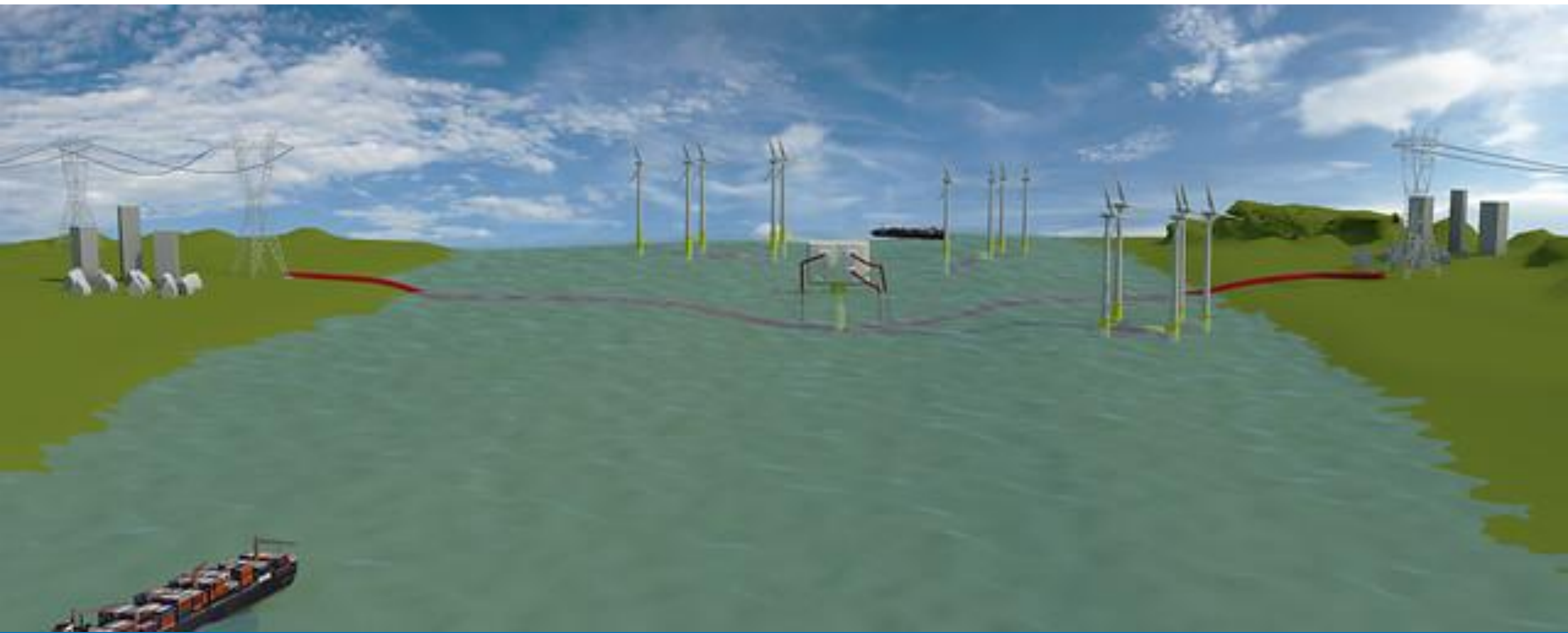

Subproject 2 – Financial structures

Final Report Work Stream 3

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Date: 02 July 2015

Synergies at Sea is a consortium that investigates the feasibility of an innovative electricity infrastructure on the North Sea. The consortium examines technical solutions, changes to international legislation and regulations and new financing models. The consortium consists of Nuon/Vattenfall, ECN, RoyalHaskoningDHV, Groningen Centre of Energy Law of the University of Groningen, Delft University of Technology, DC Offshore Energy and Energy Solutions, and is coordinated by Grontmij.

Energy Solutions

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ECN

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1 Summary

"WP 2 - new financial structures and products" studies external funding and products for extra financing, and opportunities for further improvement of the business case by incorporating flexibility to the combination of interconnection with offshore wind production facilities. While focusing on reduction of the financing costs and analysis of the business case, this study contributes to the overall goal to reduce the levelized cost of energy (LCOE). This document covers the assessment of flexibility: we analyze the incremental elements of the business case, evaluate the performance of each element, suggest optimized timing and re-assess the business case by economic feasibility. The re-assessment of the business case identifies the (possible) reduction of LCOE.

Our analysis provides a holistic approach to the business case that shows that current infrastructure to connect offshore wind production onshore is used inefficiently. The capacity of connecting infrastructure is only used for approximately 50%. Using the latter 50% for transmission provides a significant upside to the business case. Our analysis also shows that the interconnecting infrastructure has the largest economic value; out of every euro invested it generates the highest yearly revenues.

Based on our assessment the connection of offshore wind production capacity to interconnecting infrastructure introduces potential for savings of approximately 5-15% LCOE. If interconnecting infrastructure is already in place, new production capacity would only need a platform to connect the production capacity with the transmission infrastructure. This is in contrast with the current connection of production capacity to the onshore grid which consists of offshore platforms, connecting cables and onshore transmission capacity.

We recommend to introduce a grid operating entity that interconnects the different wind farms with the countries. We note that this recommendation will evolve towards a European grid infrastructure. This differs from the current Dutch situation where the grid operator Tennet will provide the infrastructure to connect (new) production capacity with the onshore grid. Our analysis shows potential savings based on the optimized use of infrastructure by interconnecting properties. Tennet only connects new production capacity onshore with no opportunities for optimized use of infrastructure by means of interconnection.

The combination of infrastructure and production capacity, developed in different stages should be based on one set of technical characteristics. All the different elements should be integrated to make the system operate. This may require standardization within the industry as an integrated system is mandatory.

2 Introduction

This document studies the optimal development and timing of a offshore wind production capacity combined with interconnection infrastructure. This study identifies the incremental elements that contribute to the joint development. The economic profitability of every element is analyzed to determine its importance within the entire development. Based on this analysis we propose a phasing order to develop offshore wind and interconnection capacity. We then estimate the impact of this joint approach (to combine production capacity with interconnection infrastructure) on the Levelized Cost of Energy (LCOE).

This study is part of the TKI Synergies at Sea programme. Led by Grontmij, industry partners and research institutes study the combination of offshore wind with interconnecting infrastructure. The consortium aims at an effective cost reduction of 40% of offshore wind as well as improvement of the economic activities in the Netherlands, strengthening the international leading position of the Dutch offshore wind sector.

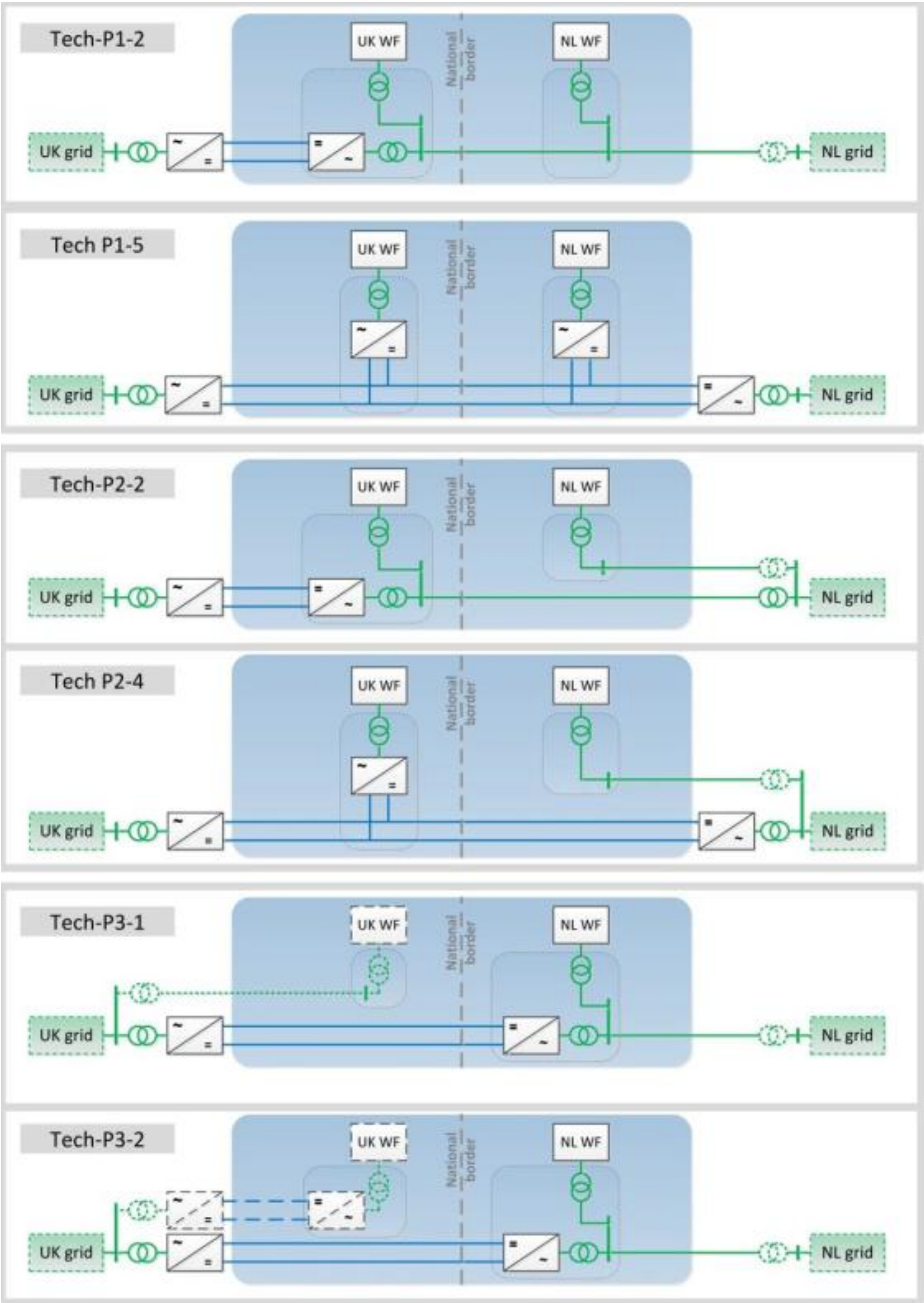
This document is based on the feasibility analysis WP 1 interconnection and offshore wind farms (report d.d. 15 January 2015). WP 1 studies the legal legislation, technical conditions and socio economics, and included an economic analysis of the interconnector. This work stream 3 of WP 2 studies the economic feasibility of the joint development of interconnecting infrastructure and offshore wind farms. Here we provide a holistic analysis and identify the advantages to combine interconnecting infrastructure with offshore wind production capacity.

The identification of advantages consists of an analysis of the incremental elements of the business case and economic evaluation of the (financial) performance of each element. This evaluation provides the basis to suggest optimized timing. It measures the contribution of each element of the business case.

The remainder of this document is structured as following. The next chapter Capacity Analysis outlines current use of capacity and defines a transport and production entity to allocate costs. Chapter 4 studies the profitability of investments and recommends for an order of investments based on the profitability analysis. Chapter 4 also shows the impact of the combined offshore wind and transmission infrastructure on the LCOE.

3 Capacity analysis

The project Synergies at Sea identified five different technical topologies in order to study the feasibility of interconnection and wind production capacity. These topologies are given below:



The scenarios above differ by the connection of the wind parks on the interconnecting link or onshore grid, and the use of Alternating Current (AC) or Direct Current (DC) transmission. Production of wind energy results in Alternating Current. As AC is a rather cheap technical solution to transport energy, over large distances the energy dissipation becomes large. Direct Current technology requires (expensive) converter stations to transform the energy, but has less dissipation of energy over long distances in comparison with AC technology. The scenarios present different use of AC and DC technologies. The boxes show the converter stations, the DC transmission is given with the blue double lined connections and AC transmission is given by the green single line connections.

Please remark that some scenarios have limited differences, while others differ significantly. For instance, scenario P1_5 only differs from P2_4 by the separate connection of the Dutch offshore wind farm. A converter station of the Dutch wind farm attached to the interconnecting link turns scenario P2_4 into scenario P1_5. Likewise scenario P2_2 turns into P1_2 if the Dutch wind farm would be connected to the interconnecting link. Other scenarios are more difficult to integrate by the choice forconnection of the wind park with the interconnecting link orwith the onshore grid, and on the use of AC or DC technology. For more information on the technical properties and differences of the scenarios please consider the study WP 1 interconnection and offshore wind farms.

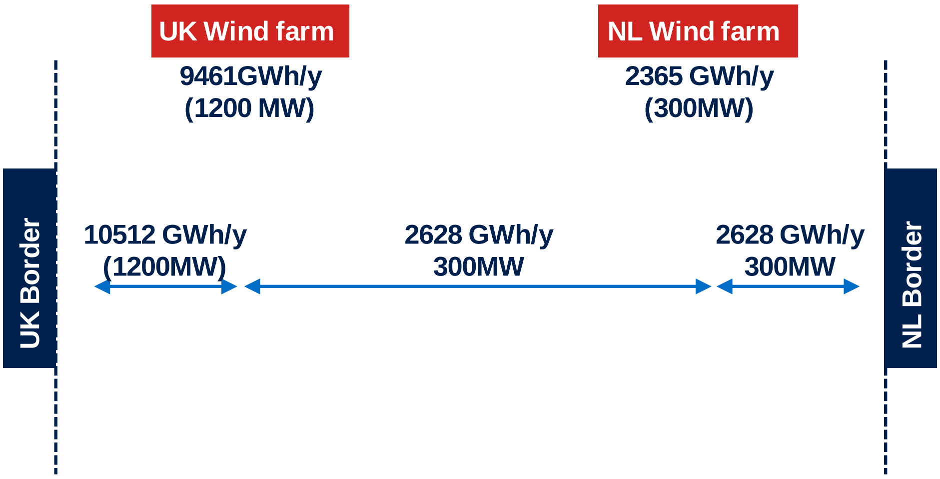
3.1 *Incremental elements and performance*

In addition to the different scenarios we identified the incremental elements. One may also define these elements as building blocks of every scenario. We have chosen the elements based on the type of connection of the wind park with the interconnecting link or with the onshore grid. We note that the choice for a combination of elements leads to the choice for AC or DC technology. For instance, the distance of the interconnector requires (partial) use of DC technology. The connection of wind parks to the interconnecting link would automatically require AC or DC technology.
The table below shows the different elements

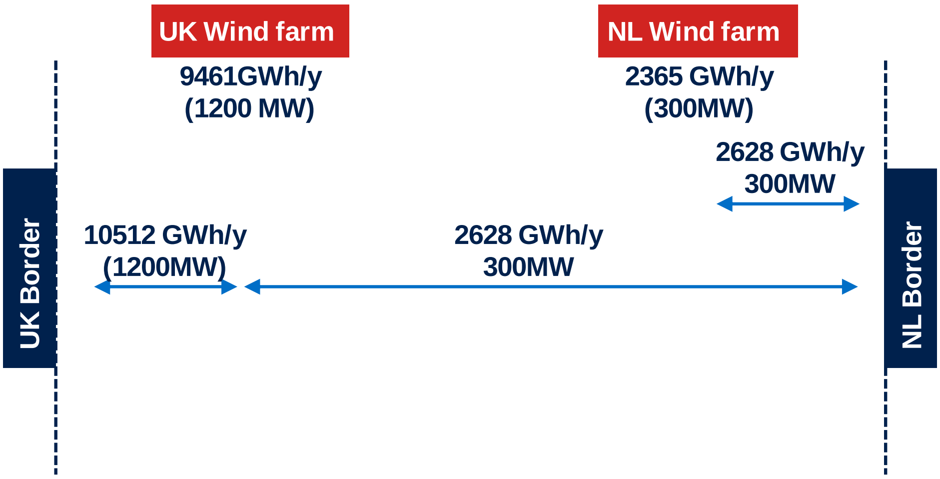
Incremental element	Description
UK wind farm	Offshore wind production facility at the UK border
NL wind farm	Offshore wind production facility at the Dutch border
Connection UK	The infrastructure connection between UK and UK wind park or connection between UK and converter station as part of the UK wind park at the interconnecting link
Connection NL	The infrastructure connection between NL and NL wind park or connection between NL and converter station as part of the NL wind park at the interconnecting link
Interconnecting link (IL)	Connection between the borders (no production attached to the IL) or connection between a converter station and country border (one wind farm attached to the IL) or connection between the converter stations (both wind farms attached)

From the elements we have identified the capacity in production and transmission for the different scenarios. The capacities are given in the table below. The red boxes show the production capacity and the blue arrows give the transmission capacity.

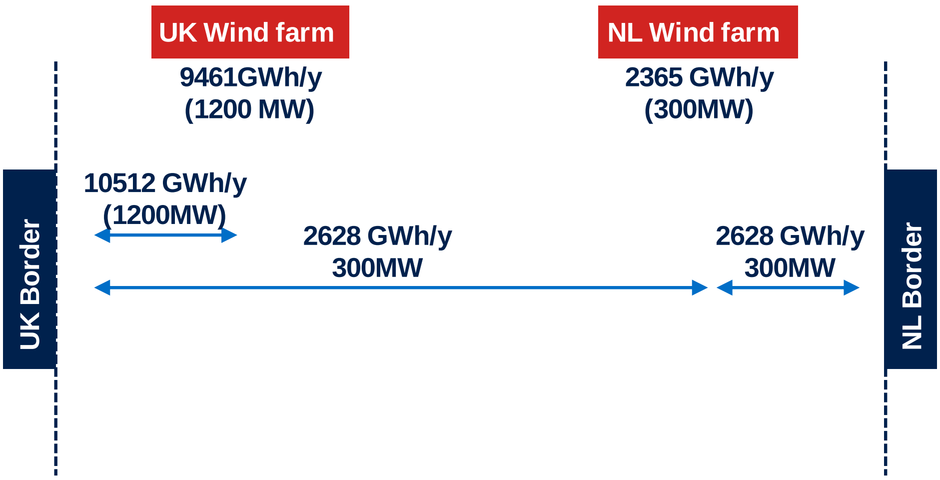
Capacity scenario 1*



Capacity scenario 2*



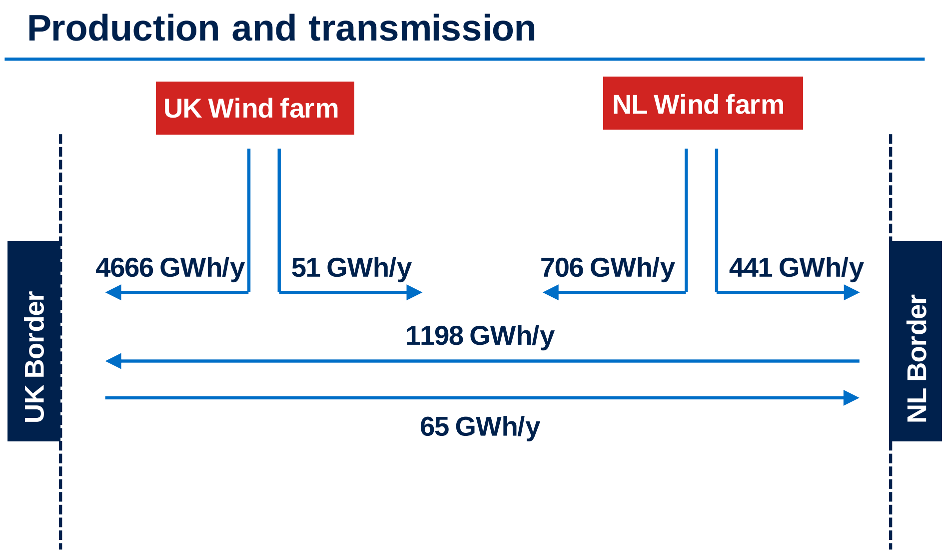
Capacity scenario 3*



(*) The capacities of the different scenarios shows the 300 MW interconnecting capacity. The analysis covers the 300 MW IL-scenarios as well as 1200 MW IL-scenarios.

3.2 *Incremental transmission and production*

Of every element within each scenario we identified the magnitude of production and transmission. Based on the 300 MW interconnecting capacity, the production and transmission of scenario 1 is given below:



This scenario 1 shows that the majority of UK production, 4666 GWh/y out of the total 4717 GWh/y, is transferred towards the UK border. Only 51 GWh/y is transferred towards The Netherlands. Technically, the wind park can generate 9461 GWh/y. Because of the changing wind speeds the operational performance is no more than 4717 GWh/y, which is approximately 50% of the technical capacity.

At the Dutch wind farm we see that most of the produced energy, 706 GWh/y out of 1147 GWh/y is transferred towards the United Kingdom. The remaining 441 GWh/y is transferred to The Netherlands. The NL wind park has an operational performance of only 49%, which is similar to the UK situation.

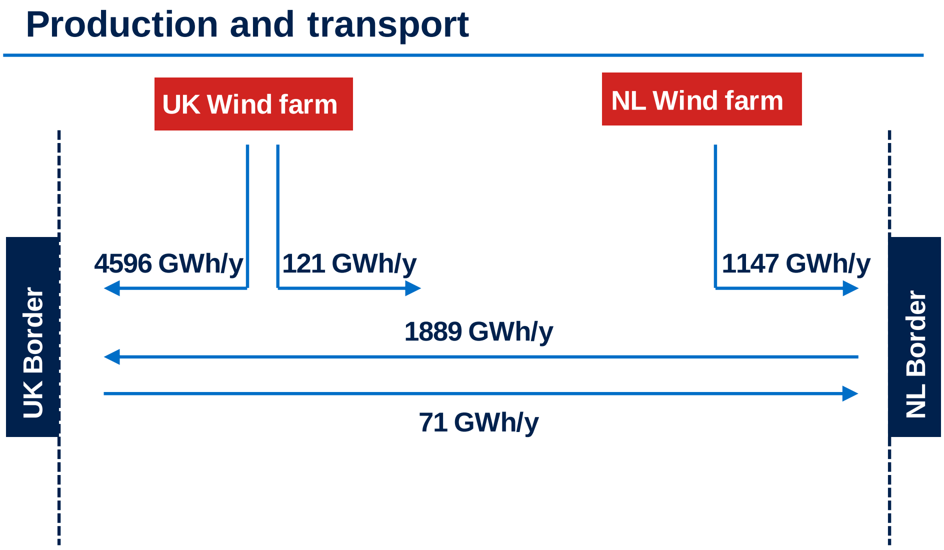
The transmission infrastructure of this scenario 1 uses at maximum 77% of its capacity. The interconnecting link transports in total 2020 GWh/y (51+706+1198+65) and has a capacity of 2628 GWh/y. The lines that connect the wind farms to onshore (i.e. between the converter stations and coasts) have a capacity of 63% towards the UK coast and 67% towards the Dutch coast.

Analysis of the production and transmission shows that the opportunity of increase are limited. Production rates of around 50% are driven by the changing and low wind speeds, and maintenance schemes. In comparison, real time data of the test field OWEZ show a 36% production rate as well as the 2012 study ‘Offshore wind cost reduction pathways’ by BVG associates show approximately 50% production performance. These observations underline the production estimates.

Opportunities to enlarge transmission are limited by the technical topology. One of the line segments is always at maximum capacity. Thus, there are no opportunities for additional transmission.

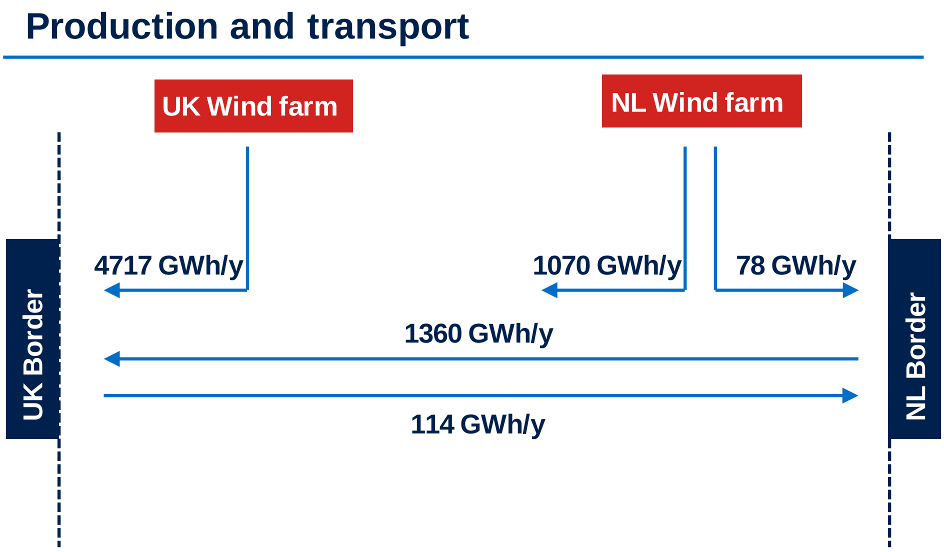
Please note that all WP 1 scenarios, including those with 1200MW interconnecting capacity or a different capacity in wind production, have been included in our analysis but have not presented here. The outcomes of this analysis are not presented here as the additional capacity does not have an impact on the amount of transmission. Different dimensions of wind parks or the interconnecting link have a limited effect on the use of capacity. The connections of the wind parks to the interconnecting link have a more significant impact on the use of capacities as we will show next.

The figure below shows the results of scenario 2.



The production of both wind farms is again at 49% and 50% for the Dutch, respectively for the UK farm. The transmission capacity of the Dutch Wind farm is 49% as the Dutch Wind farm is not connected with the interconnecting link within this scenario 2. The line between the UK coast and the converter station is at 62% of its capacity where the interconnecting link is at 79% of its capacity use.

The results of scenario 3 are given in the next figure.



The production rates remain equal. However, the utilization of transmission capacity is different. The capacity of the interconnecting link is 2628 GWh/y and transports 2544 GWh/y. This implies a use of capacity of 97%. The connection of the UK wind farm onshore is at 50% and the capacity utilization between the NL wind farm and the interconnecting link is 55%.

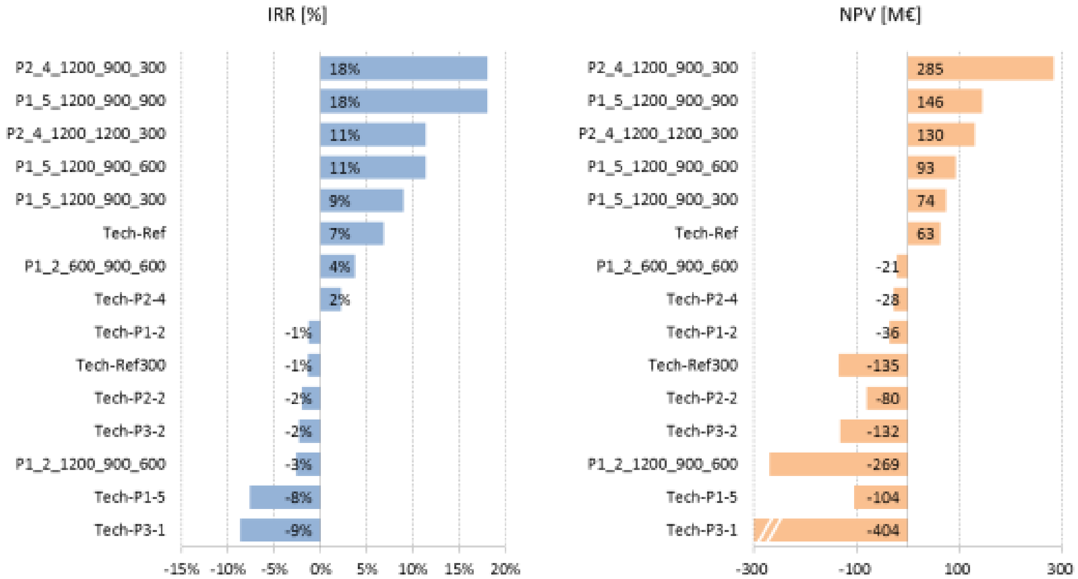
Based on these observations we draw two main conclusions:

1. The combination of transmission and production improves the utilization of the infrastructure.
   With the production rates at approximately 50%, the latter 50% of the infrastructure capacity is unused. Using this capacity for transmission improves the operational use with another 15% to 45%.
2. The transmission and production capacity should be balanced.
   The scenario 3 with only a 300 MW wind farm connected to the 300 MW interconnecting link shows a very good performance of the infrastructure. The other scenarios show less use of capacity which is caused by the large production volume at the UK wind farm.

3.3 *Financial analysis of the infrastructure*

The figures of the last two paragraphs showed the results of the 300 MW transmission infrastructure. This paragraph presents the results of the financial feasibility of the infrastructure. In fact, this analysis evaluates the financial performance of the different technologies and topologies. The evaluation directs the choice for AC or DC technology by trading off the energy losses, capital expenditures operational expenditures based on a transport fee. In addition, the choice for 300 or 1200 MW infrastructure is included. We present the main findings that are of importance to this study. For additional information please consider the WP 1 report.

The bar charts below present the IRR and NPV of the different scenarios. The “Tech”-scenarios relate to a 300 MW interconnecting link, the “PX_X_”-scenarios relate to a 1200 MW interconnecting link.



The graphs clearly show the good performance of the 1200 MW scenarios. The top 5 scenarios all have a 1200 MW interconnecting link. In addition, these top 5 scenarios are all based on DC technology. The difference between scenario P2_4 and P1_5 is the connection of the Dutch wind field with the interconnector, as also addressed in the introduction of this chapter. With these two scenarios with good performance and combination opportunities, we will further analyse the scenarios P1_5 and P2_4 in the remainder of this report. We compare these scenarios with the scenario “Tech-Ref” that includes a two standalone wind farms and one interconnecting link.

3.4 *Conclusions*

This chapter 3 has identified incremental elements that are the building blocks of each scenario. These elements are:

- UK Wind farm
- NL Wind farm
- Connection UK
- Connection NL
- Interconnecting link

The wind farms produce approximately 50% of their capacity. The maintenance schemes (i.e. outage time) and differences in wind speed determine this production rate.

With 50% use of production capacity, a connection towards The Netherlands or the UK is utilized for approximately 50% of its full capacity. In case the infrastructure is combined with interconnecting infrastructure, the utilization increases to 55% - 95% of its capacity. The increase depends on the chosen infrastructure line segment and the scenario.

The main conclusion of this chapter is that a combination of transport and production improves the use of infrastructure capacity. The utilization of transmission infrastructure increases with the combination of transport and production capacity. The economic analyses of the transmission infrastructure shows that the scenarios which combine transmission and production using DC technology are the most profitable.

4 Order of investments

This chapter discusses the sequence of investments. In order to determine the best phasing of investments we first define the entities to allocate costs and revenues. Thereafter we analyze the profitability of each entity for the top 5 scenarios. This analysis will indentify the driver of the business case and will be provide the basis to determine the order of investments.

4.1 *Production and transport entities*

Based on the elements and the different scenarios we distinct production and transport entities. There is an entity responsible for production of energy and the connection on a grid. This connection may be onshore, it may also be offshore. We call this entity the production entity. This entity receives a compensation per unit of produced energy.

There is also a transmission entity in place. This entity is responsible for the transport of energy, from the production facilities to its consumers. The entity receives a compensation for the transport of energy. In this particular case of interconnection, the entity receives the price difference between The Netherlands and the United Kingdom.

We will use this distinction between entities for the estimates of reduction of Levelized Cost of Energy (LCOE) in chapter 4. The production entity would impact LCOE because of the different connection to the grid (onshore vs. offshore). The transmission entity is only responsible for transport and cannot directly impact LCOE. Please note that the transmission entity can be a catalyst to impact the LCOE of the production entity.

This separation of entities may also serve as a solution to the legal discussions. The production entity operates within country borders under the country legislation and subsidy regimes. It is attached to infrastructure that provides (international) transport of energy. A different work stream within the Synergies at Sea project studies the legal aspects of this approach. Please consider this work stream for additional information.

From the economic analysis of the transport infrastructure we observed that the scenarios P2_4 and P1_5 show the best results. We compare these scenarios with the reference scenario Ref. This scenario consists of a NL and UK wind farm connected onshore and an interconnecting link between the UK and NL. From these scenarios we can identify a NL production entity, a UK production entity and a transmission entity. The table below shows which incremental elements are part of the different entities:

Scenario	Entity	Incremental elements
Ref	Production NL	Wind farm capacity 300 MW
		AC infrastructure to onshore infrastructure
	Production UK	Wind farm capacity 1200 MW

		Offshore DC converter station and cable to onshore infrastructure
	Interconnection	Onshore infrastructure and 1200 MW interconnecting cable
P2_4_1200_900_300	Production NL	Wind farm capacity 300 MW
		AC infrastructure to onshore infrastructure
	Production UK	Wind farm capacity 900 MW
		Offshore DC converter station
	Interconnection	Onshore infrastructure and 1200 MW interconnecting cable
P1_5_1200_900_900	Production NL	Wind farm capacity 900 MW
		Offshore DC converter station
	Production UK	Wind farm capacity 900 MW
		Offshore DC converter station
	Interconnection	Onshore infrastructure and 1200 MW interconnecting cable
P2_4_1200_1200_300	Production NL	Wind farm capacity 300 MW
		Offshore AC infrastructure to onshore infrastructure
	Production UK	Wind farm capacity 1200 MW
		Offshore DC converter station
	Interconnection	Onshore infrastructure and 1200 MW interconnecting cable
P1_5_1200_900_600	Production NL	Wind farm capacity 600 MW
		Offshore DC converter station
	Production UK	Wind farm capacity 900 MW
		Offshore DC converter station
	Interconnection	Onshore infrastructure and 1200 MW interconnecting cable
P1_5_1200_900_300	Production NL	Wind farm capacity 300 MW
		Offshore DC converter station
	Production UK	Wind farm capacity 900 MW
		Offshore DC converter station
	Interconnection	Onshore infrastructure and 1200 MW interconnecting cable

The difference between scenarios P1_5 and P2_4 is the linkage of the Dutch wind farm to the interconnector (P1_5) or to the onshore grid (P2_4). In case the Dutch wind farm is connected to the interconnector it makes use of DC technology. In case the Dutch wind farm is directly connected onshore, it makes use of AC technology. Please note that the difference between the scenario Ref and P2_4 is the connection of the UK wind farm onshore (Ref) or with the interconnector (P2_4). The difference between scenario P1_5 and Ref is the choice for a fully integrated system (P1_5) or stand-alone system (Ref). We will use these differences between the scenarios to identify the differences of replacing AC infrastructure for a DC interconnecting link and the differences to replace the DC infrastructure for a DC interconnecting link.

4.2 *Estimation of financials of the scenarios*

Having identified the different entities we can estimate revenues and costs (OPEX and CAPEX) based on production and transmission estimates to each entity. The table below gives the overview:

	Tech-Ref	P1_5_1200_900_300	P1_5_1200_900_600	P2_4_1200_1200_300	P1_5_1200_900_900	P2_4_1200_900_300
UK Production						
UK production (MWh, yearly)	4.396.000	3.538.000	3.538.000	4.717.000	3.538.000	3.538.000
UK revenues* production (€, yearly)	241.513.767	194.375.730	194.375.730	259.149.327	194.375.730	194.375.730
UK OPEX (€, yearly)	266.430.000	197.149.500	197.149.500	262.866.000	197.149.500	197.149.500
UK CAPEX production (€)	4.562.000.000	3.243.300.000	3.243.300.000	4.324.400.000	3.243.300.000	3.243.300.000
Production	3.960.000.000	2.970.000.000	2.970.000.000	3.960.000.000	2.970.000.000	2.970.000.000

Infra	602.000.000	273.300.000	273.300.000	364.400.000	273.300.000	273.300.000
NL Production						
UK production (MWh, yearly)	1.124.000	1.124.000	2.248.000	1.124.000	3.372.000	1.124.000
UK revenues* production (€, yearly)	53.898.477	53.898.477	107.796.953	53.898.477	161.695.430	53.898.477
UK OPEX (€, yearly)	66.339.000	65.943.000	131.886.000	66.339.000	197.829.000	66.339.000
UK CAPEX production (€)	1.122.600.000	1.096.200.000	2.192.400.000	1.122.600.000	3.288.600.000	1.122.600.000
Production	990.000.000	990.000.000	1.980.000.000	990.000.000	2.970.000.000	990.000.000
Infra	132.600.000	106.200.000	212.400.000	132.600.000	318.600.000	132.600.000
Interconnection						
IL Transmission (MWh, yearly)	9.204.000	9.204.000	9.204.000	9.204.000	9.204.000	9.204.000
IL revenues** (€, yearly)	68.141.064	68.141.064	68.141.064	68.141.064	68.141.064	68.141.064
IL OPEX (€, yearly)	8.386.250	8.386.250	8.386.250	7.926.250	8.386.250	7.926.250
IL CAPEX (€)	670.900.000	670.900.000	670.900.000	634.100.000	670.900.000	634.100.000

(*)As the basis of revenues we take the average day ahead price of power on the UK and NL power exchange between January 1st of 2011 and December 31st of 2014.

(**)As the basis of revenues we take the average price difference between the day ahead price of power on the UK and NL power exchange between January 1st of 2011 and December 31st of 2014.

The estimation of the transmission, production, CAPEX is derived from the estimates within WP 1. The cost estimates of the production entities are also based on the 2012 study 'Offshore wind cost reduction pathways' by BVG associates. The OPEX of the production entities are estimated by the assumption of 6,5% annual costs for the production CAPEX and 1,5% for the infrastructure CAPEX. For the interconnecting link the OPEX is estimated at 1,25% which is according to the WP 1 cost estimates.

The yearly revenues and yearly OPEX show that the wind production farms are not feasible without subsidies. The revenues do not compensate for the operational expenses. However, the interconnecting infrastructure is economically feasible. The revenues compensate for the operational costs. The next table below studies the economic feasibility in greater detail.

	Tech-Ref	P1_5_1200_900_300	P1_5_1200_900_600	P2_4_1200_1200_300	P1_5_1200_900_900	P2_4_1200_900_300
UK Production						
(Rev-OPEX)/CAPEX	-0,0055	-0,0009	-0,0009	-0,0009	-0,0009	-0,0009
NL Production						
(Rev-OPEX)/CAPEX	-0,0111	-0,0110	-0,0110	-0,0111	-0,0110	-0,0111
Interconnection						
(Rev-OPEX)/CAPEX	0,0891	0,0891	0,0891	0,0950	0,0891	0,0950

The table shows the gross cash flow (revenues – OPEX) divided over the initial CAPEX. This shows the payoff of every euro invested p.a. For instance, out of every euro invested in the interconnecting link one would receive approximately 9 ct. p.a. The UK wind farms shows a slightly negative payoff, where the Dutch wind farm requires an additional 1 ct. p.a. extra to keep the operations running. This analysis shows the interconnecting link is the most profitable entity in the development of the combination of offshore wind and interconnection.

The interconnecting link shows the best performance within the P2_4 scenario. This scenario has a lower CAPEX as the interconnecting link does not require a connection with the NL wind farm and the scenario can be constructed with a shorter distance of the cable between the UK wind park and the Dutch coast. This reduction saves initial investments which increases its profitability. Scenario P1_5 and Tech-Ref show a comparable result.

The connection of the UK production entity to the interconnecting link shows a significant increase in performance. The revenues do not change, but the CAPEX and OPEX decrease by 5% and 1% respectively. The connection of the Dutch wind farm to the interconnecting link shows a marginal improvement. The CAPEX decreases by 2% and the OPEX by 1%.

The use of AC or DC technology that is replaced by the interconnecting infrastructure determines the cost decreases. The Dutch wind farm is connected within scenario Tech-Ref and P1_5 with AC technology. This technology is cheaper to build in comparison with DC technology. But as the production entities only require a connection to the interconnecting link, less infrastructure needs to be build. This drives the 2% savings on CAPEX in the Dutch situation. The CAPEX of the UK production entity decrease by 5% as it will always requires DC technology to connect the production entities. Please note that this decrease is the decline of the total CAPEX. The CAPEX of the infrastructure of the UK production entity declines by 40%, while the CAPEX of the NL entity declines by 20%.

4.3 *Order of investments*

The analysis of the profitability of entities shows the interconnecting infrastructure generates the largest profits. Therefore we recommend to start constructions with the interconnecting infrastructure. In addition, the revenues of the interconnecting link are more certain as the performance of the infrastructure is independent from the wind speed.

Given the current approach to connect UK wind farms onshore with DC technology, it is very cost efficient to connect the production entities to the interconnecting infrastructure. Based on the yearly revenues and savings in infrastructure we propose to connect the UK wind farm following the construction of the interconnecting infrastructure. In addition, we recommend to replace DC technologies with an interconnecting DC grid.

Based on the yearly result of the different entities we can also determine whether the Dutch Wind farm should be connected to the interconnecting link or not. The connection of the Dutch wind farm with the interconnecting link generates 2% decline in CAPEX. The shorter connection of the interconnecting link in scenario P2_4 saves approximately 5%. Based on these estimates we do not recommend to connect the Dutch wind farm to the interconnecting link. The estimates show that the change of AC connection onshore to a DC interconnecting link should be evaluated on an individual basis. If an interconnecting link is close to the wind park it is profitable, otherwise it is not.

Please note that the yearly profit of UK is higher than the NL production profit. This difference is based on two elements. First the day ahead price of power in the UK is approximately 15% higher in the UK than in the Netherlands. The remaining difference is determined by the replacement of AC or DC technology.

The different scenarios distinct different capacities of offshore wind production. This analysis does not identify any differences between the different capacities. Optimizations by size may be opportune but have not been identified in this analysis that is based on the initial feasibility study of WP 1.

In addition, the OPEX of the production entities also includes compensation for transmission. This compensation accounts for approximately 1/3 of total OPEX. Here we have shown that an interconnecting link saves significant costs of infrastructure. The compensation may therefore also decline by 0,75% as the transmission compensation (1/3 of total OPEX) declines by 1/3. We propose to study this aspect in further detail and note this may have further positive impact on the economic feasibility. We will measure the impact of this additional compensation in the next paragraph.

4.4 *Impact of optimizations on LCOE*

Based on the estimated financials for the different scenarios we estimate the LCOE for the different production entities. We estimate the LCOE based on:

$$LCOE = \frac{\sum_{t=1}^{n} \frac{Production_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{CAPEX_t + OPEX_t}{(1+r)^t}}$$

Here we take n = 20 years and r = 6%. These estimates comply with the inputs from WP 1.

The LCOE for the production entities within the different scenarios is given in the table below:

	Tech-Ref	P1_5_1200_900_300	P1_5_1200_900_600	P2_4_1200_1200_300	P1_5_1200_900_900	P2_4_1200_900_300
UK Production						
LCOE (€/MWh)	168,96	152,63	152,63	152,63	152,63	152,63
NL Production						
LCOE (€/MWh)	163,68	161,43	163,68	161,43	161,43	163,68

The table above shows that the connection of DC technology to the interconnecting link saves 10%. The LCOE drops from € 168,96/MWh to € 152,63/MWh. The replacement of the AC technology by the DC interconnecting link saves approximately 1%. The LCOE drops from € 163,68/MWh to € 161,43/MWh.

In the last paragraph we suggested that the OPEX of production may decline by approximately 0,75% to 5,75% as the infrastructure costs decline by the combination of interconnection and production. With OPEX for production at 5,75%, the LCOE for the UK (i.e. DC technology) production entities drops to € 142,91/MWh and for the NL (i.e. AC technology) to € 151,23/MWh. For the UK situation this implies another 5% saving to 15% savings in total. For the Dutch situation this implies an additional 6% saving up to 7% in total.

The calculations above lead to the recommendation to design a DC interconnecting grid instead of stand-alone AC infrastructure. Based on the conclusion of paragraph 4.3 not to design a DC grid instead of stand-alone AC infrastructure, we recommend to evaluate the connection on an individual basis.

4.5 *Conclusions*

This chapter showed that the combination of interconnection and production entities generates significant savings. These savings result from less need for infrastructure. The reference scenario is based on a € 602 Mn construction budget to connect the 1200 MW UK offshore wind farm with DC technology to the onshore grid. Connecting the infrastructure to the interconnecting link requires only € 364 Mn construction budget.

These 40% savings require the use of DC technology. DC transmission technology, in comparison with AC technology, is mandatory for long distance transport, but expensive to construct. Especially if the design is based on DC technology, an integrated solution of a wind park and interconnecting link would generate savings.

The savings on infrastructure determine a decline of the LCOE by 10%. As the savings on interconnecting infrastructure reduce costs of transmission, this is likely to reduce OPEX. Here we estimate the reduction on OPEX to further reduce LCOE by 5% to 15% in total.

The replacement of AC infrastructure by a DC interconnecting grid should be evaluated on an individual basis. Here we estimate initial savings of LCOE at 1%, but reduction of OPEX may reduce the LCOE to 7% in total.