North Sea Energy II
Strategic Assessment of Environmental Impacts of Offshore system Integration Options

Deliverable D.2

As part of Topsector Energy:
TKI Offshore Wind & TKI New Gas

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List of Acronyms

AMK	Archaeological Monument Map (in Dutch: Archeologische Monumenten Kaart)
CCS	Carbon Capture and Storage
CO	carbon monoxide
EEZ	Exclusive Economical Zone
EIA	Environmental Impact Assessment
EU	European Union
EZK	Ministry of Economic Affairs and Climate Policy (in Dutch: Economische Zaken en Klimaat)
IPCC	Intergovernmental Panel on Climate Change
IVO	Inventory survey
KNA	Dutch National Archaeology Quality Standard (in Dutch: Kwaliteitsnorm Nerderlandse Archeologie)
MSFD (KRM)	Marine Strategy Framework Directive (in Dutch: Kaderrichtlijn Mariene Strategie)
NeR	Nederlandse emissierichtlijn lucht (Dutch)
NOx	nitrogen oxides
NSE	North Sea Energy Program
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PCBs	Polychlorinated biphenyl
P2G	Power-to-Gas
3 Ps	Planet People Profitability
SEA	Strategic Environmental Assessment
SO2	sulpur dioxide
Svw	Shipping Traffic Act (in Dutch: Scheepvaartverkeerswet)
TKI	Topconsortia voor Kennis en Innovatie
Wozep	Wind on Sea Ecological Program (in Dutch: Wind op Zee Ecologisch Programma)

1 North Sea Energy Program – opportunities for system integration

1.1 Why is system integration in the offshore energy domain necessary?

The international society faces the important challenge to implement the Paris Agreement to substantially reduce greenhouse gas emissions and limit global temperature increase. A transition to a new energy system is needed, i.e. shifting towards renewable and low carbon energy sources, and making more efficient and responsible use of energy. In this spirit, the Dutch ''Energieakkoord'' prescribes 14% of renewable energy by 2020, with a further increase towards 16% in 2023.

In the most recent coalition agreement (2017) a new national climate and energy agreement is foreseen. This new agreement will be based on a reduction target for CO_2 emissions of 49% by 2030. In the coalition agreement a considerable role of the 59 Mt CO_2 reduction is foreseen to be reached by more offshore wind development and by implementing carbon capture and storage (CCS) with up to 20 Mt CO_2 per year by 2030. Offshore sustainable energy, most dominantly offshore wind, and CCS will thus have a very important contribution to the accelerated growth of a low carbon and sustainable energy supply in the Netherlands.

The North Sea is an important area where this energy transition takes place. The Netherlands is currently experiencing a strong ramp-up of offshore wind energy construction activities in the North Sea. PBL recently has performed spatial scenario analyses for the North Sea (PBL, 2018) (Netherlands Continental Shelf - NCP). With regards to energy production the study anticipates in the most ambitious scenario an offshore wind growth towards 15 GW installed capacity in 2030 and 60 GW in 2050. Also CCS offshore is estimated to considerably grow towards 2030 (20 Mt CO_2/yr) and 2050 (45 Mt CO_2/yr). Recently, it has been announced that offshore wind is planned to grow from 4,5 GW in 2023 towards 11,5 GW in 2030, which is relatively close to these ambitious scenarios.

Next to wind energy the North Sea hosts several important (economic) activities, including oil and gas production, fisheries, sand and shell extraction, shipping, areas for military use, nature reserves, and recreational activities. The area thus has an important economic and environmental function for the Netherlands' economy; and there is competition for space. Offshore wind capacity growth will draw a considerable burden on the spatial claim of offshore energy production. For wind this means up to 26% of the NCP is being 'used' by offshore wind. The spatial claim of offshore hydrocarbon production and transport is considerably declining in the same period; although CCS and offshore hydrogen production and transport would likely involve re-use of oil and gas infrastructure and thus that a part of the spatial claim remains. Strong offshore wind deployment also has the challenge according to the PBL study (2018) that new landing points ('aanlandingspunten') are difficult to realise and that in periods of high wind electricity production the onshore grid cannot cope with the high volumes, i.e. grid congestion. This already may become a serious issue before 2030. Offshore system integration could be one of the options to alleviate this situation, for instance via platform electrification and offshore energy conversion and storage (e.g. via power to hydrogen; power-to-x).

The offshore oil and gas industry has the major challenge of re-use and decommission of its offshore assets after production has ceased. The Dutch state, via EBN, has already reserved billions of euros for this endeavour for the coming decades. Re-use of infrastructure for the offshore energy transition may reduce costs of achieving medium and long-term climate goals. The decline of gas assets on the one hand, and the build-up of offshore wind assets on the other hand, offers an opportunity where system integration between these two may be of added value to accelerate the energy transition at the North Sea. There are various system integration options that could enable and accelerate this transition including:
a) Electrification of platforms to decrease emissions and feed other future activities with clean energy

b) Offshore Power2Gas on existing gas platforms and energy islands
c) Carbon Capture and Storage using existing gas pipelines and depleted fields
d) Energy storage using existing offshore assets

These options may jointly lead to an accelerated growth to sustainable energy production at the North Sea by

i. Reducing the costs of decommissioning of the fossil energy infrastructure on the one hand, and the build-up of the new energy infrastructure on the other;
ii. Enabling the production and transport of large amounts of wind energy to the shore by partly transporting in the form of green molecules (e.g. hydrogen);
iii. Reducing the CO_2 emissions during the transition phase between these energy systems;

Re-use of existing gas infrastructure (both pipelines, platforms and depleted fields) may open the route towards a North Sea scenario for energy production at reduced costs and making use of the potential of green molecules (e.g. green hydrogen) to play a major role in our new energy system. By smartly combining various uses of the North Sea, the competition for space may be reduced, which improves the balance between energy production, food production and ecological value. For a more detailed description of the reasoning behind this vision, reference is made to the Whitepaper "Offshore Systeemintegratie als Transitieversneller Noordzee" (TNO, 2018).

1.2 Objectives of this report

The North Sea Energy II Program (NSE II) focuses on screening and assessment of demonstration locations for system integration. More specifically, this includes an assessment of system integration options for three locations (case studies) for a hybrid and integrated energy supply from offshore wind farms and gas production infrastructure. See Figure 1-1 for the specific locations of the case studies. The objective of NSE II is to develop knowledge on the feasibility of offshore system integration scenarios for these three locations from technical, economic, environmental and regulatory perspective.

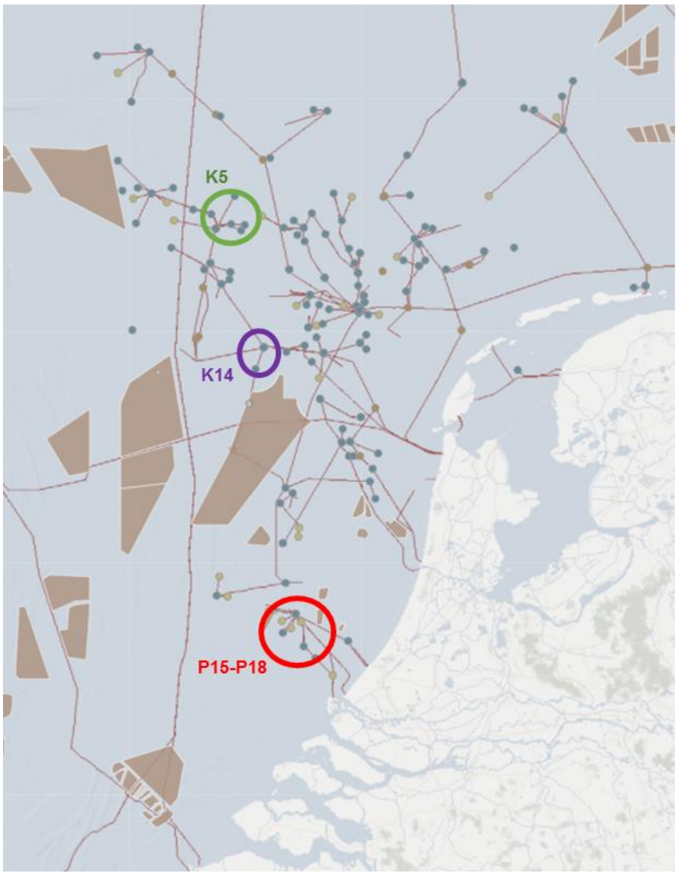


Figure 1-1 – Location of case study area; green: K5, TOTAL; purple: K14, NAM; red: P15-P18, TAQA

One of the work packages of NSE II concentrates on a strategic assessment of environmental impacts of system integration options (work packages D2). Royal HaskoningDHV is requested by TNO to conduct this strategic assessment. This work package aims to answer two research questions:

1 What are the known and potential spatial and environmental impacts of the presence of both wind farms and oil and gas installations in the selected case study areas?

2 What critical information is currently missing to assess these impacts?

Hence, this report identifies spatial and environmental impacts of the system integration options for the four case studies, as well as related knowledge gaps. The assessment is conducted at a strategic level. This report can be compared to a Strategic Environmental Assessment (SEA) but does not have the legal status of a formal SEA. A formal SEA is conducted prior to a spatial of policy decision in order to ensure that possible impacts on the environment are included in the decision making. NSE is a research program and as such does not include a spatial or policy decision. Accordingly, no SEA can be conducted. However, this document provides a first indication of the type and extend of environmental impacts related to system integration at the North Sea. In case of implementation of one of the system integration options or a full system integration scenario this would require the necessary permit applications and possibly related SEA or EIAs.

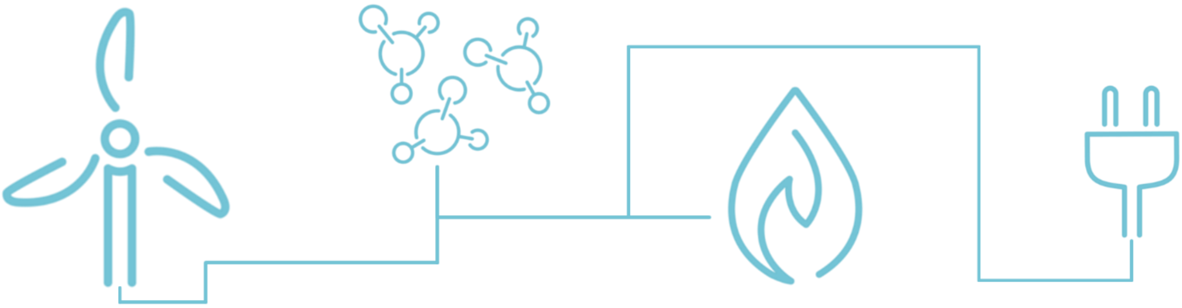
2 System integration options

The strategic environmental assessment focusses on three different options for system integration, in alignment with the other work packages under NSE II. These include:

- Electrification
- CO_2 transport & storage
- Green hydrogen production

These system integration options are converting conventional offshore assets that produce natural gas, into assets using power generated by wind farms (electrification via connection to the electrical grid), for carbon capture and storage (CCS), and/or for the production and transportation of H_2 as an energy source (green hydrogen assets).

System integration does not consist of only one option per asset, more options can be combined resulting in system integration scenarios. For example, electrification could be applied in the short term, whereas green hydrogen production is expected to become viable only in the longer term. Hence, per case study scenarios have been developed as part of NSE II work package A. In this chapter the system integration options are presented and described in general terms and per case study the different scenarios are detailed.



2.1 Electrification

Currently the power supply on platforms is provided by gas and/or diesel generators. With the electrification of natural gas platforms, the energy demand of platforms is provided by electrical power. Generators often have a low efficiency level. By means of electrification, the diesel generator will be replaced by electrical generators. Whereby the energy will be supplied from specific wind turbines or windfarms. The platforms need to be connected to the electrical grid: a new cable from a wind farm (substation) to a platform provides this connection (see Figure 2-1).

Electrification of platforms is expected to reduce emissions to air, but also noise levels as produced by generators may be lower compared to conventional platform operations. From an energy system perspective, emissions are also anticipated to reduce as electrification further increases the energy efficiency. This reduces the operational costs and reduces the amount of gas used offshore, which allows a relatively larger volume of gas to be used onshore with a higher efficiency.

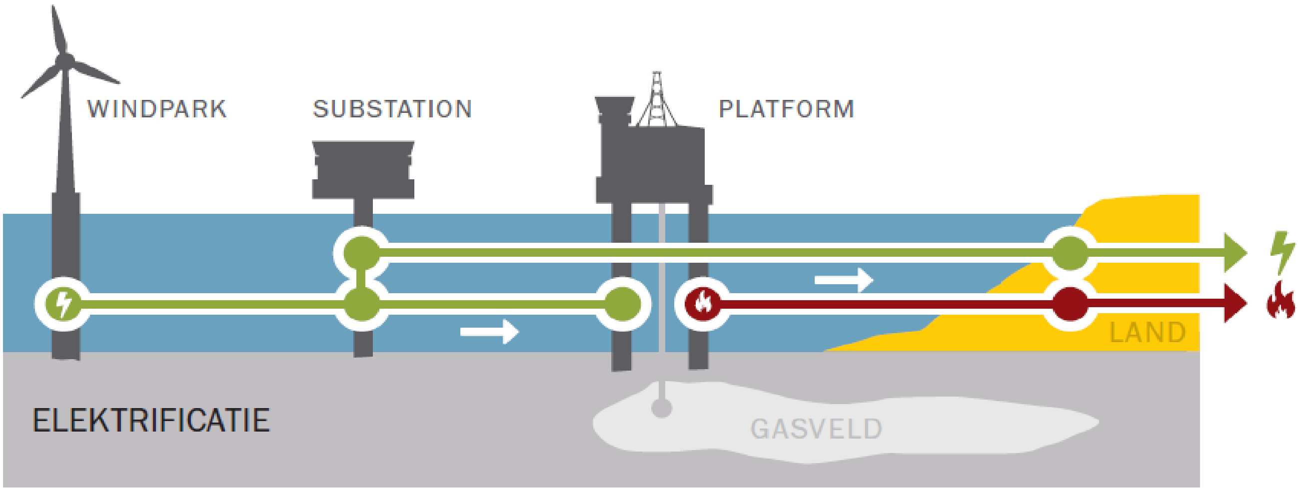


Figure 2-1 - Schematic overview of electrification of a platform via a wind farm (TNO, 2018)

2.2 CO_2 transport & storage

When gas fields are depleted, the wells are closed and plugged. A possible re-use opportunity is to use the depleted gas reservoir as a CO_2 storage facility. CO_2 is captured onshore and transported offshore through new or existing pipelines and injected in the geological formation of the original (produced) gas field.

Based on NSE II work package A the assumptions are that compression of CO_2 takes place onshore, as well as other necessary treatment (e.g. heating), CO_2 is accordingly transported and injected in offshore depleted gas fields in liquid phase. The CO_2 is slowly injected in the reservoir, which will increase the pressure in the reservoir. Injection will continue until the reservoir's pressure has risen to almost the same level as the original natural gas pressure. The pressure in the reservoir is kept at lower level than the original pressure, to ensure the natural geological closure of the reservoir.

The existing gas infrastructure and pipelines can be used, or new pipelines need to be placed to transport the CO_2. In some cases the pipelines need to be provided with an isolation layer. Additionally, the wells require a workover to make them suitable for CO_2 injection and storage.

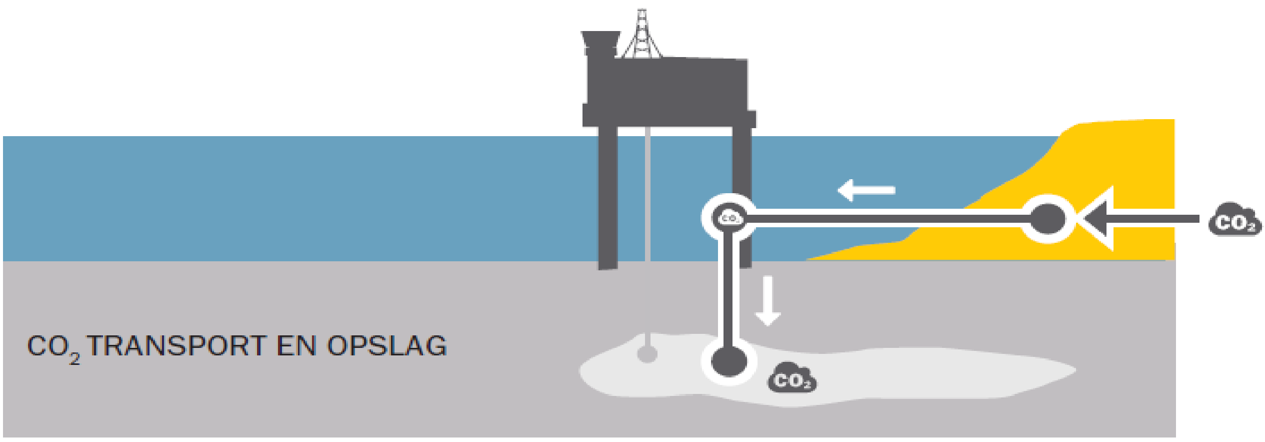
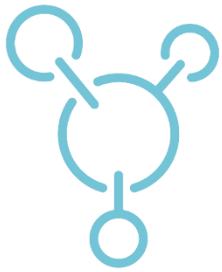


Figure 2-2 - Schematic overview of CO_2 transport and storage (TNO, 2018)

2.3 Green hydrogen production



Power can be converted into hydrogen using electrolysers. This could be attractive for several reasons: to avoid large and long-term investments in the power network, to fully utilize renewable energy, to accommodate large amounts of offshore wind energy, to offer flexibility services, to store energy. In this study we focus on the impact of offshore production of green hydrogen, where new or existing gas infrastructure could be used to transport this 'green' hydrogen for use in industry (e.g. the Rotterdam area is developing plans for sustainable hydrogen use), mobility (e.g. hydrogen filling stations) and other applications. (DNV GL, 2018)

Currently electricity generated by offshore wind farms is transported by cables to shore. Availability of storage is limited, especially during periods of oversupply. By converting the electrons into molecules, there are more and efficient possibilities for energy storage. This storage technology is also known as Power-to-Gas (P2G). Electrical energy, derived from wind farms, is transported to an offshore platform to be used to produce hydrogen. On the platform, the electrical energy (electrons) is converted into chemical energy in the form of gas (molecules). Seawater is desalinated first and filtered into demi water that will be used for electrolysis. In this case electricity is converted by electrolysis into hydrogen gas (H_2) and oxygen. From the platform the hydrogen is compressed and transported to shore through new or existing pipelines. In this study, only the offshore production of green hydrogen is part of the option and *not* the storage of green hydrogen on / or offshore.

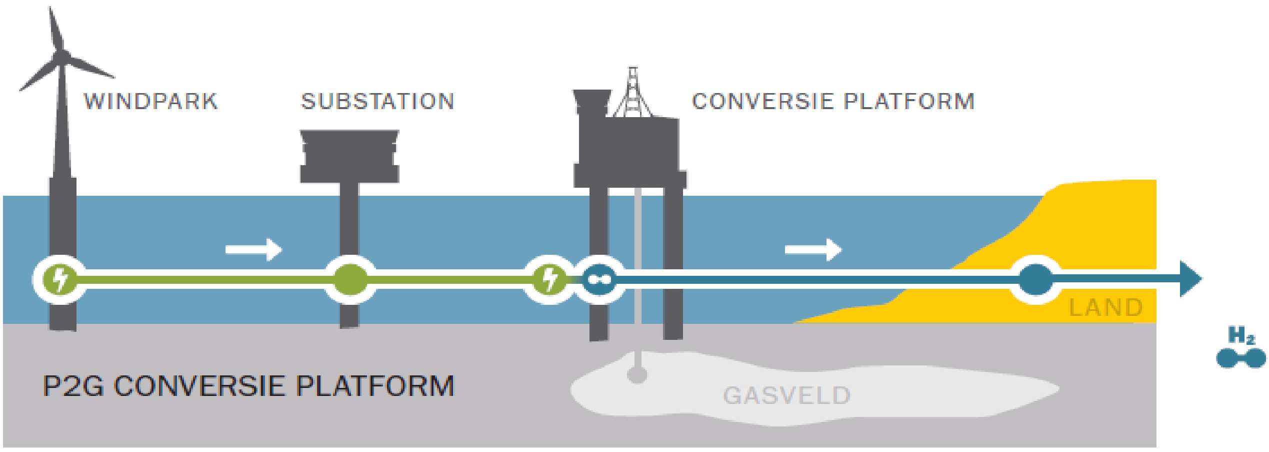


Figure 2-3 - Schematic overview of conversion to H_2 (TNO, 2018)

2.4 Scenarios per case study

NSE II focuses on an assessment of system integration options for three demonstration locations (case studies). For three case studies system integration scenarios are detailed, as part of NSE II work package A. The scenarios differ per case study and vary in lifetime. This paragraph describes the three case studies and the related system integration scenario. An overview of the locations of the case studies is provided in Figure 1-1.

2.4.1 K5 area

Approximately 100 km offshore (from the coast of Den Helder) and about 30 km from the North Sea border with the UK the K5 area is located (see Figure 1-1). The K5 area consists of five platforms and is expected to be in operation until 2033 (based on information provided by Total). The area is operated by Total.

As production is still ongoing, a first step towards system integration is electrification. An electricity connection could be provided from one of the windfarms in wind energy area Hollandse Kust Noord or IJmuiden Ver. The gas production will be continued, but electrified. Electrification is followed by three options:

(i) Start with electrification in 2024, continue natural gas production, and in parallel start with CCS in 2029;
(ii) Start with electrification in 2023, and CCS will start after ending gas production in 2033.
(iii) Start with both electrification and CCS in 2028 in 'hybrid mode'

Only in case of a 'hybrid mode' an additional pipeline is required. For CCS only, the old infrastructure of the gas production (pipelines) can be used.

Hence, two system integration options are considered for this area, with three different timing options, resulting in the following scenario, as detailed in Figure 2-4 below:
Electrification & CCS hub

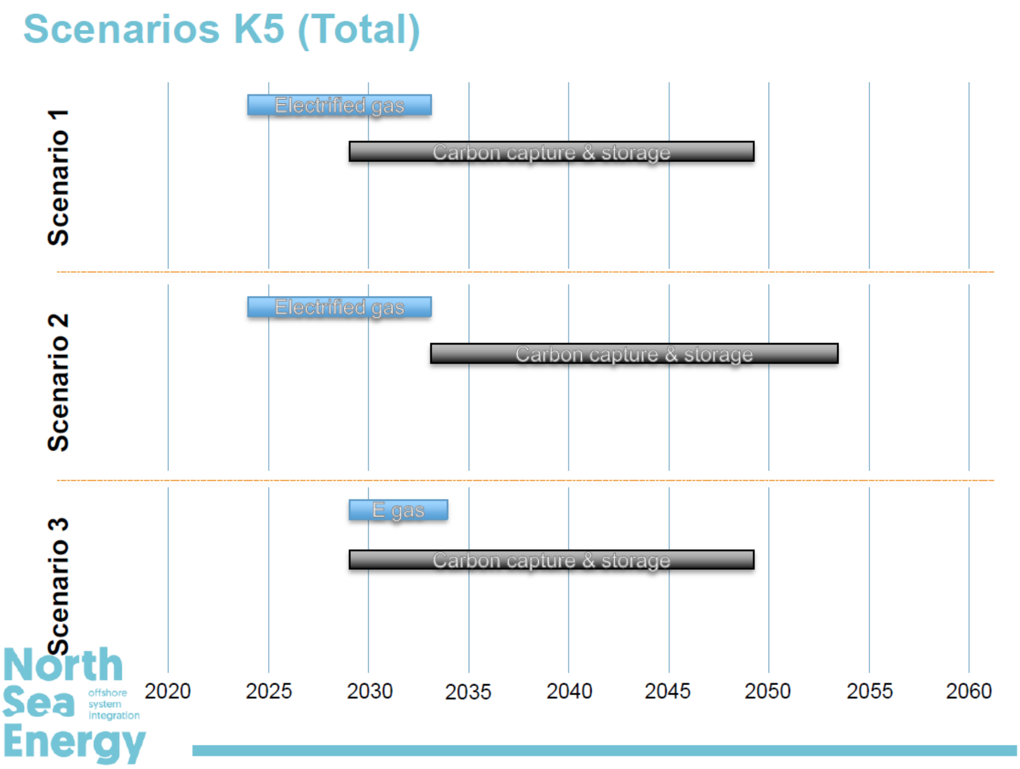


Figure 2-4 - System integration scenarios for K5

2.4.2 K14 area

Approximately 80 km offshore (northwest from Den Helder) and 10 km north of wind energy area IJmuiden Ver, the K14 area is located (see Figure 1-1). The K14 consists of two production platforms. The hub platform

(K14-FA-1) is expected to be in operation until 2036-2050. (Royal HaskoningDHV, Northsea Spatial Information, 2018) An overview of the K14 area is included in Figure 2-6. The area is operated by NAM.

NAM is considering the K14 area as a study area for small or large-scale power2gas (specifically power2hydrogen) in combination with CCS facilities; both after platform electrification has been implemented. A cable connection from new windfarms (Hollandse Kust Noord or IJmuiden Ver) to K14 would need to be constructed for platform electrification and the conversion of electric power to hydrogen (power to gas). In case of hydrogen production, a new pipeline connection (in addition to existing gas pipeline) would need to be constructed from K14 to Den Helder for the transportation of hydrogen to shore

Three different scenarios are considered for K14, each one starting with electrification, followed by a hybrid combination with small scale H2 production. There are three different options following the hybrid of electrification and small scale H2 production, as detailed in Figure 2-5 below:

(i) CCS with after 10 years combination of large scale H2 production
(ii) Only CCS
(iii) Only large scale H2 production.

Hence, all three system integration options are viable for this area, resulting in the following scenario with three different options:
Electrification & small scale H_2 production & large scale H_2 and/or CCS hub

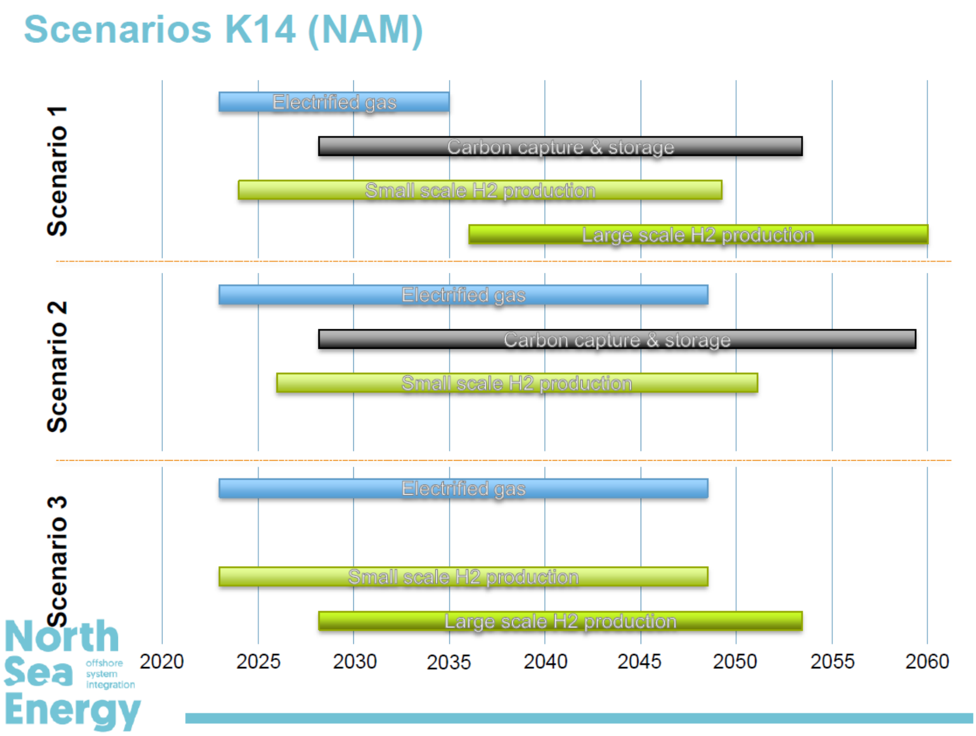


Figure 2-5 - System integration scenarios for K14

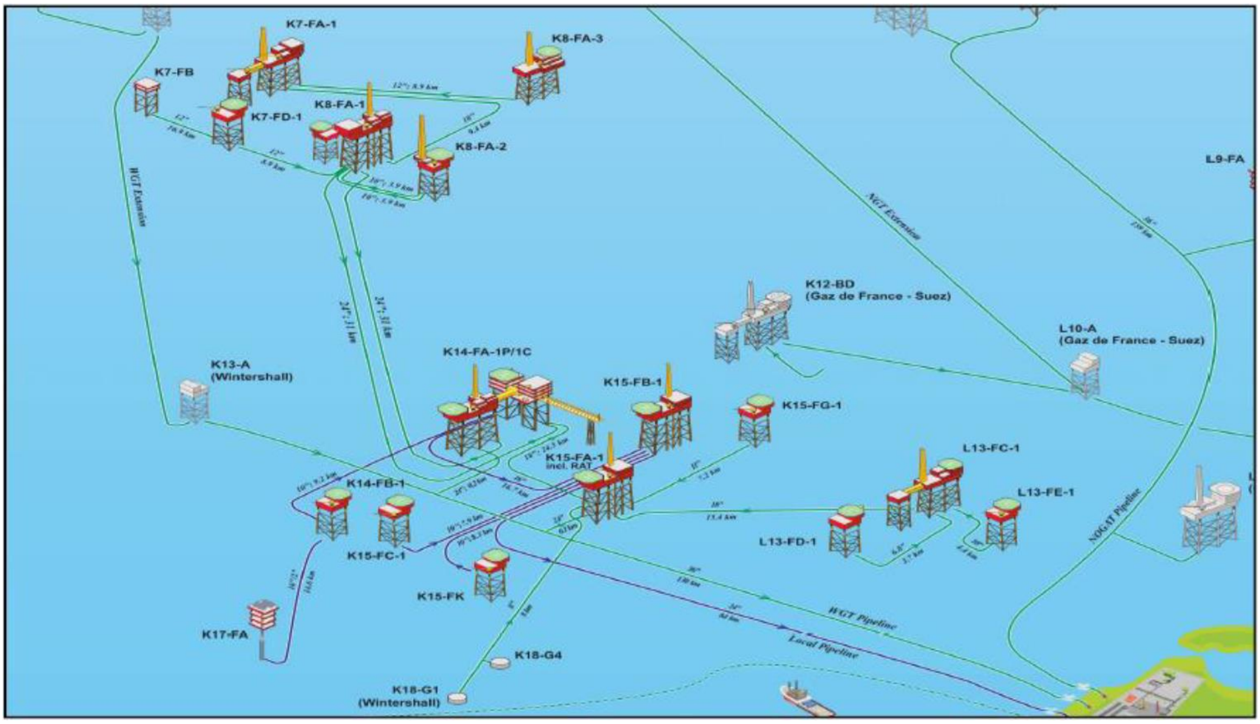


Figure 2-6 - K14 area (NAM, 2017)

2.4.3 P15-P18 area

Close to the shore, at about 20-40 km, the P15-P18 area is located. The assigned area consists of ten platforms (oil wellhead platform, oil production platform, gas production platform, four gas satellite platforms and three gas subsea completions) with pipe connections to Maasvlakte and Hoek van Holland. The area is operated by TAQA Energy. The P15-P18 area is currently still in production, with an expected lifetime until 2023. (TAQA, 2017). It is expected that based on current new initiatives the lifetime is expected to exceed 2023 by several years.

As production is still ongoing, a first step towards system integration is electrification. An electricity connection could be provided from one of the platforms from TenneT in the wind energy area Hollandse kust Zuid. In NSE I the business case for electrification of the P15-P18 area was studied.

Due to its location relatively close to shore, the P15-P18 area has been on the radar as a potential CCS pilot/project and hub. For that reason, several studies on the possibilities for CCS in the P15-P18 area are available. Furthermore, NSE I assessed the potential for H_2 production from nearby windfarms.

Hence, all three system integration options are viable for this area, resulting in the following scenario, with three different timing options, as detailed in Figure 2-5 below:
Electrification & small scale H2 production & large scale H_2 production combined with CCS

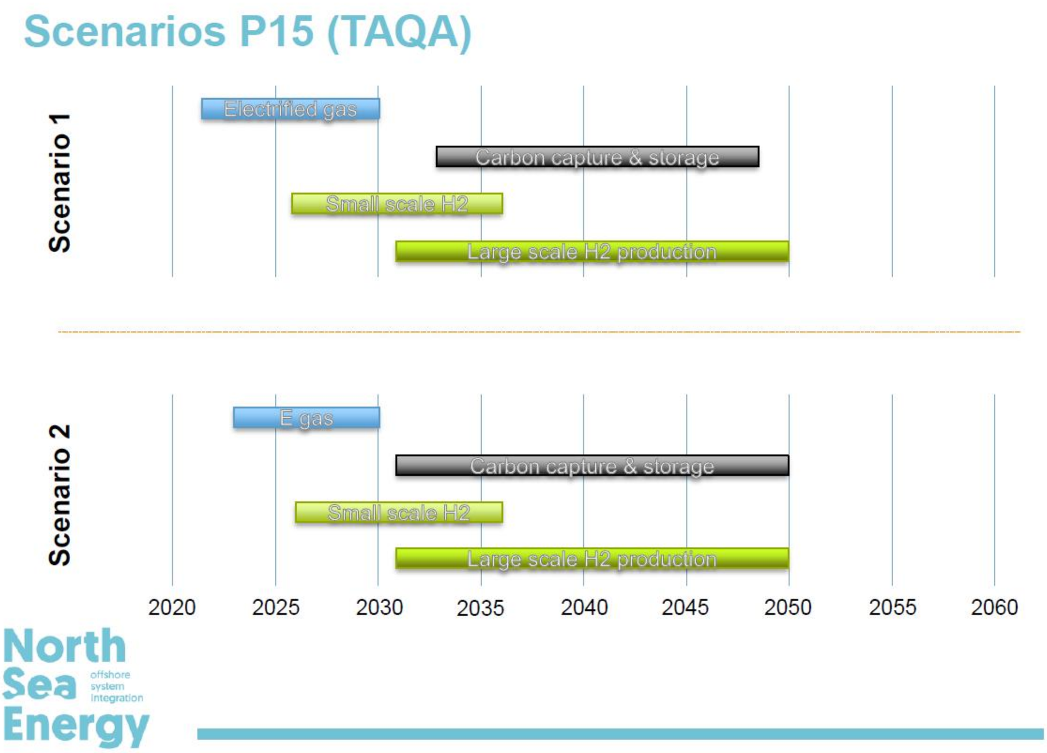


Figure 2-7 - Scenarios for P15

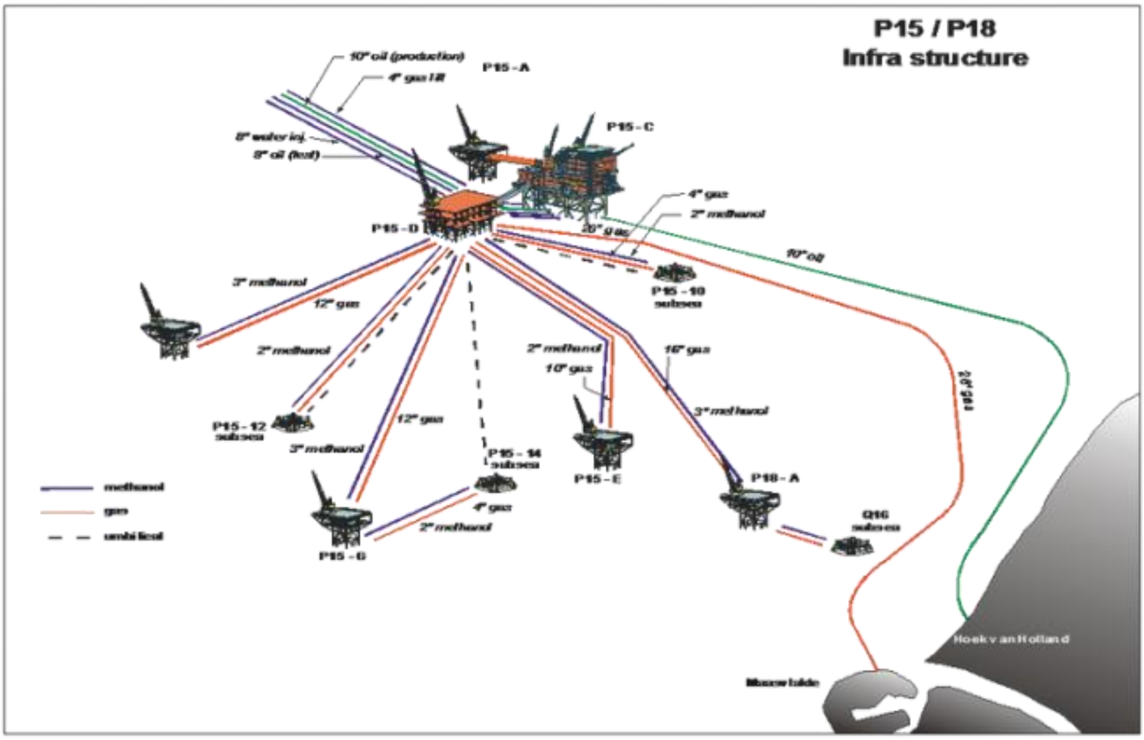


Figure 2-8 - P15-P18 infrastructure (TAQA, 2017)

3 Policy framework

Reference is made to work package B of NSE II which analysed the legal barriers and drivers for offshore system integration. This study provides (i) an overview of relevant international maritime law, (ii) an analysis of the current Dutch legislation in place pertaining to offshore hydrocarbons production, wind energy activities, carbon storage and hydrogen production, and (iii) an overview of possible barriers and drivers in realizing an integrated and hybrid offshore energy system.

3.1 National North Sea Policy

The North Sea has a special place in the Dutch water system. A large number of (user) functions make use of the North Sea and must be assessed in an integrated manner to make the best possible use of the limited space. The current North Sea Policy Document 2016-2021 (Ministry I&M and EZ, 2016) offers an integral framework for the use of the space on the North Sea. It describes how assessments are made for all permit applications for designated uses on the North Sea. Based on this framework, choices are made about how the space on the North Sea is used.[1]

Oil and gas extractions
Oil and gas extraction, including the requisite pipelines, are regarded as activities of national interest. National policy is geared towards making the most of the potential of the offshore oil and gas reserves available. Use is regulated primarily by means of permit issuance within the framework of the Mining Act (Mijnbouwwet). Platforms no longer in use must be removed. Shipping is not permitted around existing oil and gas platforms, with a minimum safety zone of 500 meters (Mining Act). Where platforms with a helipad are concerned, the starting point is an obstacle-free zone of five nautical miles to guarantee access to these platforms.

Cables and pipelines
To promote efficient use of space in the North Sea, electricity cables, telecommunications cables and pipelines will be bundled as much as possible. Offshore substations owned and operated by TenneT will have to ensure that the growing quantity of energy generated by wind farms is efficiently connected to the grid on land. There is a maintenance zone of 500 meter around cables and pipelines in the North Sea, and sand may not be extracted within this zone. Research has shown that in principle, when building wind farms, a 500-metre zone should be adhered to for pipelines and electricity cables and a 750-metre zone for telecommunications cables. With a view to efficient use of space, maintenance zones for cables and pipelines can be reduced where possible.

Wind energy
Areas have been designated where the construction of wind farms will be allowed. Outside of designated areas the Dutch Government does not grant permission for wind farms. Within designated wind energy areas, the Dutch Government only grants permission for wind farms to be built within the bounds of the regulations for wind farms. Use is regulated primarily by means of permit issuance within the framework of the Wind Energy at Sea Act (Wet windenergie op zee). The development of energy in the North Sea is closely related to developments in the field of oil and gas extraction, energy storage and transport and CO_2 storage, and will be further detailed in the new North Sea 2030 Strategy.

CO_2 storage

[1] The Water Act is the legal basis for the national water plan. This plan outlines the national water policy, including the spatial aspects of the different uses of national water bodies, such as the North Sea. Moreover, the national water plan contains a separate annex outlining the North Sea policy of the Dutch government (*beleidsnota Noordzee*). Source: NSE II work package B.

CO_2 storage, as a temporary solution on the path to a fully renewable energy supply, is an activity of national interest. Having sufficient space for CO_2 storage in vacant gas and oilfields or in aquifers and for the accompanying pipelines is a prerequisite. This could potentially be done throughout the EEZ and territorial waters. To facilitate CO_2 capture and storage, part of the pipeline infrastructure will have to be renewed. Existing oil and gas pipelines can only be used once the fields in question have been completely exhausted. At present, the Mining Act mandates the decommissioning of depleted fields (removal of platforms not in use). In the CCS Roadmap (Gemeynt, 2018) is assessed whether policy changes would be desirable in this respect (see also paragraph 3.3).

3.2 Offshore Wind Energy Road Map 2024-2030

The Dutch Government has announced plans to realize new wind farms in the North Sea with a total additional capacity of 7 GW during the period 2024 to 2030. In addition to the 4.5 GW which will be installed up to and including 2023 (first Offshore Wind Energy Road Map up to 2024), this would increase the total installed capacity of offshore wind farms in the Dutch North Sea to 11.5 GW in 2030.

Table 3-1 – Dutch offshore wind road map

Dutch wind energy area	Capacity	Tender in	Operational in
Borrsele I and II	700	2016	2020
Borssele III and IV	700	2016	2020
Hollandse Kust Zuid I and II	700	2017	2021
Hollandse Kust Zuid III and IV	700	2018	2022
Hollandse Kust Noord	700	2019	2023
Hollandse Kust West	1400	2020/2021	2024/2025
Ten Noorden van de Wadden	700	2022	2026
IJmuiden Ver	4000	2023 / 2026	2027/2030
Tbd	900	tbd	tbd

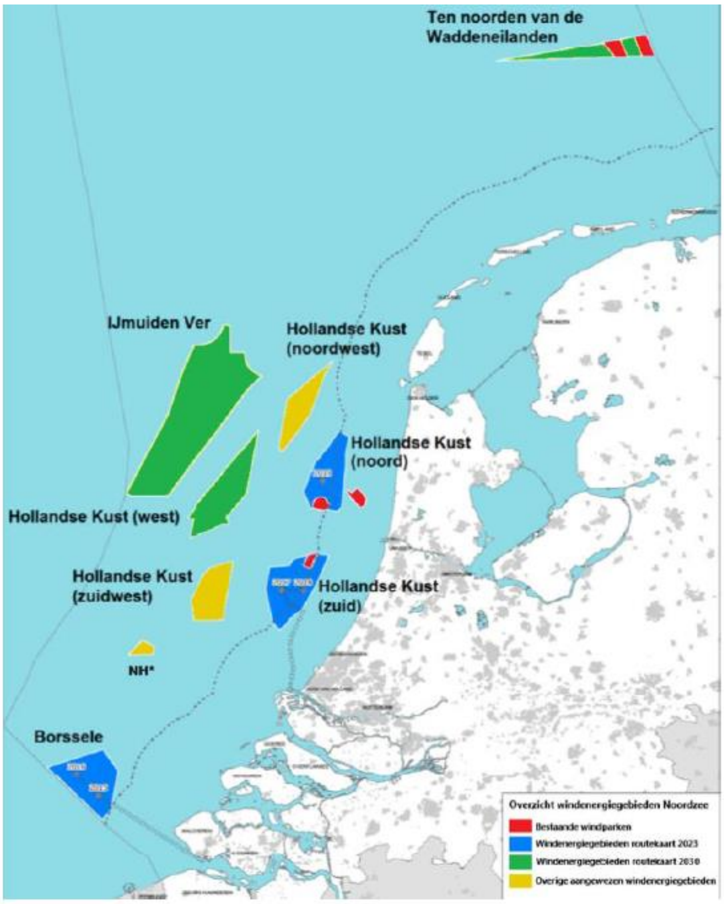


Figure 3-1 – Overview of wind energy areas in the Dutch EEZ (Source Offshore Wind Energy Road Map 2024-2030)

3.3 CCS Roadmap

Almost all (global) scenarios show that the achievement of the climate objective (climate agreement, Paris 2015) to limit global warming to a maximum of two degrees is not possible without the use of CCS (Carbon Capture and Storage). The Ministry of Economic Affairs and Climate Policy (EZK) has asked De Gemeynt, CE Delft and Margriet Kuijper Consultancy to draft a roadmap for CCS (Gemeynt, 2018). This roadmap provides a long-term perspective on the development opportunities for CCS in the Netherlands and possible short-term actions.

3.4 Hydrogen Roadmap

Hydrogen production is a relatively new development, and no clear policy is yet available. The Ministry of Economic Affairs and Climate Policy (EZK) asked TKI Nieuw Gas[2] to draft a roadmap for hydrogen. This roadmap addresses the technical and non-technical actions that need to be taken to introduce hydrogen into the Dutch energy system. Currently, there is no central and structural policy that could contribute to the development of hydrogen. A significant proportion of safety regulations and the associated safety requirements are based on the large-scale use of hydrogen as an industrial gas and as a feedstock in the chemical industry.

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[2] TKI Nieuw Gas is a top consortium for knowledge and innovation within the top sector Energy. Funded by the Dutch Government to accelerate developments within the gas sector.

It would be desirable to develop an adapted safety regulations and requirements that meets the applicable standards but at the same time take these new applications into account. (Gigler & Weeda, 2018)

3.5 North Sea 2030 strategy

The current North Sea Policy will expire in 2021. A new '2030 North Sea Strategy' is currently being prepared. This new policy will give direction to the extensive developments in the North Sea, now and in the decades ahead. The ambition is to coordinate developments in energy, food supply and nature protection and restoration, with each other and with all the other designated uses, particularly regarding the use of space.

4 Approach and methodology

To assess the (possible) environmental impacts of the system integration options (as described in chapter 2), a breakdown in activities is prepared. In this chapter, these activities and sub-activities are described. Furthermore, the approach and methodology of the strategic environmental assessment is detailed.

4.1 Breakdown of options in activities

The activities and sub-activities associated with the options for system integration are shown in Table 4-1. There are similar sub-activities for the different system integration options. To allow for efficient assessment of the activities, these have been rearranged per key components of the infrastructure (cable/pipeline, platform and well/reservoir, see Figure 4-1) and per development phase (construction, and operation). Furthermore, clustering of the (sub-)activities gives insight in the activities for a specific component and during a specific phase, which ensures a complete and integrated assessment of the environmental impacts of system integration, see Table 4-2.

Table 4-1 - Breakdown of activities and sub-activities.

Option	Activity	Sub-activity
Electrification	Connection to e-grid and platform electrification	Shipping of construction material and personnel Cable laying Construction works at / of platform
	Natural gas production (electrified)	Shipping of O&M equipment and personnel Natural gas transportation Natural gas production electrified
CO_2 transport and storage	Conversion/addition of CO_2 transport and storage assets	Shipping of construction material and personnel Pipeline laying Construction works at/of platform Well workover
	Operation of CO_2 transport and storage assets	Shipping of O&M equipment and personnel CO_2 transport CO_2 compression and heating CO_2 venting CO_2 storage
Green hydrogen production	Conversion/addition of green hydrogen assets	Shipping of construction material and personnel Pipeline laying Construction works at/of platform
	Operation of green hydrogen assets	Shipping of O&M equipment and personnel H_2 transport H_2 production

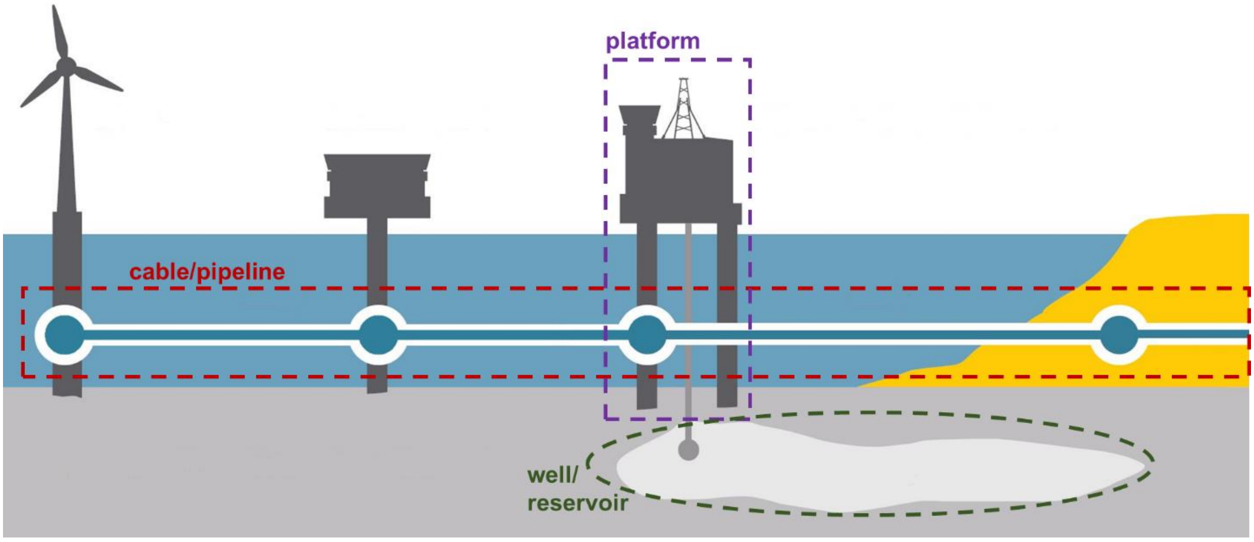

Figure 4-1 – Key infrastructure components of offshore system integration options (modified figure, based (TNO, 2018)

Cable / Pipeline:	Activities related to new or existing pipelines and or cables
Platform:	Activities executed on the platform (including the possible construction of a new platform) and the pipeline to the reservoir, until the connection to the well/reservoir
Well/reservoir	Activities related to the well/reservoir

Table 4-2 - Sub-activity by component and phase

Sub-activity	*Description*	Component	Phase
Shipping	*Shipping activities for cable and pipeline laying, transport to and from platform.*	Cable/pipeline	Construction
Cable laying	*For an e-grid connection a cable from the TenneT transformer station to the platform need to be established.*		
Pipeline laying	*Two ships needed, one that will place the pipeline, one that will cover the pipeline with sand.*		
Electricity transportation	*By/through (existing) cables, from TenneT transformer station to platforms/ onshore*		Operation
Natural gas transportation	*By/through (existing) pipelines, from platform to onshore*		
CO_2 transportation	*Existing pipeline needs to be isolated. Pure (pressurised) CO_2 will be transported from a location (onshore/ 'afvanglocatie') via a new/existing pipeline to the platform.*		
H_2 transportation	*Via new (and existing) pipelines*		

Constructions works at/of platform	*Remove or replace existing constructions/machinery /equipment for other use. Pipeline system will be equipped with safety valves (to be able to close off the pipeline for maintenance or in the event of malfunctions.)*	Platform	Construction
Natural gas production	*Propulsion/operation by gas-fuelled equipment. Using existing well.*		Operation
Natural gas production electrified	*Propulsion/operation powered by electricity. Using existing well.*		
CO_2 compression and heating	*The pipeline that supplies the CO_2 is transported straight up from the seabed to the platform. CO_2 will be heated and compressed on the platform before injecting in the old gas field, using special equipment on the platform.*		
CO_2 venting	*Releasing CO_2 in case the pressure will reach its maximum. Via pipeline and equipment on the platform.*		
H_2 production (operational)	*Electrical energy (from wind farms) converted to H_2 on the platform including the required production processes like desalination of seawater*		
Well workover	*Replacing valves (instead of gas out of the field, CO_2 need to go in the field)*	Well / reservoir	Construction
CO_2 storage	*CO_2 pumped in the old gas field, using existing well*		Operation

4.2 Assessment approach

In this strategic environmental assessment, the system integration options are first assessed as stand-alone options (Chapter 5, 5.14 and 0). This is followed by an assessment of the different system integration scenarios (combination of options) per case study (Chapter 7). This two-step approach (assessment of stand-alone options, followed by scenarios) provides insight in the environmental impacts of each specific system integration option, but also of the scenarios for the specific case studies.

The following assessment approach is used:

- The description of the existing situation and the autonomous development is used as reference to determine the impacts of the proposed system integration options. The reference situation is further detailed in paragraph 4.3.
- In the description of impacts a distinction is made between temporary impacts and permanent impacts. The focus is on permanent, irreversible impacts.
- The impacts are assessed for construction/transition, operations and decommissioning.

- The impacts are described in a quantitative way, as much as possible, based on publicly available information. Where not possible or less relevant the description of impacts is qualitative based on expert judgement.
- Following the *People, Planet, Profitability* approach an assessment framework is prepared. This framework structures the various environmental aspects (for more detail see paragraph 4.4).
- Tables show the scores per system integration option for the different environmental aspects. Note that by comparing the option with the reference situation, the score of the reference situation is always zero.
- In case no impact is possible, the environmental aspect has a grey marking.
- Cumulative impacts are indicated where relevant.
- The impacts assessment uses a scoring system with seven categories, see the details below:

+++	Strongly positive impact, the development has clear added value
++	Positive impact, clear improvement compared to the reference situation
+	Moderately positive impact, no significant improvement
0	No impact / Neutral
-	Moderately negative impact, no disrupting effect
- -	Negative impact, mitigation measures should be investigated
- - -	Strongly negative impact, effect is outside of the judicial framework
	No impact possible

4.3 Reference situation

The reference situation is the situation which is used to compare and assess the impact of the system integration options and scenarios on the environmental aspects. For a regular strategic or project EIA the reference situation is the existing situation combined with the autonomous development. As this study aims to assess the environmental impacts of possible system integration options and scenarios the reference situation is based on assumptions. Below the assumed reference situation is detailed for both the system integration options (electrification, CCS and H2 production) as well as the case study scenarios (K5, K14, P15-P18).

System integration options
When considering the system integration options as stand-alone options the reference situation for the options differ, as the options have different time scales (see the assessment in Chapter 5, 5.14 and 0):

Electrification: The assumption is that a platform will only be electrified if it is still producing gas (and will continue producing for a considerable amount of time). Therefore, the reference situation for the electrification option is that the platform and related infrastructure are still in place and operational.

CCS: The assumption is that after natural gas production has ceased the platform is not decommissioned, but that the opportunity remains to use the infrastructure for other purposes. The reference situation for CCS is that platforms and their related infrastructure are still in place, but no longer operational (mothball situation). The well is plugged but not abandoned.

H_2 production: The assumption is that after natural gas production has ceased the platform is not decommissioned, but that the opportunity remains to use the infrastructure for other purposes. The reference situation for H_2 production is that platforms and their related infrastructure are still in place, but no longer operational (mothball situation). The well is plugged but not abandoned.

System integration scenario's

The system integration scenarios for the three case studies each start with electrification, followed by a combination of small/large scale H2 production and or CCS:

K5: *Electrification & CCS hub*
K14: *Electrification & small scale H_2 production & large scale H_2 and/or CCS hub*
P15-P18: *Electrification & small scale H2 production & large scale H_2 production combined with CCS*

The scenarios have different timing options, as detailed in work package A of NSE II. For this study the order of system integration options will be considered, whereas details related to the exact timing of the start of the different system integration scenarios is not directly relevant for this high-level assessment of environmental impacts.

Hence, when considering the system integration scenarios, the reference situation is similar to the electrification option (see the assessment in Chapter 7). Accordingly, the assumption is that a platform will only be electrified if it is still producing gas (and will continue producing for a considerable amount of time). Therefore, the reference situation for the system integration scenarios is that the platform and related infrastructure are still in place and operational.

4.4 Assessment framework

Sustainable development is development that meets the needs of the present without limiting the ability of future generations to meet their own needs. There are three sustainable development capitals, on which the criteria used in this assessment are based: PLANET, PEOPLE, PROFITABILITY, also known as the 3 Ps. Using this approach allows for an integrated assessment of the possible environmental impacts. The 3 Ps' approach is in line with the approach used in the Strategic Environmental Assessments (planMERren) prepared for the designation of the offshore wind energy areas.

Following the *People, Planet, Profitability* approach an assessment framework is prepared, as shown in Table 4-3. This framework gives an indication which component could have a possible impact on the various environmental aspects. The environmental aspects - and their possible impact - are presented in chapter 5.

Table 4-3 – Assessment framework

	Theme	Components of system integration options	
		Cable / Pipeline	Platform
Planet	Nature	X	X
	Seabed	X	X
	Water quality	X	X
	Sound	X	X
	Air / Smell	X	X
	Electromagnetic fields	X	-
	Materials and waste	X	X
People	Landscape and light	X	X
	Cultural heritage and archaeology	X	X
	Sustainable energy use	X	X
	Traffic	X	X

	Operations safety	X	X
Profitability	Other spatial uses	X	X

5 Environmental aspects

The possible impacts on the environmental aspects are described in this chapter, according to the planet, people and profitability approach. Per environmental aspect first, the regulatory framework is drawn, followed by a brief description of the current situation. With this information, the impacts are assessed. A distinction is made between the impacts related to construction phase and impacts related to operational phase.

5.1 Nature

5.1.1 Regulatory framework for nature

Flora and fauna is protected under a number of European regulations, including the European Birds Directive and the European Habitat Directive, which are translated into the Dutch Nature protection law (Wet Natuurbescherming). Activities in the North Sea with possible impacts on nature must comply with the Nature protection law, which is also applicable to the Dutch EEZ. Furthermore, specific nature areas (Natura 2000 areas) are protected to ensure availability of valuable habitat, regulated under the European Habitat Directive.

5.1.2 Current situation for nature

Protected areas (N2000)
Figure 5-1 shows the protected nature areas (Nature 2000 areas (N2000)) present at in the Dutch EEZ. None of the case studies is located in a N2000 area, but external effects could cause effects on the conservation goals of these N2000 areas. In all N2000 areas, management and design measures have been taken to achieve the conservation goals of the respective areas. These measures are taken in the context of the N2000 management plans and the Programmatic Approach to Nitrogen[3] (PAS). The natural quality of the N2000 areas is therefore expected to improve over time.

Phytoplankton and zooplankton
Impacts on phytoplankton and zooplankton as a result of the implementation of the system integration options are not expected to be noticeable on the population level of the NCP and therefore will not affect the food chain. Hence, these species groups are not included in this study.

Benthos
Benthos is the collective term for crabs, lobsters, shellfish, worms and echinoderms that live in or on the seafloor and feed on phyto- or zooplankton. These benthic animals are local and their operating radius is very limited. Diversity and biomass of benthos decrease with the distance to the coast except for the Dogger Bank and the Oyster grounds. In the transitional zone (5-20 km from the coast) the soil fauna is characterized by a relatively high density and biomass of crustaceans and further seaward by worms (Van Scheppingen & Groenewold 1990).

Fish and fish larvae
The highest density of fish occurs in the transition zone between salt and freshwater, due to the nutrient-rich environment. The coastal zone, Wadden Sea and the Southwest Delta are important breeding and growing grounds for different fish species. Ter Hofstede & Baars developed a cumulative distribution map in 2006 of all migratory fish on the Dutch Continental Shelf. In the study area there may be migratory fish that are

[3] Less nitrogen, more resilient nature and economic development are the goals of the Programmatic Approach to Nitrogen (PAS). For many years there has been a surplus of nitrogen in many Natura 2000 areas (ammonia and nitrogen oxides). This is harmful to nature. With the implementation of PAS the Dutch government aims to reduce the nitrogen emissions on N2000 areas.

protected under the Habitats Directive, but Ter Hofstede & Baars conclude that the NCP is not very important for this group.

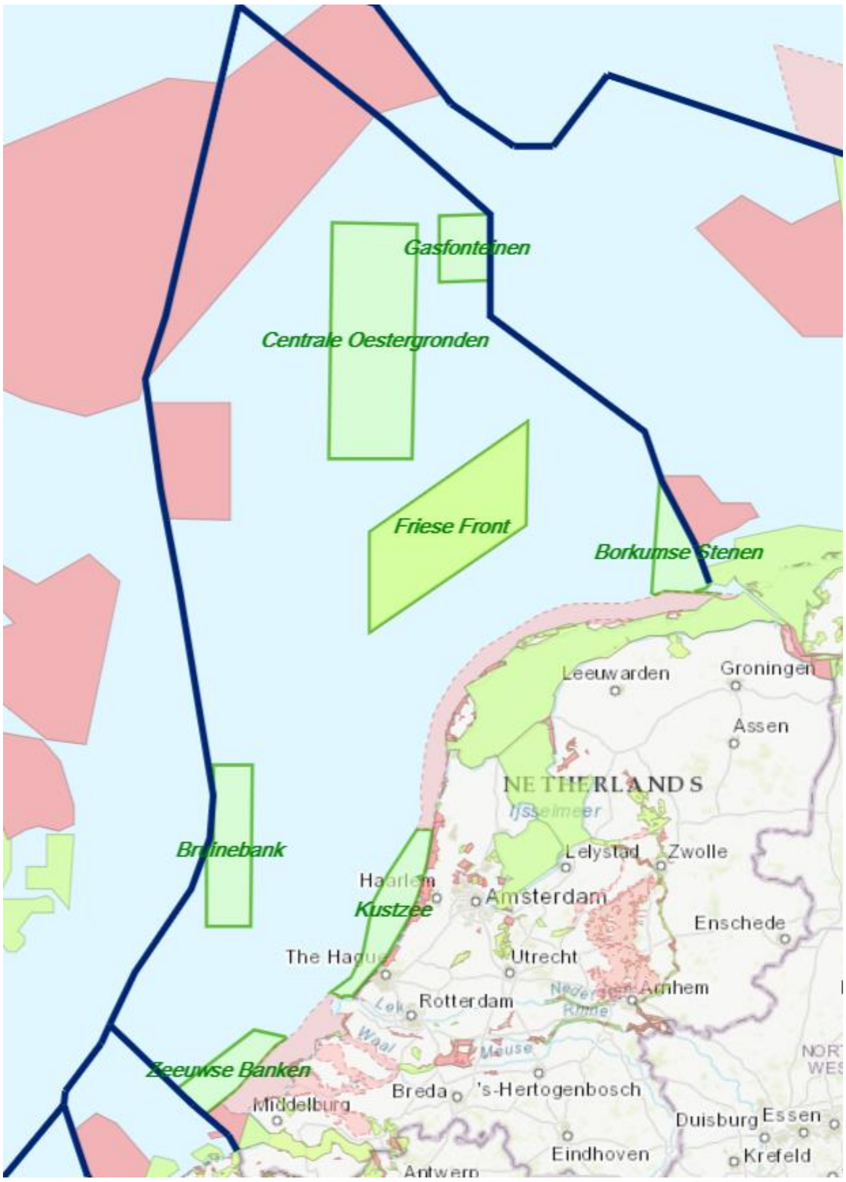

Figure 5-1 - N2000 areas in Dutch EEZ (source RHDHV North Sea Web viewer)

Sea mammals

Common and gray seals are protected species under different conventions and qualified as protected species under the European Habitats Directive. The Wadden Sea is an important area for the Dutch seal population, furthermore there is also a subpopulation in Zeeland and South Hollandse Delta. Accordingly, there is a migratory route along the coast between the Wadden and Delta areas. Most seals are concentrated at the North Sea coast of the Wadden Islands. Recent distribution dates of the gray seal are given in Brasseur et al. (2014). There are no reproduction or permanent resting places for seals in the study area. However, low numbers of seals, especially the gray seal, could occur to forage.

The harbor porpoise is protected under various conventions, such as the Berne Convention and the Bonn Convention and is qualified as a protected species under the European Habitat Directive. The Dutch North Sea is used for foraging (Brasseur et al. 2008, Camphuysen & Siemensma 2011). The distribution maps of Geelhoed et al. (2013, 2014) show that porpoises occur in the study area. There are no breeding or resting places of the porpoise in the study area. The Dutch government has estimated the Dutch population at roughly 51,000 animals and this is the number on which impact calculations are based. The Ecology and Cumulation Framework (KEC) gives densities of porpoises per sub-area and per season (KEC 2018).

In the last decades, 17 species of whales and dolphins have been observed alive in the southern North Sea (Camphuysen & Peet 2006). On the NCP, most whales are scarce or extremely rare; only the minke whale occurs regularly in the North Sea. Deep-diving species such as beaked snouts and gray dolphins avoid the shallow North Sea and are only known for strandings. The white-nosed and white-tailed dolphins reach the southern boundary of their native range in the North Sea. For southern species such as bottlenose dolphins and ordinary dolphins, the North Sea lies at the northern boundary of their native range. Only the minke whale, white-beaked dolphin and bottlenose dolphin are considered indigenous (Geelhoed & Polanen Petel 2011).

Birds
There are several bird species in the North Sea that are sensitive to the light of offshore platforms, including locally foraging and migrating seabirds (divers, guillemots, alken, gannets, gulls, hunters, divers and sea ducks) and foraging and migratory land birds (songbirds, waders and geese). Some of these birds are protected under the European Birds Directive.

Migratory birds
There are roughly two relevant migratory movements across the North Sea: the east-west and north-south movements, which, depending on the location of descent and destination of the birds, can be subdivided further (Lensink & Van der Winden 1997). The width of the migration zone is variable, depending on the type of bird species, season and weather conditions (Camphuysen & Leopold 1998). The coastal areas are important for orientation, rest and foraging. Birds originating from Scandinavia and / or birds that are not bound to the coastal zone for foraging often fly over the open ocean. For the study area, the following species are particularly important: curlew, black tern, small swan, three-toed sandpiper, starling, coot and the black-tailed godwit.

Colony breeding coastal birds
In the study area, the following colony-breeding birds can occur: northern petrel (foreign colonies), cormorant, large tern and lesser black-backed gull. Northern fulmars forage in Dutch waters from breeding colonies in the United Kingdom and Germany. The northern petrel is mainly found in late summer and autumn with the largest numbers in August (Poot et al. 2011).

At sea there are mainly foraging or resting cormorants from breeding colonies on Vlieland, Zwanenwater, the dunes of Castricum, and Voornes Duin. Cormorants are increasingly being observed at sea, up to a maximum of 60 km from the coast, as the presence of resting points at sea are increasing, such as platforms and wind turbines. This species occurs year-round, but especially in April through September large numbers occur in the coastal waters (Poot et al. 2011).

Large terns can occur in the study area to forage. They breed almost exclusively on difficult to reach islands and salt marshes in the Wadden and Delta area. Large terns are mainly present outside of the breeding season from March to mid-November. In the winter months up to a few dozen can stay in the Delta area.

Lesser black-backed gulls breed at different locations along the Dutch coast. The focal points are on the Wadden, Southwest Delta (including Maasvlakte) and IJmuiden and in some cities along the coast. The total Dutch population is 82,000 breeding pairs (Prins et al. 2008). The lesser black-backed gulls arrive from their wintering grounds in southern Europe in March and leave in September. This temporal distribution is also visible in aircraft counts on the North Sea with the largest numbers in the period from April to July (Poot et al. 2011).

Non-breeding birds
In the Netherlands, shellfish-eating sea ducks, such as eider, topper and black sea duck, spread throughout the coastal zone in the winter months. The highest densities are seen within the 20 m depth line. The study area does not overlap with the preferred area of the black sea ducks or eiders and toppers so no significant numbers are expected.

In the category of fish eaters on the open sea there are species of birds that are not breeding, such as alk, guillemot, great hunter and gannet (colonies in the United Kingdom and Germany) that stay at sea and forage. Seagull species are also included among the fish eaters. The spread of seagulls, such as herring gull, great black-backed gull and lesser black-backed gull, is often tied to that of fish cutters, because they forage on the fish that is thrown overboard. They know, depending on the species, a more or less coastal distribution. For example, the great black-backed gull has the highest numbers along the coast in autumn and winter (Lindeboom et al. 2008).

The great skua has an even distribution across the NCP (Lindeboom et al. 2008). The largest numbers are counted on the NCP in the period August / September, with peak values from 1500 to 2900 individuals. The species is a breeding bird only in Europe and stays on open sea for a large part of the year. In the autumn the great skua migrates via the coast to the southwest European and northwest African open sea and breeds in northern Europe (Jak et al. 2009).

Guillemots and razorbills are mainly found in the winter, spreading over the entire North Sea (KEC 2015). The coastal areas are of secondary importance for these species compared to fish-rich areas such as the Frisian Front, Dogger Bank, Central Oyster Grounds and the Brown Bank.

In addition, there are divers and grebe-like fish eaters that are spread out on the open sea. The red-throated diver is present in the North Sea from September to April. This species is mainly observed in small groups of 10 to 20 birds and has a predominantly coastal distribution in Dutch waters (Poot et al. 2011), just like the pearl diver. These species are very shy. Since there is already activity in the study area, these species are expected to hardly occur in the study area.

Bats
Observations from offshore platforms in the North Sea show that various bat species migrate across the North Sea between the British Isles and the European continent. Potentially relevant species are Nathusius' Pipistrelle (Pipistrellus nathusii), Common Noctule (Nyctalus noctula) and Particoloured Bat (Vespertilio murinus) (Boshamer & Bekker 2008). In recent years new research focussed on obtaining more information about the migration of bats across the North Sea, this has shown that that there is regular seasonal migration of bats over sea, has provided an estimate of migratory population sizes and an indication of seasonal and spatial migratory patterns (including Limpens, et al, 2017 and Lagerveld, et al 2017). Hence, a number of species of bats can be found in the study area.

5.1.3 Type and extent of the impacts on nature

Impacts related to construction (--,-)
During the construction of new pipelines or cables, dredging activities will take place, which could disturb protected species of flora and fauna. Compared to the reference situation, the impact of these additional construction activities will be negative (- -).

Impacts related to operations (- /0, 0 /-)
In case of the electrification option and the green hydrogen production option there is an impact on nature values caused by electromagnetic fields. During operations when electricity is transported (either for electrified natural gas production, or for green hydrogen production) electromagnetic fields will occur around the cables. This could have a moderately negative effect on (ground) fish, sharks, rays etc, as these species are able to detect electromagnetic fields and use these for orientation. It is theoretically possible that the orientation and migration of these species may be influenced by limited change in magnetic fields caused by the electrical

cables[4]. It can be assumed that the influence is local and does not extend to more than a few metres on either side of the cable route. No significant impact on susceptible organisms are to be expected, but electromagnetic fields are present in case of operation and therefore scored as moderately negative for both the electrification option and production of green hydrogen (-).

For both the CCS and green hydrogen option, the reference situation, to assess the environmental impacts, is a situation where the platforms have ceased to produce natural gas. When platforms will be taken into operation again this could cause disturbance of fauna in the local vicinity of the platform, caused by shipping movements, industrial operations and human activity on and around the platform. Compared to the reference situation the impact is not considered significant and is therefore scored as a moderately negative impact (-).

It should be noted that in case of implementation of one of the system integration options or a full system integration scenario this would require the necessary permit applications. This could include an exemption related to the Nature Protection Law. In order to determine if such an exemption would be required an Appropriate Assessment should be conducted to determine the extent of the impacts on protected areas and species.

5.2 Seabed

5.2.1 Regulatory framework for seabed

The old Soil Protection Act (in Dutch: Wet bodembescherming (Wbb)) has been transferred to the Water Act. The Water Act regulates the maintenance and management of surface water and groundwater and improves the coherence between water policy and spatial planning. The Water Act is applicable to the Dutch EEZ. Offshore Rijkswaterstaat is the responsible authority for the Water Act, any possible waterbed contamination is subject to the Water Act.

5.2.2 Current situation for seabed

The sea is continuously in motion as a result to waves, tide, currents and wind. Due to these water motions, sand and silt on the seabed will get in suspension and will be transported. This sediment transport has impact on the seabed: height, shape, formation and sediment concentration in the water column. Water depth is a critical factor determining the impact of natural processes on the seabed. The water depth around the platforms of the K14 area is about 20-30 m, large sandbanks are present (length of several kilometres and bank heights vary between 1-10 m). The area of the P15-P18 contains sand waves in the seabed, varying from 4-6 m as well as sand waves higher than 6 m. No sand waves can be found further up north in the K5 area. In every case the slope of the seabed is smaller than 1:1000. (Rijksoverheid, 2018)

5.2.3 Type and extent of the impacts on seabed

Impacts related to construction (-)
For every system integration option new cables or pipelines need to be constructed. It is expected that a strip of about 10 m width will be disturbed (Royal HaskoningDHV, MER platform Q10 en pijpleidingen op zee, 2016a). Furthermore, the cable trench need to be dredged through possible sand waves to ensure the cable or pipeline will be laid at sufficient depth. Both activities lead to a local small morphological disturbance. In view of the large spatial scale of sand waves and the natural impacts storms have on these sand waves, this disturbance is not considered significant. Due to the dynamics of the sand and the speed of movement of the

[4] Note, the effects and impact of the electromagnetic fields on species is currently investigated in Wozep (Wind on Sea Ecological Program, in Dutch: Wind op Zee Ecologisch Programma). This is a five-year research program that was launched to investigate the knowledge gaps concerning the ecological effects of offshore wind energy.

sand waves, it is expected that any impacts of the intervention will no longer be noticeable within one year from construction.

As these activities are additional to the reference situation, there will be some impact on the seabed due to transport activities and activities around the platform (extra pipeline or cable needs to be connected to the platform). The impact on the seabed during construction phase is scored moderately negative (-) for every system integration option.

Impacts related to operations (0)
During operations existing or newly laid cables/pipelines are in use and the activities on the platform do not have any interaction with the seabed. Therefore, no impacts on the seabed are expected, and scored (0).

5.3 Water quality

5.3.1 Regulatory framework for water quality

The European Marine Strategy Framework Directive (in Dutch: ‘Kaderrichtlijn Mariene Strategie’) provides a legal framework for the protection and preservation of the marine environment, the prevention of its deterioration and, where possible, the restoration of that environment in the areas where it has been adversely affected. In addition, it aims at preventing, reducing and eliminating pollution. The ultimate objective is to achieve or maintain "good environmental status of the marine environment" by the year 2020. The Netherlands has taken this legal framework into account as part of the Dutch Water Act. (Royal Haskoning, 2011)

The European Marine Strategy Framework Directive (MSFD) aims to protect and restore Europe's seas and oceans and to promote sustainable use. The MSFD requires each European member state to adopt a marine strategy. This strategy must be aimed at protecting, preserving and restoring the marine environment (good environmental status), while at the same time guaranteeing sustainable use of the North Sea. Member States should take the necessary measures to achieve this ambition in their marine waters. They must cooperate as EU Member States and with other countries in their marine region. The framework directive recommends making as much use as possible of existing regional sea conventions. Following approval by the European Parliament, the European Commission issued the European Marine Strategy Framework Directive in 2008. In 2010, the Netherlands included the effects of the directive in the Water Decree under the Water Act. (Noordzeeloket, sd)

5.3.2 Current situation for water quality

The water quality of the North Sea is determined by the concentrations of algae, suspended parts (sludge in particular) and atrophying and polluting substances. The floating parts in the water are important for the bonding and transport of many harmful substances. Pollutants include heavy metals (including cadmium, zinc and mercury), inorganic compounds with chlorine / bromine, organic micro-pollutants (aromatic hydrocarbons, dioxins, PCBs, etc.), plasticisers and flame retardants. The above pollutants are known to be harmful to bottom-dwellers and marine mammals. The major rivers in the Netherlands play an important role in the water quality of the North Sea as the rivers flow into the North Sea. In addition, air transport also plays a role and pollution occurs because of industrial activities at sea (such as shipping, platforms, etc.) (Royal HaskoningDHV, PlanMER en PB windenergie op zee binnen 12mijlszone, 2016b).

5.3.3 Type and extent of the impacts on water quality

Impacts related to construction (-)
In the event of disturbance of the seabed related to the construction of pipelines or cables, part of the sediment (sludge) will be suspended and the concentration of suspended matter in the water column will temporarily increase. This increase can be several hundred mg/l, which is comparable to the increase of the concentration of suspended matter during a storm (Royal HaskoningDHV, MER platform Q10 en pijpleidingen op zee, 2016a).

During construction, the impact on the water quality (due to laying pipelines/cables) is temporarily and therefore scored moderately negative (-).

Impacts related to operations (0)
All system integration options make use of closed systems to prevent environmental pollutants, such as oils, from entering the surrounding environment. There is a risk that these closed systems fail, but this risk is not different compared to the reference situation. The impact on the water quality is therefore comparable to the reference situation (0).

For the green hydrogen option, by-products (salt/natriumchloride and 'waste', i.e. organisms, plankton) are produced that need to be disposed or transported from the platform. In case of disposal of these by-products, the salinity and concentration of 'waste' will increase. It can be expected that the change in concentration is insignificant as the disposed amount would be small compared to the vast volume of the North Sea. Due to currents, the local concentration will be spread quickly. In case of collection and transportation of the by-products from the platform, it would not have any impact on these aspects. Therefore, in both situations the impact is scored as neutral (0).

5.4 Underwater sound

5.4.1 Regulatory framework for sound

The Marine Strategy Framework Directive (in Dutch: 'Kaderrichtlijn Mariene Strategie' (KRM)) is applicable in the regulation of underwater noise. The aim of this directive is to protect and improve the European marine environment. The MSFD enforces measures in all kinds of areas. One of these areas is underwater noise. Measures will have to be taken to limit harmful underwater noise. The Dutch Government uses the knowledge and proposals from the international maritime convention OSPAR, including those for underwater noise, to implement the KRM in practice. (Noordzee, 2008)

5.4.2 Current situation for sound

Several sources are producing underwater sound in the North Sea, especially underwater sound. This sound is a result of, among others, the intensively navigated North Sea (many ship movements) and the activities on the platforms (i.e. the diesel/ gas generators, production of gas (pumping activities)), but also includes the piling noise generated by construction of offshore wind farms.

5.4.3 Type and extent of the impacts on underwater sound

Impacts related to construction (--,-)
During the construction of new pipelines or cables, dredging activities will take place, which will cause underwater sound. Compared to the reference situation, the impact of these additional ship movements and dredging activities will be negative (- -).

Impacts related to operations (+,0)
During operations, in the electrification option, the sound would be comparable with the current natural gas production (reference situation). The electrical driven installations are expected to cause less noise, which will have a positive impact. Therefore, the impact on sound is scored as moderately positive (+) in case of electrification (based on expert knowledge).

For both the CCS and the green hydrogen option, the reference situation is a non-operational platform (see paragraph 4.3 for argumentation as regards the reference situation). The platform will be back in operation, generating sound in its direct vicinity only. Mitigation measures can be applied to reduce the impact, such as isolation of installations and equipment. Hence, the impact is minimal and considered neutral (0).

5.5 Air emissions

5.5.1 Regulatory framework for air emissions

Since 15 November 2007, the most important provisions on air quality requirements have been included in the Environmental Management Act (Chapter 5, Title 5.2 Wm). However, in the EEZ, only the provisions governing greenhouse gas emissions are applicable. Pertaining to greenhouse gas emissions, all establishments containing one or more greenhouse gas installations are obliged to hold an emissions permit issued by the Dutch Emissions Authority. (based on NSE II work package B)

As part of the Mining Act, mining installations require a special environmental mining work permit. Without such a permit, the erection and operations of a mining installations is prohibited. The permit may contain restrictions with the aim of protecting nature or the environment, including air quality requirements. Moreover, pertaining to offshore mining works, so-called mining installations, ministerial approval is needed before a platform for production or storage purposes can be put in place. This approval will be granted if the platforms adheres to a set of technical standards and norms (based on NSE II work package B).

5.5.2 Current situation for air

Normal gas production and platform operations as well as related shipping movements cause CO, CO_2 and NO_x emissions. To provide platforms with power, currently gas/diesel generators are used, which have high CO, CO_2 and NO_x emissions, whereas the emissions related to diesel and oil generators cause higher emissions in comparison to gas generators.

5.5.3 Type and extent of the impacts on air

Impacts related to construction (-)
Construction activities largely involve the use of combustion engines (cranes, ships). Therefore, an increase in emissions (CO_2, NO_x) can be expected for each system integration option. These emissions are temporary and spread across a large surface area (e.g. transportation over large distance from shore to offshore location). Hence, the related impact on air is considered limited, but is still additional to the reference situation, in which no construction works take place. The impact is therefore scored moderately negative (-).

Impacts related to operations (++,-,0)
The system integration options differ in the impact on air during operations. For the electrification option the impact is scored positive (++). The emission of CO_2 will be drastically reduced as the combustion engines (diesel/gas generators) are replaced by electrical driven equipment that produces no CO_2 or NO_x emissions.

In case of CCS the platform is abandoned in the reference situation but will be in use again. This means that emissions will again occur. Moreover, CO_2 will be incidentally vented, causing incidental CO_2 emissions. The capture and treatment of CO_2 is taking place onshore. As the scope of this study covers the offshore environmental impacts, onshore impacts are not included. Therefore, the positive impact of the CO2 capture onshore is not included in the assessment. Hence, considering the offshore impacts described above the impact on air is assessed as moderately negative. (-)

Production of green hydrogen will be executed by electrical driven equipment (using electrical power from nearby wind turbines or wind farms to convert electrical power into green hydrogen). In the reference situation there are no air emissions, as the platform is abandoned. For the green hydrogen production phase emissions are neglectable, and therefore comparable to the reference situation. Hence the score is no impact (0).

5.6 Electromagnetic fields

5.6.1 Regulatory framework for electromagnetic fields

A regulatory framework applicable offshore is not available for this environmental aspect.

5.6.2 Current situation for electromagnetic fields

In the current situation the platforms included in the three case studies are not electrified, and no electrical cables from shore or to the platforms are present. Accordingly, there are no significant electromagnetic fields.

5.6.3 Type and extent of the impacts on electromagnetic fields

Impacts related to construction (0)
Electromagnetic fields only exist/are present when cables are used for transportation of electricity. During construction the main activity is cable trenching and laying, no transportation of electricity is involved. Hence, there is no impact (0).

Impacts related to operations (-)
In case of the electrification option and the green hydrogen production option there is an impact on electromagnetic fields. During operations when electricity is transported (either for electrified natural gas production, or for green hydrogen production) electromagnetic fields will occur. This could have a moderately negative effect on (ground) fish, sharks, rays etc, as these species are able to detect electromagnetic fields and use these for orientation. It is theoretically possible that the orientation and migration of these species may be influenced by limited change in magnetic fields caused by the electrical cables[5]. It can be assumed that the influence is local and does not extend to more than a few metres on either side of the cable route. No significant impact on susceptible organisms are to be expected, but electromagnetic fields are present in case of operation and therefore scored as moderately negative for both the electrification option and production of green hydrogen (-).

5.7 Materials and waste

5.7.1 Regulatory framework for materials and waste

As part of the Mining Act, mining installations require a special environmental mining work permit. Without such a permit, the erection and operations of a mining installations is prohibited. The permit may contain restrictions with the aim of protecting nature or the environment, including requirements related to materials and waste. Moreover, pertaining to offshore mining works, so-called mining installations, ministerial approval is needed before a platform for production or storage purposes can be put in place. This approval will be granted if the platforms adheres to a set of technical standards and norms. (based on NSE II work package B)

5.7.2 Current situation for materials and waste

Waste is generated during operational and maintenance work on platforms; the average quantity of waste generated is estimated at 100 kg of industrial waste per year and 50 kg of hazardous waste per year for 'normal'

[5] Note, the effects and impact of the electromagnetic fields on species is currently investigated in Wozep (Wind on Sea Ecological Program, in Dutch: Wind op Zee Ecologisch Programma). This is a five-year research program that was launched to investigate the knowledge gaps concerning the ecological effects of offshore wind energy.

natural gas production operations ((Royal HaskoningDHV, MER platform Q10 en pijpleidingen op zee, 2016a). No waste is stored on the platforms.

5.7.3 Type and extent of the impacts on materials and waste

Impacts related to construction (--)
The most important materials for construction are steel and copper. These are needed to construct new pipelines and cables. Furthermore, in the electrification option the old diesel/gas generators will be removed from the platforms and transported back to shore. Refurbishment of the platforms for CCS or hydrogen production will require change of equipment, and transportation of the 'old' natural gas production equipment back to shore. Possible toxic waste can be released. Isotopes are present in the soil, which is not a problem, except when these have been pumped up together with the natural gas and had the chance to accumulate at the inside of the pipelines. When removing or cutting pipelines, possible radioactive accumulations of isotopes could be released. Therefore, there is a risk that equipment on the platforms could be radioactive when removed for refurbishment. Hence, this 'old' equipment can be considered toxic waste and are expected to be dealt with appropriately. (based on expert knowledge)

Considering that in all system integration options toxic waste is to be dealt with in the construction phase (refurbishment of platforms), the impact related to materials and waste is scored as negative (--). For all system integration options holds that waste is collected according to the statutory provisions: collected separately as much as possible, packaged and labelled appropriately, stored and transported to authorized processing companies on shore.

Impacts related to operations (+,-)
Continuation of the natural gas production, but electrified, is expected to use less materials and/or produce less waste during the operational phase compared to the reference situation, as electrical installations and equipment are expected to be more reliable and require less maintenance. Therefore, the impact for the electrification option is scored as moderately positive (+).

For both the CCS and green hydrogen option, the reference situation, to assess the environmental impacts, is a situation where the platforms have ceased to produce natural gas. When platforms will be taken into operations materials will again be used and waste is produced. Compared to the reference situation the impact is not considered significant and is therefore scored as a moderately negative impact (-).

5.8 Landscape and light

5.8.1 Regulatory framework for landscape and light

The national policy with respect to landscape is included in the Spatial Planning Structure Vision, as part of the Spatial Planning Act (Ministry of Infrastructure, 2012). The spatial assignment for the North Sea Landscape is to maintain a clear view of the horizon from the coast to 12 NM (about 22 km). (Royal HaskoningDHV, MER platform Q10 en pijpleidingen op zee, 2016a)

5.8.2 Current situation for landscape and light

All the platforms in this study are outside the 12 NM zone. These platforms are currently in operation and are not visible from the coast. Even the platforms of P15-P18 are not visible, with a distance of 35 km from the coast these are the case studies located the closest to shore.

The platforms are in operation, ship movements from and to the platforms are visible at the horizon. As well as light coming from platforms and ships.

5.8.3 Type and extent of the impacts on landscape and light

Impacts related to construction (0)
The platforms are already located at the North Sea, and at far away distance from shore. So, more disruption of the view is not an issue in this case. During construction, more ship movements will take place, so disruption of the view could be an issue. This increase in shipping movements is considered neglectable, as these include a fraction of the total shipping movements that take place at the North Sea. It is expected that there will be some extra light coming from the ships, but this is very little and neglectable on this large scale. Hence, the score is no impact (0).

Impacts related to operations (0,-)
For the electrification option there is no difference in disruption of the view or light pollution compared to the reference situation. Moreover, in the reference situation the light pollution is not considered to have a negative impact on nature or safety. Therefore, the impact is scored as no impact (0). (Royal HaskoningDHV, MER platform Q10 en pijpleidingen op zee, 2016a)

The reference situation of both the CCS and green hydrogen option is a platform out of production, which means no (maintenance) ship movements and very limited light pollution. As the platforms are taken back into operations for CCS or hydrogen production, this creates additional shipping movements and light pollution compared to the reference situation. Therefore, a moderately negative (-) impact is scored for those two options.

5.9 Cultural heritage and archaeology

5.9.1 Regulatory framework for cultural heritage and archaeology

In 1992 The Netherlands signed the European treaty for the protection of archaeological heritage (the Malta or Valletta Convention), which was elaborated in the Dutch Law on Conservation of Archaeological Monuments. This stipulates, among other things, that (preliminary) research into possible archaeological remains for new spatial developments is mandatory. Possible locations must be preserved as much as possible. Archaeological values must be considered as early as possible in the planning process.

Archaeological monuments that are found during the construction or maintenance of cables, pipelines or platforms must be reported to the Minister of Education, Culture and Science. Prior to the submission of the permit request an inventory survey (IVO) (exploratory research on water) must be carried out into the possible presence of archaeological monuments. Any research must be carried out according to the Dutch National Archaeology Quality Standard (KNA) Water Bottoms (version 3.2).

5.9.2 Current situation for cultural heritage and archaeology

Drowned settlements, traces of habitation, remnants of lost shiploads and skeletons of extinct animals are examples of cultural-historical and archaeological artefacts in the North Sea seabed. Moreover, there are many known shipwrecks located on and in the seabed. On a regular basis, cultural-historical and archaeological artefacts or parts of wrecks are found, for example during sand extraction or fishing operations. These artefacts can be of great cultural-historical and archaeological value. In some parts of the North Sea the chance of finding cultural-historical and archaeological values is greater than in other parts; these areas have a higher expectation value.

On the Indicative Map of Archaeological Values (Noordzeeloket, sd), part of the study area (the locations of the three case studies) fall into a zone with a low/mid low archaeological expectation. This valuation is based on the soil conditions. In the study area there are no known archaeological sites registered on the Archaeological Monument Card (AMK).

5.9.3 Type and extent of the impacts on cultural heritage and archaeology

Impacts related to construction (--)
Archaeological sites could be affected by, depending on the depth of the archaeological remains, the installation of cables or pipelines. Hence the impact is scored as negative (- -). Detailed investigation/study are required before detailed engineering and construction.
In case a wreck or other valuable object is detected on the cable or pipeline route, the best way to mitigate this is simply to divert the route over a certain distance. The costs of removing the wreck or object are often much larger than changing the routing of the pipeline over roughly 100 meters.

Impacts related to operations (not applicable)
Only during construction an impact on cultural heritage and archaeology is possible, as no activities will be conducted in the seabed during operations.

5.10 Sustainable energy use

5.10.1 Regulatory framework for sustainable energy use

The Dutch Government aims to increase the use of sustainable energy sources, to reduce the CO_2 emissions as per the Paris Agreement (climate agreement, Paris 2015). The Energy Agreement details the percentage of sustainable energy sources in the Dutch energy supply by 2023. The Energy Agenda sets the goals up to 2050. The government has set up a system of subsidies to encourage private companies to reduce their CO_2 emissions and use sustainable energy sources.

5.10.2 Current situation for sustainable energy use

The current production of natural gas does not use sustainable energy. Oil/gas/diesel generators are used to operate the equipment on the platforms.

5.10.3 Type and extent of the impacts on sustainable energy use

Impacts related to construction (-)
Energy is used for cable or pipeline trenching and laying, replacement of equipment on the platform, as well as other activities during construction. This requires more energy than use in the reference situation. Moreover, these activities are carried out by fossil fuelled equipment. As the activities are temporary, the impact is scored moderately negative (-).

Impacts related to operations (++,-)
For the electrification and green hydrogen option the use of sustainable energy is scored positively during operations. In the case of electrification normal gas production will make use of the green energy supply of wind farms instead of fossil fuelled generators. Whereas green hydrogen is produced converting the electrical energy of nearby wind turbines or wind farms. Both options score positively (++).

For CCS the energy balance is negative. CO_2 will be captured onshore from other productions/activities, but it cannot be reused. Moreover, it uses energy to transport and inject CO_2 in the well/reservoir. Impact on sustainable energy use is therefore scored moderately negative (-).

5.11 Traffic

5.11.1 Regulatory framework for traffic

The Shipping Traffic Act (in Dutch: Scheepvaartverkeerswet, Svw) is applicable for traffic at the North Sea. The Act regulates, among others:

- The safety and continuity of the flow of shipping traffic;
- Maintenance of waterways;
- Preventing or limiting damage, caused by shipping traffic on banks, dikes, bridges etc.;
- Preventing or limiting pollution by shipping;

During the construction of pipelines and during shipping movements for the purpose of modifications to platforms, the Shipping Traffic Act applies to the ships concerned.

5.11.2 Current situation for traffic

In the North Sea, 'route-related ships' are mainly merchant ships that sail from one port to another, following the shipping routes and 'non-routine ships'. Non-routing shipping is, for example, fishing, supplementation, smaller cargo traffic, working and recreational shipping, but also passengers' ferries to England. Non-routing ships and recreational sailing boats make use of the entire coastal zone and sail outside the shipping routes.

5.11.3 Type and extent of the impacts on traffic

Impacts related to construction (-)
When placing pipelines/cables at sea, smooth (efficient) and safe shipping must be maintained throughout the North Sea. The increase in shipping movements for the supply and removal of material to the platforms, and the construction of the cable and pipelines is not expected to result in capacity problems on the shipping routes. The construction works for the pipelines and cables could hinder other shipping movements, especially when crossing shipping lanes. Hence, the impact on traffic is scored moderately negative (-). It is expected that proper planning in consultation with the shipping authorities and the use of pilots will limit the nuisance.

Impacts related to operations (0/+,-)
Ships must respect a safety zone of 500 m around the existing platforms.

Electrical installations and equipment are expected to be more reliable and require less maintenance. For smaller unmanned platforms this is expected to result in less traffic movements, as less maintenance visits are required. For larger manned platforms this will however not make a difference as personnel works in shifts and transportation by boat or helicopter will not differ from the reference situation. The impact is scored as neutral (0) for the electrification option in case of manned platforms, and moderately positive (+) in case of unmanned platforms.

In case of CCS and green hydrogen production, the platform will be in operation again. Which means that maintenance and the accompanied ship and helicopter movements will be there again, resulting in a moderately negative impact (-).

5.12 Operational safety

5.12.1 Regulatory framework for operational safety

The Mining Act and the Working Conditions Act (Arbowet) regulate offshore operations. Each operator has a Health and Safety Document/Protocol in place, as legally required. This details the safety aspects and proposed mitigation measures to limit risks for people and the environment to an acceptable level.

5.12.2 Current situation for operational safety

The platforms are set up and maintained in accordance with the requirements of the Mining Act and Working Conditions Act (Arbowet). The essential parts of the installations are designed according to the fail-safe principle so that the installation automatically enters a safe state in case of failure of an essential component, such as a control valve or pump. The control and safety systems intervene automatically if critical threshold values are exceeded, at which the well is closed and safety measures are taken to ensure that the installation is brought into a safe state.

5.12.3 Type and extent of the impacts on operational safety

Impacts related to construction (0)
During construction impact on the operational safety is not applicable.

Impacts related to operations (+,-)
Electrical installations and equipment are more reliable and need less maintenance, compared to diesel or gas generators. Especially for smaller unmanned satellite platforms the impact is positive, because less maintenance visits are required and therefore less possibilities for human accidents. The impact is scored moderately positive for the electrification option (+).

Depending on the fact if a platform is manned or unmanned, the impact for both CCS and green hydrogen production option scores moderately negative on the aspect of operations safety. For CCS and hydrogen production the reference situation is a mothballed platform, which means that in the reference situation safety risks and maintenance are very limited. In case of CCS and hydrogen production the platform will be back in production and therefore risks will be present again, although it should be noted that these are smaller for operation with electrical installations. In case the platform is manned, the operation takes place 24/7, which results in daily operational safety risks. In case the platform is not manned, the platform will occasionally be visited for maintenance. The risks for operations safety are then lower and therefore scored moderately negative (-).

5.13 Other spatial uses

5.13.1 Regulatory framework for other spatial uses

The Spatial Planning Act (*Wet ruimtelijke ordening*) regulates spatial planning onshore and offshore, both on the territorial sea and in the EEZ. Most importantly, the Act includes the possibility to draft a structure vision for the North Sea describing the main aspects of the spatial development of a particular area. The spatial aspects of the National Water Plans drafted pursuant to the Water Act are a structure vision within the meaning of the Spatial Planning Act (based on NSE II work package B). As part of the National Water Plan, the current North Sea Policy Document 2016-2021 offers an integral framework for the use of the space on the North Sea (see also paragraph 3.1). The policy describes how assessments are made for all permit applications for designated uses on the North Sea. Based on this framework, choices are made about how the space on the North Sea is used.

5.13.2 Current situation for other spatial uses

The Dutch part of the North Sea is intensively used for shipping activities, both route-bound shipping (merchant vessels), as well as non-route-bound shipping activities (commercial fishing, sport fishing, sand extraction vessels, reactional shipping, and smaller cargo vessels). Route-bound shipping uses the shipping lanes, whereas non-route bound shipping takes place across the whole coastal zone and outside of the shipping lanes.

On the North Sea there are data cables (telecom cables) and (high-voltage) electricity cables, as well as existing pipelines used for the transport of oil and gas from platforms to the mainland. The Policy Document on the National North Sea Policy (2016-2021) states that a safety and maintenance zone of 500 m is to be maintained around operational cables and pipes. The safety and maintenance zone can be reduced in consultation with the owners of these assets.

In the area between the 20 m depth contour and the boarder of the 12 NM-zone sand extraction is taking place in designated areas (about 5000m^2). These activities do not coincide with the proposed study area.

The Ministry of Defense uses airplanes and helicopters for training over parts of the North Sea. For this purpose, areas have been designated where low flying and shooting are allowed. In the areas used for shooting the Ministry of Defense uses a safety zone of 5 NM to prevent projectiles from landing outside of the designated area. Furthermore, practices take place with ships, whether or not in combination with aircrafts and helicopters. The military training areas do not overlap with the study area.

5.13.3 Type and extent of the impacts on other spatial uses

Impacts related to construction (-)
Shipping lanes (with a depth of > 20m) need to be crossed by new pipelines and cables. Hence, cable / pipeline trenching will need to be executed in these locations. During construction, shipping can be hindered (see also paragraph 5.11). During construction of pipelines and cables, measures can be taken to ensure that existing pipelines and cables are not damaged, and mutual safety is guaranteed. The impact on other spatial uses during construction will be temporary and is not considered significant. Therefore, the impact is moderately negative scored for all options (-).

Impacts related to operations (-)
The cables and pipelines do not impose any restrictions on the fishing industry. The fish stocks on the North Sea are not negatively affected. The pipelines are buried deep enough to prevent safety risks for fishermen.

The safety zones around the platforms fall into a restricted area for shipping, so there are no effects on other user functions during the production phase.

The new pipelines and cables pose an additional spatial claim, this space cannot be used for other cables, pipelines or wind farms. However, considering the area concerned and compared to the size of the Dutch EEZ the impact is not significant.

The impact on other spatial uses during operations is scored moderately negative (-). This score is the same for both electrification, CCS and green hydrogen production.

5.14 Changes in the deep subsurface

5.14.1 Definition of deep subsurface and possible changes

Regular environmental impacts can be determined for the biosphere, the area up to a depth of some 500 meters. The deep subsurface is located under the biosphere and located deeper than 500 meters. Regular environmental impacts in the deep subsurface are not present. For example, there are no protected natural values that can be disturbed, there is no traffic and there are no archaeological values. Hence, impacts on the deep subsurface are considered changes in subsurface, relative to the current or natural situation. When considering the system integration options this is only relevant for the CCS option, where CO_2 is stored in the deep subsurface.

This paragraph describes possible changes to the deep subsurface related to offshore CO_2 storage. As these are not considered environmental impacts, the possible changes are only described at a high-level and not scored against the scoring system used for the environmental impacts. Based on the knowledge obtained in the ROAD-project there may be mechanical, chemical or thermal changes on overlying geological layers. (Royal Haskoning, 2011).

5.14.2 Changes in deep subsurface related to CCS

Only for the CCS option there are possible impacts on the deep subsurface as this is the only system integration option where activities are conducted in the reservoir/well (injection of CO_2). The injection of CO_2 will again increase the pressure in the reservoirs that could result in the following impacts on the deep subsurface (Royal Haskoning, 2011):

- Mechanic: Due to pressure variations, small cracks in the reservoir rock or top layers could occur. Or nearby geological faults could be influenced.
- Mechanic: Storage of CO_2 could increase the pressure in the reservoir compared to the lower pressure levels at the end of natural gas production. This could improve the geological stability of the reservoir. The pressure in the reservoir is closely monitored to ensure that the pressure will not rise above the original pressure level before natural gas production started. This aspect could have a positive contribution to the 'restoration of the natural situation'.
- Chemical: Under influence of water injected CO2 could cause chemical reactions with the gasses/rocks in the reservoir. This could cause structural degradation and therewith instability of the local deep subsurface. Chemical reactions could occur at different time scales, ranging from seconds to thousands of years.
- Thermic: It is expected that the temperature in the reservoir is higher than the temperature of the injected CO_2. In the case of uncontrolled or too high temperature differences, this could result in small cracks in the reservoir rocks. As thermic difference within the reservoir will even itself out, it is expected that this change is temporary and concentrated locally around the point of entry of the well.

5.14.3 Mitigation measures

It is important that during and after the injection of CO_2 the conditions in the deep subsoil are fully controlled (control measures), and that what happens with the injected CO_2 is monitored closely. The main control measure is to ensure that the pressure in the reservoir is never higher than it was at the time before gas production started. This control measure, together with other control measures, ensures safe permanent storage (Royal Haskoning, 2011).

6 Environmental impacts of system integration options

Each system integration option is assessed for the different environmental aspects, this chapter provides an overview table per option. Every paragraph (one for every option) gives the summary of the reference situation, followed by the table with the scored environmental impacts. Key impacts are detailed below each table. For completeness, the overview of the scoring system is included (see also paragraph 4.2):

+++	Strongly positive impact, the development has clear added value
++	Positive impact, clear improvement compared to the reference situation
+	Moderately positive impact, no significant improvement
0	No impact / Neutral
-	Moderately negative impact, no disrupting effect
- -	Negative impact, mitigation measures should be investigated
- - -	Strongly negative impact, effect is outside of the judicial framework
	No impact possible

6.1 Electrification

The reference situation (see paragraph 4.3) for the electrification option is that the platform and related infrastructure are still in place and operational, as the platform is still producing natural gas (and will continue producing for a considerable amount of time). Keeping this in mind and considering the expected environmental impacts (see chapter 5), the scores per environmental aspects are shown in Table 6-1.

Table 6-1 – Overview of offshore environmental impacts of electrification

		Electrification			
		Construction		Operation	
	Theme	Cable/ pipeline	Existing platform	Cable/ pipeline	Platform
Planet	Nature	- -	-	-	0
	Seabed	-	0	0	0
	Water quality	-	-	0	0
	Underwater sound	- -	-	0	+
	Air emissions / Smell	-	-	0	++
	Electromagnetic fields			-	
	Materials and waste	-	- -	0	+
People	Landscape and light	0	0	0	0
	Cultural heritage and archaeology	- -	0	0	0
	Sustainable energy use	-	-		++
	Traffic (ship movements)	-	-	0	+*
	Operational safety			0	++**
Profit ability	Other spatial uses	-	0	-	0

** In case of an unmanned satellite platform (+) and neutral (0) in case of a manned platform.*
***In case of an unmanned satellite platform (++) and moderately positive (+) in case of a manned platform.*

Construction phase

Compared to the reference situation, during the construction phase additional activities will take place. These include additional ship movements and construction works that will 'disturb' or have a moderate impact on most of the environmental aspects. Negative impacts, were mitigation measures need to be investigated, are expected to impact *nature (- -)*, *sound (- -)* and *cultural heritage and archaeology (- -)*. Cable laying is expected to disturb local flora and fauna, generate under water sound, and could impact objects of cultural or archaeological value.

Both during construction and operation the impact on *landscape and light* is comparable to the reference situation. The additional ship movements that could cause additional light disturbance, are considered marginal compared to the reference situation. Hence, the impact is scored as neutral (0) compared to the reference situation.

Operational phase

The operational phase for the system integration option of electrification does not differ much from the operational phase in the reference situation, as the platform and its assets will continue to produce natural gas.

The main difference is that conventional power equipment (gas or diesel generators) has been replaced by electrically-powered equipment, which is cleaner and greener. Hence, a positive impact on the *air emissions (+ +)* is expected, as gas or diesel generators are replaced for cleaner electrically-powered equipment. Furthermore, as electrical installations and equipment are expected to be more reliable and require less maintenance the impact on *materials and waste* (+), *traffic* (0/+) and *operations safety* is scored (moderately) positive (+/++). Especially for smaller unmanned satellite platforms the impact is expected to be even more positive, as less maintenance visits by helicopter or boat are required, and therefore accidents involving human casualties are less likely.

Due to electrification, the use of fossil fuels for gas production is altered to the supply of energy from sustainable sources. The impact on *sustainable energy use* is therefore scored positive (+ +).

A moderate negative impact (-) will be expected on the environmental aspect *electromagnetic fields*. The cables transporting the electricity will cause some electromagnetic radiation that could negatively impact the flora and fauna (*nature*).

The aspect *other spatial uses* is scored moderately negative (-) because the new cables or pipelines have a spatial claim, limiting the use of the space by other uses. As the total space used is considered limited compared to the Dutch EEZ or even the Southern North Sea, the score given is moderately negative (-).

6.2 CCS

The reference situation (described in paragraph 4.3) for CCS is that platforms and their related infrastructure are still in place, but no longer operational. The well is plugged but not abandoned. Keeping this in mind and considering the expected environmental impacts (described in chapter 5), the scores per environmental aspects are shown in Table 6-2.

Table 6-2 – Overview of offshore environmental impacts of CCS

		CCS			
		Construction		Operation	
	Theme	Cable/ pipeline	Existing platform	Cable/ pipeline	Platform
Planet	Nature	- -	-	0	-
	Seabed	-	0	0	0
	Water quality	-	-	0	0
	Underwater sound	- -	-	0	0
	Air emissions / Smell	-	-	0	-*
	Electromagnetic fields				
	Materials and waste	-	- -	0	-
People	Landscape and light	0	0	0	-
	Cultural heritage and archaeology	- -	0	0	0
	Sustainable energy use	-	-		-
	Traffic (ship movements)	-	-	0	-
	Operational safety			-	-**
Profit ability	Other spatial uses	-	0	-	0

** As the scope of this study covers the offshore environmental impacts, onshore impacts are not included. Therefore, the positive impact of the CO_2 capture onshore is not included in the assessment.*
***In case of an unmanned platform (-) and negative (--) in case of a manned platform.*

Construction phase
For CO_2 transport and storage, the construction phase will include activities comparable to the electrification option. Construction of new pipelines is expected to have similar impacts compared to cable laying. The impact on *nature (- -), sound (- -)* and *cultural heritage and archaeology* (- -) is expected to be negative. Cable laying is expected to disturb local flora and fauna, generate under water sound, and could impact objects of cultural or archaeological value. The impact on *materials and waste* is expected to be negative (- -). In case of CCS the installations need to be replaced and possible toxic waste (due to accumulated isotopes that will be radioactive) could be released.

Both during construction and operation the impact on *landscape and light* is comparable to the reference situation. The additional ship movements that could cause additional light disturbance, are considered marginal compared to the reference situation. Hence, the impact is scored as neutral (0) compared to the reference situation.

Operational phase

In case of venting CO_2 on the platform, CO_2 is emitted to the atmosphere, which will have an incidental negative impact on *air emissions,* and therefore scores moderately negative (-). It should be noted that the capturing of CO_2 has a (strongly) positive impact on air emissions but takes place onshore. As the scope of this study only focusses on offshore activities and impacts, the capturing of the CO_2 is not included in the assessment.

The installations and equipment on the platform are comparable to the installations and equipment in case of natural gas production. As the platform will be in operation again compared to the reference situation, the impact on *waste and materials* will be moderately negative (-).

It requires energy to transport the CO_2 to the platform and well in the right conditions (temperature and pressure). Therefore, the impact on (*sustainable) energy use* is scored moderately negative (-).

Depending on the fact if a platform is manned or unmanned, the impact scores moderately negative for *operational safety*. The reference situation is a mothballed platform, which means that safety risks and maintenance are very limited. The platform will be back in production and therefore risks will be present again, although it should be noted that these are smaller for operation with electrical installations. In case the platform is manned, the operation takes place 24/7, which results in daily operational safety risks. In case the platform is not manned, the platform will occasionally be visited for maintenance. The risks for operations safety are then lower and therefore scored moderately negative (-).

The aspect *other spatial uses* is scored moderately negative (-), because the new pipelines have a spatial claim, limiting the use of the space by other uses. As the total space used is considered limited compared to the Dutch EEZ or even the Southern North Sea, the score given is moderately negative (-).

6.3 Green hydrogen production

The reference situation (described in paragraph 4.3) for green hydrogen production is that platforms and their related infrastructure are still in place, but no longer operational. The well is plugged but not abandoned. Keeping this in mind and considering the expected environmental impacts (described in chapter 5), the scores per environmental aspects are shown in Table 6-3.

Table 6-3 – Overview of offshore environmental impacts of green hydrogen production

		Green hydrogen production			
		Construction		Operation	
	Theme	Cable/ pipeline	Existing platform	Cable/ pipeline	Platform
Planet	Nature	- -	-	-	-
	Seabed	-	0	0	0
	Water quality	-	-	0	0*
	Underwater sound	- -	-	0	0
	Air emissions / Smell	-	-	0	0
	Electromagnetic fields			-	
	Materials and waste	-	- -	0	-
People	Landscape and light	0	0	0	-
	Cultural heritage and archaeology	- -	0	0	0
	Sustainable energy use	-	-	++	++
	Traffic (ship movements)	-	-	0	-
	Operational safety			-	-**
Profit ability	Other spatial uses	-	0	-	0

**Unclear what impact could be, due to uncertainty whether or not by-products of H_2 production are disposed*
***In case of an unmanned platform (-) and negative (--) in case of a manned platform.*

Construction phase
For the production of green hydrogen, the construction phase will include activities comparable to the electrification option. Construction of new pipelines is expected to have similar impacts compared to cable laying. The impact on *nature (- -), sound (- -)* and *cultural heritage and archaeology* (- -) is expected to be negative. Cable laying is expected to disturb local flora and fauna, generate under water sound, and could impact objects of cultural or archaeological value. The impact on *materials and waste* is expected to be negative (- -). In case of hydrogen production, the installations need to be replaced and possible toxic waste (due to accumulated isotopes that will be radioactive) could be released.

Both during construction and operation the impact on *landscape and light* is comparable to the reference situation. The additional ship movements that could cause additional light disturbance, are considered marginal compared to the reference situation. Hence, the impact is scored as neutral (0) compared to the reference situation.

Operational phase

Producing green hydrogen requires desalinated and filtered seawater (demi water) for electrolysis. In both processes of desalination and filtering, by-products are produced: salt/natriumchloride (from desalination) and 'waste', i.e. organisms, plankton (from the filtering process). It is not clear where these by-products will be disposed or collected and transported from the platform. Disposing these by-products back into the seawater may be an option. Therefore, both the salinity and 'waste' concentration can increase locally. It may be expected that the local increase of salinity is of insignificant proportions compared to the large North Sea but could have a moderately negative impact (-) on the *water quality* and therefore on flora and fauna (*nature*). On the other hand, dispose of the 'waste' (consisting of plankton etc.) could have a moderately positive effect (+) on the *water quality* and therefore on *nature*. In case of collection and transportation of the by-products from the platform, it would not have any impact on these aspects.

During the operational phase a moderate negative impact (-) will be expected on the environmental aspect *electromagnetic fields*. The cables transporting the electrical power required to produce green hydrogen will cause some electromagnetic radiation that could negatively impact the flora and fauna (*nature*).

The aspect *sustainable energy use* is scored positively (+ +). Sustainable energy from wind farms or specific wind turbines will be used to produce green hydrogen. Fossil fuels will not be used any longer. Furthermore, compared to the reference situation where no energy is being used, it is scored positively.

Depending on the fact if a platform is manned or unmanned, the impact scores moderately negative on the *operational safety*. The reference situation is a mothballed platform, which means that safety risks and maintenance are very limited. The platform will be back in production and therefore risks will be present again, although it should be noted that these are smaller for operation with electrical installations. In case the platform is manned, the operation takes place 24/7, which results in daily operational safety risks. In case the platform is not manned, the platform will occasionally be visited for maintenance. The risks for operations safety are then lower and therefore scored moderately negative (-).

The aspect *other spatial uses* is scored moderately negative (-) because new cables have a spatial claim, limiting the use of the space by other uses. As the total space used is considered limited compared to the Dutch EEZ or even the Southern North Sea, the score given is moderately negative (-).

7 Environmental impacts of the system integration scenarios

For the three case studies included in NSE II system integration scenarios have been developed, in cooperation with the platform operators. These scenarios are a combination of the different system integration options. The system integration scenarios are assessed for the different environmental aspects, this chapter provides an overview table per case study scenario.

It should be noted that when considering the system integration scenarios, the reference situation is a platform and related infrastructure still in place and operational (see paragraph 4.3), as electrification of natural gas production is the first step in each scenario.

The paragraphs below provide a table with the scored environmental impacts. Key impacts are detailed below each table. For completeness, the overview of the scoring system is included (see also paragraph 4.2):

+++	Strongly positive impact, the development has clear added value
++	Positive impact, clear improvement compared to the reference situation
+	Moderately positive impact, no significant improvement
0	No impact / Neutral
-	Moderately negative impact, no disrupting effect
- -	Negative impact, mitigation measures should be investigated
- - -	Strongly negative impact, effect is outside of the judicial framework
	No impact possible

7.1 Scenario K5 area

Two system integration options are considered for the K5 area, with three different timing options, as detailed in Figure 2 4. This resulting in the following scenario:
Electrification & CCS hub

The scores per environmental aspects are shown in Table 7-1.

Table 7-1 - Overview of offshore environmental impacts of system integration scenario for K5

		Electrification & CCS			
		Construction		Operation	
	Theme	Cable/ pipeline	Existing platform	Cable/ pipeline	Platform
Planet	Nature	- -	-	-	0
	Seabed	-	0	0	0
	Water quality	-	-	0	0
	Underwater sound	- -	-	0	+
	Air emissions / Smell	-	-	0	+
	Electromagnetic fields			-	
	Materials and waste	-	- -	0	+

People	Landscape and light	0	0	0	0
	Cultural heritage and archaeology	- -	0	0	0
	Sustainable energy use	-	-		+
	Traffic (ship movements)	-	-	0	+
	Operational safety			0	+
Profit ability	Other spatial uses	-	0	-	0

Construction phase
As the construction activities for both options (electrification and CCS) take place in different years and are temporary in nature, no increase in the extent of the impacts for the scenario as a whole is expected. Accordingly, the expected environmental impacts during the construction phase are comparable to the electrification option (see paragraph 6.1).

Operational phase
The assumption for the K5 area is that electrified natural gas production and CCS will either run in parallel for a certain period or will directly follow each other in time. The expected environmental impacts during the operational phase are comparable to the electrification option (see paragraph 6.1), apart from the scores for air emissions (+ instead of ++) and sustainable energy use (+ instead of ++). For both aspects holds that the combination with CCS slightly reduces the positive impact of electrification, due to the moderately negative (-) score for CCS related to air emissions (due to CO_2 venting) and sustainable energy use (offshore wind energy used for storage of CO_2).

7.2 Scenario K14 area

All three system integration options are viable for the K14 area, resulting in the following scenario, with three different options, as detailed in Figure 2 5:
Electrification & small scale H2 production & large scale H2 production combined with CCS

The scores per environmental aspects are shown in Table 7-2.

Table 7-2 - Overview of offshore environmental impacts of system integration scenario for K14

		Electrification & small scale H_2 production & large scale H_2 and/or CCS hub			
		Construction		Operation	
	Theme	Cable/ pipeline	Existing platform	Cable/ pipeline	Platform
Planet	Nature	- -	-	-	0
	Seabed	-	0	0	0
	Water quality	-	-	0	0*
	Underwater sound	- -	-	0	+
	Air emissions / Smell	-	-	0	+/++**
	Electromagnetic fields			-	
	Materials and waste	-	- -	0	+

People	Landscape and light	0	0	0	0
	Cultural heritage and archaeology	- -	0	0	0
	Sustainable energy use	-	-		+ / ++**
	Traffic (ship movements)	-	-	0	+
	Operational safety			0	-
Profit ability	Other spatial uses	-	0	-	0

**Unclear what impact could be, due to uncertainty whether or not by-products of H_2 production are disposed*
*** In case CCS is included in the system integration scenario the score is moderately positive*

Construction phase
As the construction activities for three options (electrification, CCS, small/large scale H_2 production) take place in different years and are temporary in nature, no increase in the extent of the impacts for the scenario as a whole is expected. Accordingly, the expected environmental impacts during the construction phase are comparable to the electrification option (see paragraph 6.1).

Operational phase
The assumption for the K14 area is that electrified natural gas production, small /large scale H_2 production and CCS will either run in parallel for a certain period or will directly follow each other in time. The expected environmental impacts during the operational phase are comparable to the electrification option (see paragraph 6.1), apart from the scores for air emissions (+ instead of ++) and sustainable energy use (+ instead of ++) when CCS is included in the scenario. For both aspects holds that the combination with CCS slightly reduces the positive impact of electrification, due to the moderately negative (-) score for CCS related to air emissions (due to CO_2 venting) and sustainable energy use (offshore wind energy used for storage of CO_2).

Furthermore, as electrified natural gas production is combined with both or either CCS or H2 production (small or large scale) it is expected that operational safety will be more complex due to the combination of three different operational processes in one operational area. Accordingly, for the scenario as a whole this aspect is scored as moderately negative (-).

7.3 Scenario P15-P18 area

All three system integration options are viable for the P15-P18 area, resulting in the following scenario, with three different timing options, as detailed in Figure 2-5:
Electrification & small scale H2 production & large scale H2 production combined with CCS

The scores per environmental aspects are shown in Table 7-3.

Table 7-3 - Overview of offshore environmental impacts of system integration scenario for P15-P18

		Electrification & small scale H2 production & large scale H2 production combined with CCS			
		Construction		Operation	
	Theme	Cable/ pipeline	Existing platform	Cable/ pipeline	Platform
Planet	Nature	- -	-	-	0
	Seabed	-	0	0	0
	Water quality	-	-	0	0*

	Underwater sound	- -	-	0	+
	Air emissions / Smell	-	-	0	+/++**
	Electromagnetic fields			-	
	Materials and waste	-	- -	0	+
People	Landscape and light	0	0	0	0
	Cultural heritage and archaeology	- -	0	0	0
	Sustainable energy use	-	-		+ / ++**
	Traffic (ship movements)	-	-	0	+
	Operational safety			0	-
Profit ability	Other spatial uses	-	0	-	0

**Unclear what impact could be, due to uncertainty whether or not by-products of H_2 production are disposed*
*** In case CCS is included in the system integration scenario the score is moderately positive*

Construction phase
As the construction activities for both options (electrification and CCS) take place in different years and are temporary in nature, no increase in the extent of the impacts for the scenario as a whole is expected. Accordingly, the expected environmental impacts during the construction phase are comparable to the electrification option (see paragraph 6.1).

Operational phase
The assumption for the P15-P18 area is that electrified natural gas production, small /large scale H_2 production and CCS will either run in parallel for a certain period or will directly follow each other in time. The expected environmental impacts during the operational phase are comparable to the electrification option (see paragraph 6.1), apart from the scores for air emissions (+ instead of ++) and sustainable energy use (+ instead of ++) when CCS is included in the scenario. For both aspects holds that the combination with CCS slightly reduces the positive impact of electrification, due to the moderately negative (-) score for CCS related to air emissions (due to CO_2 venting) and sustainable energy use (offshore wind energy used for storage of CO_2).

Furthermore, as electrified natural gas production is combined with both or either CCS or H2 production (small or large scale) it is expected that operational safety will be more complex due to the combination of three different operational processes in one operational area. Accordingly, for the scenario as a whole this aspect is scored as moderately negative (-).

8 Research questions answered

As part of NSE II a strategic assessment of environmental impacts of system integration options is conducted by Royal HaskoningDHV. This study aims to answer two questions:

1. *What are the known and potential spatial and environmental impacts of the presence of both wind farms and oil and gas installations in the selected case study areas?*

The impacts of the three system integration options are described and the extend of the impacts is scored on a seven-point scale ranging from strongly positive to strongly negative impact. For all three system integration options no strongly positive (+ + +) or strongly negative impacts (- - -) are expected. The key aspects scored positive (+ +) or negative (- -) are included below:

During the construction phase additional activities will take place, compared to the reference situation, for all three system integration options. These include additional ship movements and construction works that will 'disturb' or have a moderate impact on most of the environmental aspects. Negative impacts, were mitigation measures need to be investigated, are expected to impact *nature (- -)*, *sound (- -)* and *cultural heritage and archaeology (- -)*. Cable or pipeline laying is expected to disturb local flora and fauna, generate under water sound, and could impact objects of cultural or archaeological value. In addition, for the CCS and geen hydrogen production options negative impacts could be expected due to handling of toxic waste related to refurbishment of the platforms.

The operational phase for the electrification option does not differ much from the operational phase in the reference situation, as the platform and its assets will continue to produce natural gas. The main difference is that conventional power equipment (gas or diesel generators) has been replaced by electrically-powered equipment, which is cleaner and greener. Hence, a positive impact on air emissions (+ +) is expected, as gas or diesel generators are replaced by cleaner electrically-powered equipment. Due to electrification, the use of fossil fuels for gas production is altered to the supply of energy from sustainable sources. The impact on sustainable energy use is therefore scored positive (+ +).

During the operational phase the CCS option only scores a negative (- -) impact for operational safety, and this depends on the fact if a platform is manned or unmanned. The reference situation is a mothballed platform, which means that there are no safety risks at all and maintenance is not required. The platform will be back in production and therefore risks will be present again, although it should be noted that these are smaller for operation with electrical installations. In case the platform is manned, operations take place 24/7, which results in daily operational safety risks, and a negative score (- -). In case of an unmanned platform, the platform will occasionally be visited for maintenance. The risks for operational safety are lower and therefore scored moderately negative (-). All other environmental impacts during the operational phase of CCS score moderately or are considered neutral.

During the operational phase the green hydrogen production option scores a positive (+ +) impact for the aspect sustainable energy use. Sustainable energy from wind farms or specific wind turbines will be used to produce green hydrogen. Fossil fuels will not be used any longer. Furthermore, this option scores a negative (- -) impact for operational safety, and this depends on the fact if a platform is manned or unmanned. In case the platform is manned, operations take place 24/7, which results in daily operational safety risks, and a negative score (- -). In case of an unmanned platform, the platform will occasionally be visited for maintenance. The risks for operational safety are lower and therefore scored moderately negative (-).

Furthermore, the impacts of the system integration scenarios of the three case studies are assessed and scored. During the construction phase the activities for the different options take place in different years and are temporary in nature. Hence, no increase in the extent of the impacts for the scenario as a whole is expected.

For the operational phase the assumption for the case study scenarios is that electrified natural gas production, small /large scale H_2 production and CCS will either run in parallel for a certain period or will directly follow each other in time. The expected environmental impacts during the operational phase are comparable to the electrification option, apart from the scores for air emissions (+ instead of ++) and sustainable energy use (+ instead of ++) when CCS is included in the scenario. For both aspects holds that the combination with CCS slightly reduces the positive impact of electrification, due to the moderately negative (-) score for CCS related to air emissions (due to CO_2 venting) and sustainable energy use (offshore wind energy used for storage of CO_2). Furthermore, as electrified natural gas production is combined with both or either CCS or H2 production (small or large scale) it is expected that operational safety will be more complex due to the combination of three different operational processes in one operational area. Accordingly, for the scenario as a whole this aspect is scored as moderately negative (-).

2 *What critical information is currently missing to assess these impacts?*

This study is conducted at a strategic level (roughly comparable to a Strategic Environmental Assessment). New activities on the North Sea, such as the system integration options will require necessary permits related to the Mining Act and or Water Act. In relation to these permit applications an Environmental Impact Assessment (project EIA) will have to be prepared to detail possible environmental impacts, this study forms a first high-level inventory of these possible environmental impacts. Furthermore, in case of implementation of system integration an exemption related to the Nature Protection Law might be required. In order to determine if such an exemption would be required an Appropriate Assessment should be conducted to determine the extent of the impacts on protected areas and species.

This study is based on information available at the time of writing with regard to available knowledge and the expected emissions of material, equipment and installations. A project EIA will require quantitative impact assessments for most of the environmental aspects. Such quantitative impact assessments require a substantial increase in input information, both in establishing the extent of the impacts and in detailed knowledge on the effect of the impacts.

Specifically, for CCS several knowledge gabs are relevant for future project EIAs (based on (Royal Haskoning, 2011), these include amongst others:

- Pressure, temperature and volume scenario's; details are required to assess the impact of the volume of CCS which can be stored.
- Long-term impacts of CCS; as CO_2 is stored permanently, this means considering an indefinite storage period, impacts are assessed based on current information available but could be updated once more information from demonstration projects becomes available.
- An assessment framework for offshore CO_2 storage is currently still lacking, and relevant for future project EIAs.

Specifically, for H2 production there are several knowledge gabs relevant for future project EIAs, this includes amongst others:

- More detail is needed on the specific operations related to H_2 production offshore, such as disposal of by-products or the need for fresh water due to desalination.

For each system integration option there are several judicial barriers, as defined in the report of NSE II work package B. Clarification on these items is required and essential for any future permitting or EIA process related to the system integration options.

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