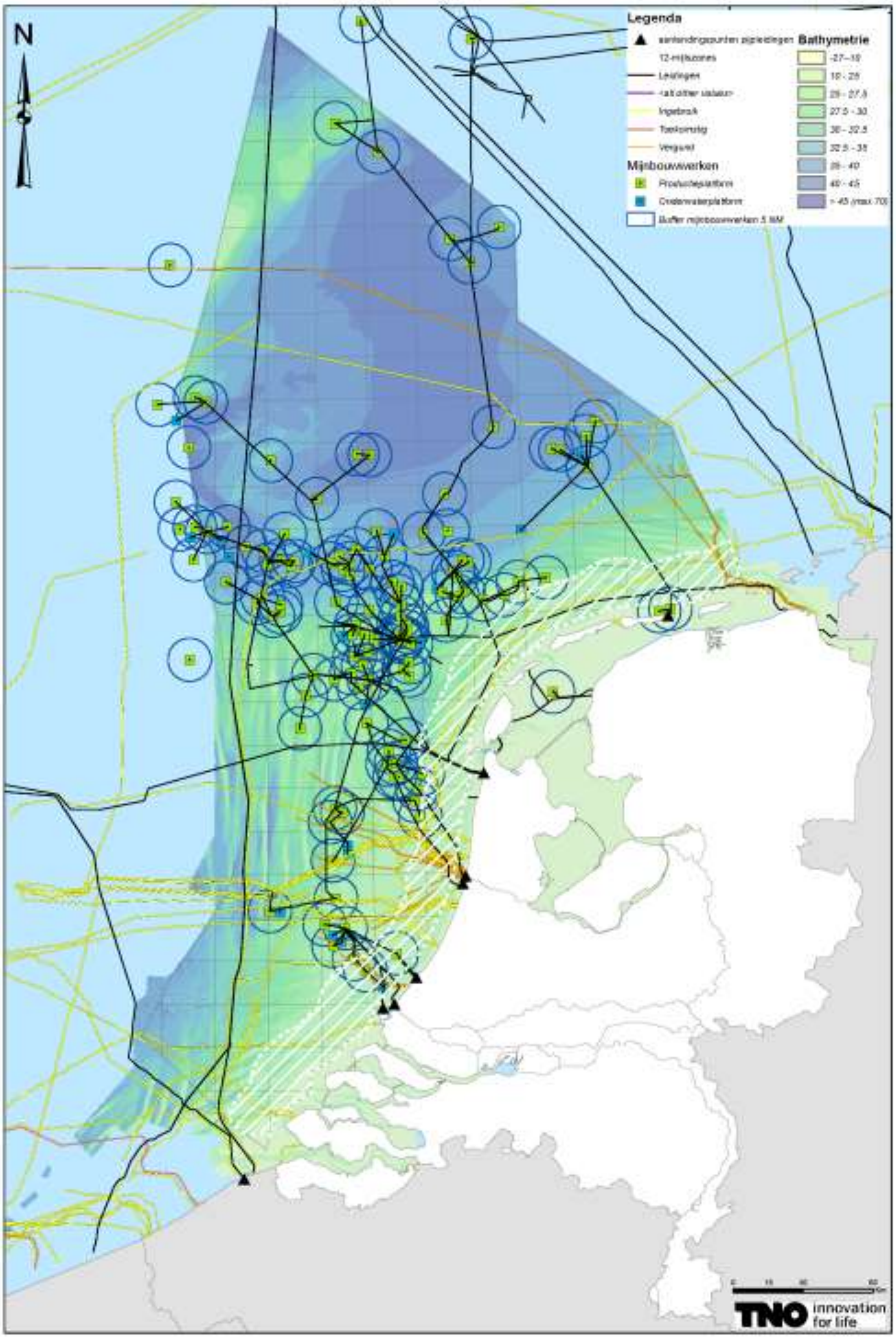
Gas fields at the North Sea

Below you can see an overview of the offshore gas fields (green) and some oil fields (red). In addition the wells are shown with their names.



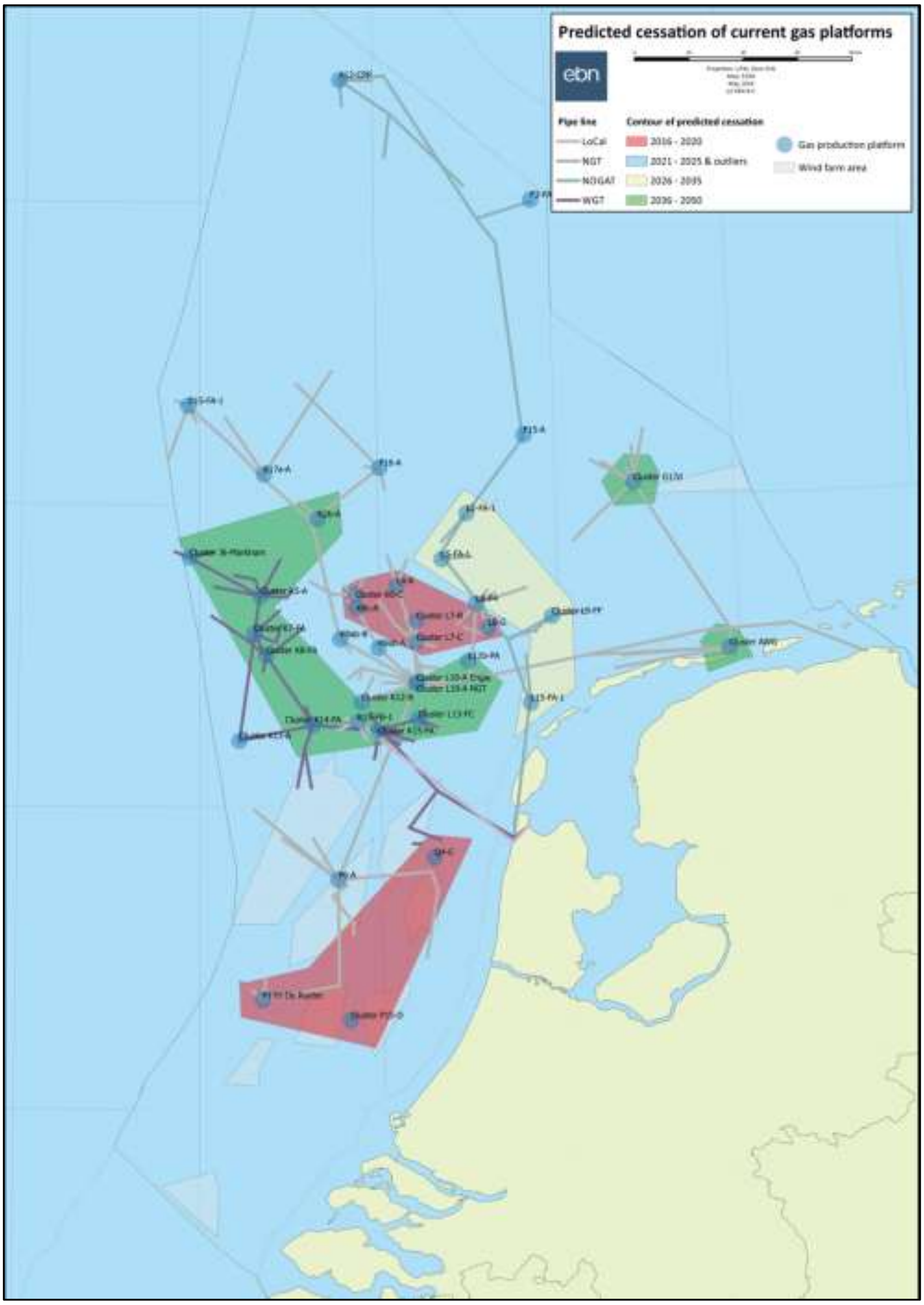
Offshore infrastructure

All gas fields are connected to shore by pipelines (main lines and intra-platform lines). The circular features depict the 5 Nm zones around platforms.



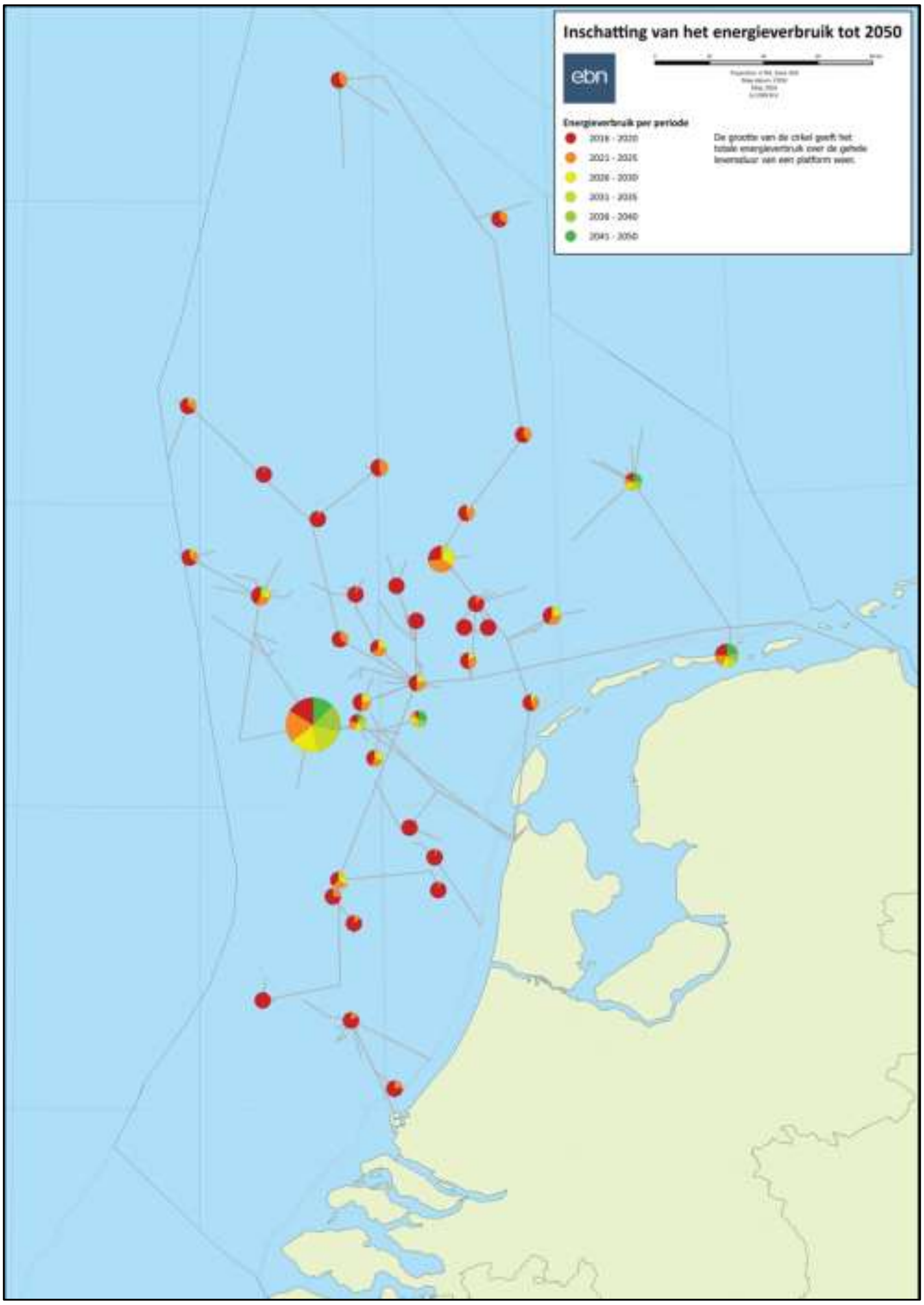
Decommissioning of offshore structures based on InfraSim

During the project, EBN has run some scenarios in InfraSim which have resulted in the map below, showing a potential scenario for the decommissioning over time with contours that most likely are related to wind farm developments. The timing of decommissioning is an import factor in designing the vision towards 2030 and beyond.



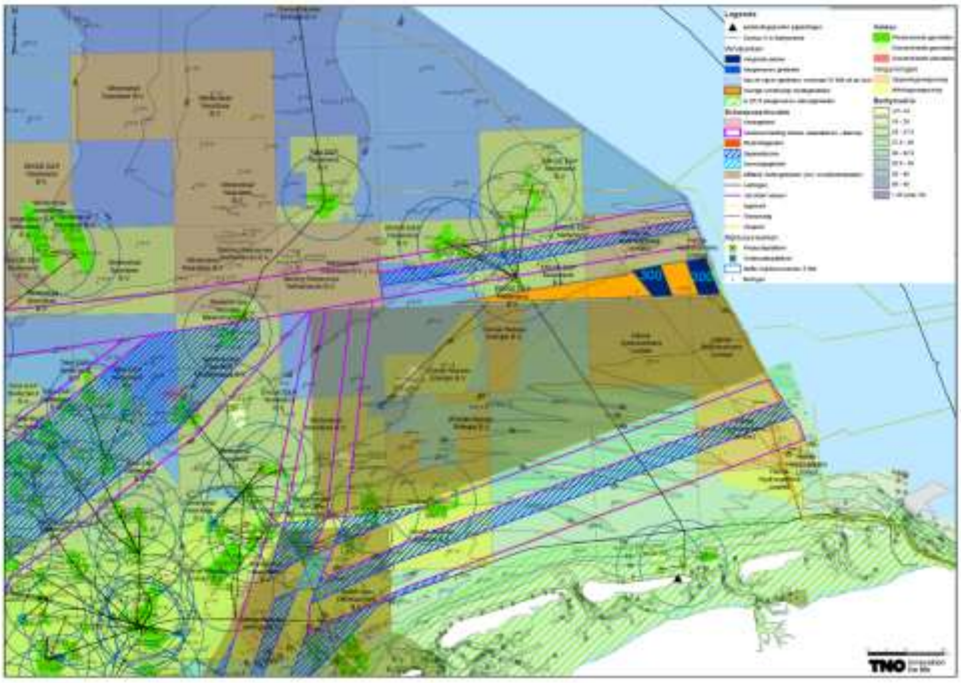
Energy use by offshore structures based on InfraSim

The map below gives an estimate regarding the total energy usage over time per offshore structure.

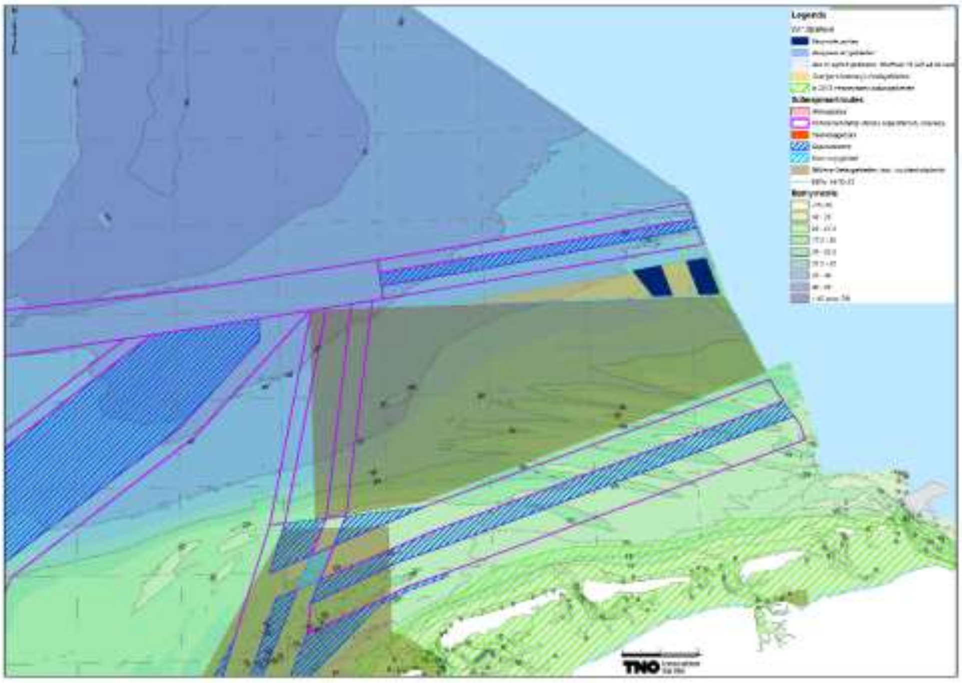


Detailed maps for the Gemini Case Study

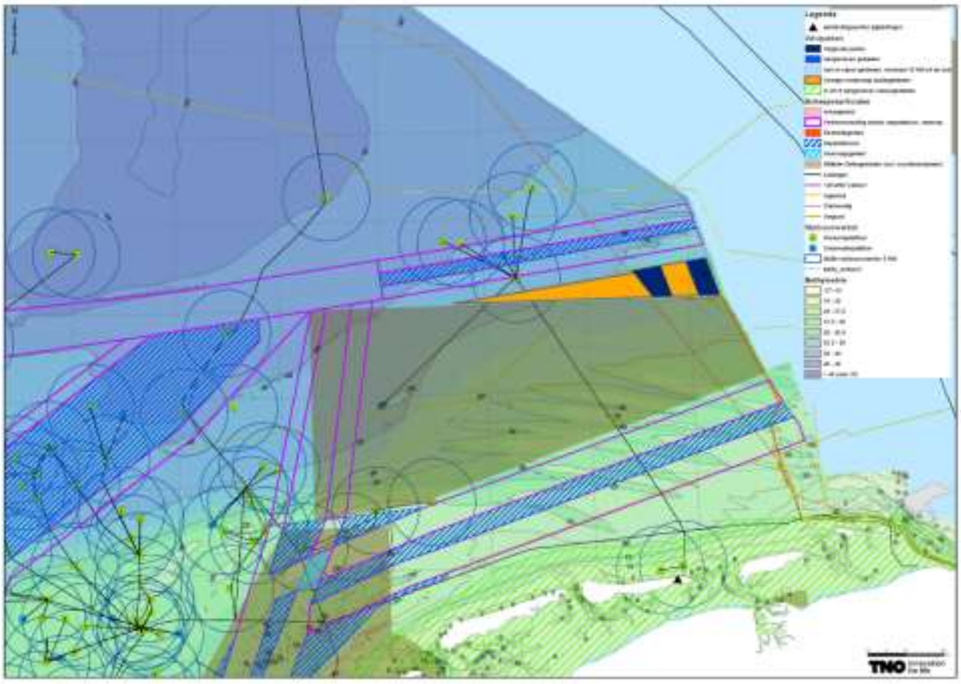
Below you can find similar maps as above, but zoomed in to the part north of the Wadden Sea area. These maps were used for the Gemini Case Study, April 2016.



Map 1: All functions combines



Map 2: Excluded areas



Map 3: Combination of Offshore wind, Infrastructure and Excluded Areas