Green Giraffe
The renewable energy financial advisors

LCOE impact of seabed fishing in OWFs

22 July 2019

Study 2 – Final version

Nomenclature

Based on offshore wind energy taxonomy list

Abbreviation	Explanation
BI	Business Interruption
Capex	Capital Expenditures
HKW	Hollandse Kust West
IJV	IJmuiden Ver
LCOE	Levelised Cost of Electricity
MW	Megawatt
MWh	Megawatt hour
NPV	Net Present Value
Opex	Operational Expenditures
OWF	Offshore Wind Farm
PD	Property Damage
RVO	Rijksdienst voor Ondernemend Nederland
TNW	Ten noorden van de Waddeneilanden
WACC	Weighted Average Cost of Capital
WFZ	Wind Farm Zones
WTG	Wind Turbine Generator

Executive summary

Context and methodology

RVO has engaged Green Giraffe to assess the impact of allowing seabed fishing on the Levelised Cost of Electricity (LCOE) and bankability of 3 future offshore wind farm (OWF) zones under the Dutch offshore wind roadmap 2030: Hollandse Kust West (HKW), Ten noorden van de Waddeneilanden (TNW) and IJmuiden Ver (IJV)

The LCOE impact has been assessed based on the following

- Outputs from a previous Study 1 (0509_RVO_WF_FISHING_0002, Rev. R2_00 dated 10 May 2019) done for RVO which covers the cost items and loss in revenue related to accommodating seabed fishing
- Green Giraffe OWF database information used in modelling the 3 specific OWFs to obtain the LCOE
- Market consultations with insurers and banks
- 2 scenarios are defined: A "Potential" and a "Requested" scenario. The former does not assume larger WTG spacing and the latter assumes 1 nm spacing

Results

The LCOE increase for the 3 specific OWFs due to the increased burial depth and additional inspection campaigns to accommodate seabed fishing is estimated to be in the range of 0-0.2 EUR/MWh for the Potential scenario

It is not unlikely that the insurers will increase the premium and/or deductibles for Business Interruption (BI) and Property Damage (PD) insurance if seabed fishing is allowed in the OWFs due to the increased exposure to cable and structure damage. When appropriate risk mitigation measures are put in place, it is expected that there will be no adverse effect on bankability and debt pricing of OWFs

The cumulative LCOE increase is strongly related to the additional insurance premiums and the frequency of incidents & impacted revenues due to damaged cables

Several downside scenarios have been analysed which resulted in a total LCOE impact range between 0.2 and 1.7 EUR/MWh for the Potential scenario with similar impact for the 3 different specific OWFs

LCOE impact of seabed fishing in OWFs

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1. Introduction and Scope of Work

Background of Study 2: LCOE impact analysis of allowing seabed fishing in OWFs

I	The Dutch government, offshore wind developers, TenneT and the fishing industry are studying options and consequences of allowing seabed fishing activities within OWFs
II	Three studies have been defined by the "*Rijkdienst voor Ondernemend Nederland*" (RVO) to provide support for the ongoing process and insights for decision making
III	For Study 2 (*the "Project"*), RVO has engaged Green Giraffe to assess the impact of allowing seabed fishing on the LCOE and finance terms and conditions of future OWFs
IV	The Project covers 3 future OWF zones under the Dutch offshore wind roadmap 2030: Hollandse Kust West, Ten noorden van de Waddeneilanden and IJmuiden Ver
V	The results of Study 1, which cover the OWF and fishery design adjustments and the capital and operational expenditures impact, has been used as a basis for the Project

1. Introduction and Scope of Work

Study 2 Scope of Work

This report is the result of the Project which covers the following Scope of Work

- Interpreting the results and analysing the required inputs of the preceding Study 1 "*Fysieke aanpassingskosten voor windparkeigenaren, net op zee en visserijsector voor het geschikt maken van windparken op zee ten behoeve van sleepnetvisserij*" (0509_RVO_WF_FISHING_0001, Rev. R2_00 dated 10 May 2019 and 0509_RVO_WF_FISHING_0001, Rev. R3_00 dated 05 July 2019), to be used for the Project
- Engaging with an insurance broker and with several banks, active in the offshore wind sector, to determine qualitatively the impact of seabed fishing on the risk profile of the wind farms and the consequential impact on the finance and insurance terms and conditions
- Developing a financial model which is reflective of OWFs in the Dutch North sea in the relevant timeframe to assess the consequences of including seabed fishing in the wind farm zones in terms of LCOE impact. This model has been made specific for the planned wind farms under the "*Routekaart 2030 Windenergiegebieden*"
- The aim of the Project is to assess the impact on the LCOE of OWFs and the focus is not on absolute values of the LCOE. Therefore, only relative differences are shown in this report. The cost modelling is based on current market competitive price levels, expected cost changes of the Balance of Plant and WTG scope and have been adjusted for specific environmental conditions of the OWF locations

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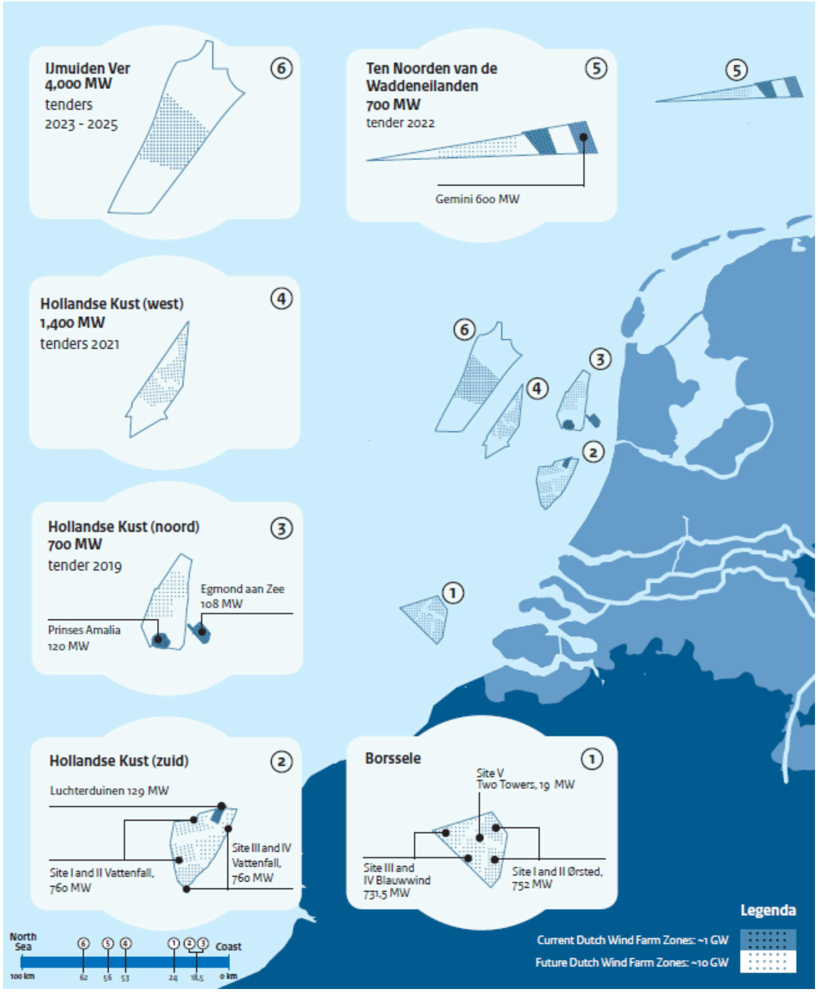
2. OWF details and assumptions

Background of the Dutch offshore wind roadmap 2030

The Ministry of Economic Affairs and Climate has set out the Roadmap for offshore wind energy 2030, which aims to deploy an additional 6,100 MW of offshore wind energy capacity by 2030. Combined with the 4,500 MW of the Roadmap 2023 as well as the existing wind farms, this capacity will bring the Netherlands' total offshore wind capacity up to 10,600 MW

Three wind farm zones (WFZs) have been identified to reach the additional 6,100 MW as shown in the green areas in the picture on the right

WFZ	# of OWFs	Year of tender	Exp. grid connection	Total capacity (MW)
HKW	2	2021	2024-2025	1,400
TNW	1	2022	2026	700
IJV	4	2023-2025	2027-2030	4,000



Source: RVO – Dutch Offshore Wind Farm Zones

2. OWF details and assumptions

Individual OWF site specifics

The wind farm zones are divided into individual wind farm sites to assess the impact on the LCOE for the developer of a single offshore wind farm within the wind farm zones as follows

- HKW: With a total WFZ capacity of 1,400 MW, it is expected that it consists of 2 sites with 700-760 MW per site
- TNW: With a total WFZ capacity of 700-760 MW, it is expected that it consists of 1 site with a 700-760 MW capacity
- IJV: With a total WFZ capacity of 4,000 MW, it is expected that it consists of 4 sites with 1,000 MW per site

The following expected WTG type and relevant environmental parameters have been used in Study 1 & 2

	HKW	TNW	IJV
# of WTGs of a single site (#)	63	63	66
WTG capacity (MW)	12	12	15
Total OWF capacity of a single site (MW)	756	756	990
Grid connection and commercial operations date	2024[1]	2026	2028[2]
Water depth (m)	19 – 31	28-40	30-40
Wind speeds @ 130m MSL (m/s)	10.1	9.9	10.3
Distance to shore (km)	51	56	53-80

[1]For HKW, the OWF which is expected to come online first is used in the LCOE modelling
[2]For IJV, the OWF which is expected to come online second is used in the LCOE modelling

2. OWF details and assumptions

OWF sites financial modelling and additional cost assumptions – Accommodation cost

For the purpose of this study, the following two scenarios have been defined and analysed. Due to the uncertainty in precise cost levels, several cases (Low, Mid & High) have been determined with different cost assumptions for each scenario

- *1. Potential spacing scenario:* This scenario is representative of an OWF with realistic distances between the individual WTGs within a defined WFZ without reflecting the 1 nm distance requirement from the fisheries. The average spacing for this reference scenario is estimated to be 1.3 km. The costs related to a longer cable length and the associated additional installation and burial activities are therefore not included in this scenario
- *2. Requested spacing scenario:* The current WFZs are not big enough to accommodate seabed fishing. In this scenario, it is assumed that the spacing between the WTGs can be increased to 1 nm (1.852 km) through an expansion of the WFZ reflecting the distance requirement from the fisheries. This comes at an additional cost for the increased cable length and the associated additional installation and burial activities. It must be noted that the analyses on this scenario do not include the positive impact of the increased spacing on wake losses nor the negative impact of a straight line layout[2]

Additional accommodation cost[1] (EUR M)	1. Potential scenario						2. Requested scenario					
	HKW/TNW			IJV			HKW/TNW			IJV		
	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
1.a. Capex: Cable purchasing cost		-			-			5.0			5.0	
1.b. Capex: Cable laying cost		-			-			1.0			1.5	
1.c. Capex: Cable burial cost (due to add. length)		-			-			2.0			2.0	
1.d. Capex: Cable burial cost (due to depth)	-	1.0	2.0	-	1.0	2.0	-	1.4	2.8	-	1.4	2.8
2. Opex: Annual inspection campaigns	-	0.3	0.6	-	0.3	0.6	-	0.3	0.6	-	0.3	0.6

[1] These costs are interpretations of the assumptions from the Study 1 report
[2] The impact of a straight line layout highly depends on the OWZ, but might lead to around 1-2% lower yield equivalent to 0.35-0.70 EUR/MWh in LCOE impact

2. OWF details and assumptions

OWF sites financial modelling and additional cost assumptions – Downside scenarios

Below the estimated replacement/repair costs and annual loss of income associated to allowing seabed fishing in OWFs are given. For Study 2 it is assumed that the replacement/repair of an infield cable or structure has a similar cost basis as Study 1

- *4. Infield cable replacement/repair cost:* Costs are shown including 50% replacement/repair of the cost are compensated by the insurers under PD insurance and excluding insurance compensation (see page 12)
- *5. Structure repair cost:* The structure repair cost is expected to be lower than the deductible under the PD insurance and it is therefore assumed that no compensation is received from the insurer
- *6. Loss of income*: The costs are calculated based on the WTGs used for the sites, a strike price of 54 EUR/MWh, capacity factor of 46%, a non-operating period of 50 days and 3 cases with 1 WTG, 4 WTGs and 7 WTGs affected by the damage in respectively a Low, Mid and High downside scenario. The first 50 days are generally excluded from insurers compensation

Additional downside cost[1] (EUR M)	1. Potential scenario			2. Requested scenario		
	HKW/TNW/IJV					
	Low	Mid	High	Low	Mid	High
4.a Infield cable replacement/repair cost (incl. 50% insurance compensation)	1.5	2.3	3.0	1.5	2.3	3.0
4.b. Infield cable replacement/repair cost (excl. 50% insurance compensation)	3.0	4.5	6.0	3.0	4.5	6.0
5. Structure repair cost		1.0			1.0	
6. Loss of income	0.4	1.4	2.5	0.4	1.8	3.1

[1]Additional downside cost are assumed to be the same for all OWF sites

2. OWF details and assumptions

Qualitative/quantitative analysis on insurance

Insights from an informal market sounding with experts in the insurance offshore wind business

- The opinion of insurance (brokers) is not unanimous: some think seabed fishing in OWFs should not be allowed, while others believe that it will become inevitably reality in the future
- It is not unlikely that insurances will increase their premiums and/or deductibles and come up with additional measures to minimise the risk of damaging subsea cables, like increased burial depth, increased cable inspection regimes or continuous monitoring of the cables

The following two insurance types are relevant for potential damages to the OWF assets due to seabed fishing

- Property Damage (PD): This insurance provides a compensation for the actual cost related to repairing or replacement of the OWF assets (above the deductible). The amount compensated by the insurers in case of damage to the OWF components depends on the deductible amount as part of the risk package selected by the developer and the actual damage cost. In this report, it is assumed that insurance covers 50% of the infield cable replacement cost
- Business Interruption (BI): This insurance provides a compensation for the loss of income due to a property damage (after a certain period)

At the moment, the insurers are unable to provide an estimate of the impact on the insurance terms. For the purpose of this study, an increase of 15%, 30% and 60% on the PD and BI premiums are applied as downside sensitivities

It is likely that allowing seabed fishing in the OWFs does have an impact on insurance deductibles and/or premiums, but it is unclear how much this could be

2. OWF details and assumptions

Qualitative analysis on bankability

Insights into the impact of fishing in OWFs on bankability have been gathered based on a consultation with experienced banks and based on the Green Giraffe experience in offshore wind

- With appropriate mitigants in place an OWF should remain bankable when fishing is allowed. In fact, several UK projects have raised non-recourse financing where fishing is not prohibited in the OWF
- Mitigants that have been proposed are
  - Appropriate measures (i.e. deeper burial, surveys, monitoring) are taken and validated by a technical advisor
  - Appropriate insurance cover (PD and BI) that will cover any damages
  - Sufficient contingencies/buffers are budgeted for any residual risk
  - A clear regulatory environment. Examples mentioned are a requirement for fishermen to have sufficient insurance cover and an obligation to report before the fishermen enter the zone. One concern is that it is often difficult to identify which party is responsible for a cable damage
  - Clear and easy accessible communication to fishing industry about locations of WTGs and cables
- A direct impact on debt pricing is unlikely. However, stacking several new risks at the same time could lead to a different risk categorization and an increase in margins
- In the current competitive offshore wind market the amount of debt that can be raised is usually limited by the amount of cash flows available to service the debt. Consequently, a part of the mitigants to be put in place (e.g. sufficient buffers, additional Capex and Opex) can in such case lead to a slightly lower leverage (debt to equity ratio)

Though no impact on debt pricing is expected, however a lower debt to equity ratio due to the mitigants can lead to a slightly higher Weighted Average Cost of Capital (WACC)

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3. Modelling approach

Levelised Cost of Energy (LCOE)

The LCOE is a widely adopted metric used to compare the lifetime investment & running costs of different electricity projects

- The LCOE is the net present value of the unit-cost of electricity over the lifetime of an electricity generating asset considering all costs over its lifetime: initial investment, operations and maintenance, taxes and cost of capital
- It implies the average minimum price at which electricity must be sold in order to break-even over the lifetime of the project
- There are multiple definitions for the LCOE, but for the Project the following definition has been used

$$LCOE = \frac{NPV\ of\ project\ costs\ over\ lifetime}{Total\ lifetime\ electricity\ production}$$

- Mathematically

$$LCOE_{real\ 2018} = \frac{\sum_{t=1}^{n} \frac{Investment_{2018t} + O\&M_{2018t} + Tax_{2018t}}{(1+r)^t}}{\sum_{t=1}^{n} \frac{Generation_t}{(1+r)^t}}$$

Where n is the life of the project, and r is the real Weighted Average Cost of Capital ($WACC_{real}$)

- The LCOE is calculated in 2018 figures which means that the costs are in 2018 figures and no indexation has been applied

3. Modelling approach

Weighted Average Cost of Capital (WACC)

Nominal vs. real WACC

- The WACC is the weighted average cost of finance, where the weighting is based on the share of funds provided from different sources (usually debt and equity)
- Mathematically

$$WACC_{nominal} = [(cost\ of\ equity\ in\ \%) * (\%\ avg.equity\ in\ project)] + [(cost\ of\ debt\ in\ \%) * (\%\ avg.debt\ in\ project)]$$

- Nominal values are often preferred by developers and investors as they infer the actual cashflow to be observed
- Real values, as used in this study, are often preferred by economists and analysts, who are interested in trends independent of economy-wide inflation
- Conversion between real and nominal WACCs , mathematically

$$WACC_{real} = \frac{1+WACC_{nominal}}{1+inflation\ rate} - 1$$

Where 2% has been assumed for the inflation rate which is equal to the long-term ECB target

Modelling approach

The LCOE calculations have been conducted with the financial model developed by Green Giraffe

- The model is based on recent market prices. It uses the latest market costs insights, experts forecasts and Green Giraffe's experience of (Dutch) offshore wind farms

The model assumes project finance

- For this study it is assumed that the wind farms are financed via project finance, as the impact of increased Capex also has an indirect effect on the cost of capital, which requires a modelling approach taking the WACC into consideration
- Project finance offers a comprehensive way of modelling this effect (vs. balance sheet financing), because any increase in risk directly translates into a linked increase in cost of capital as the project is non-recourse

Modelling assumptions taken on the seabed fishing implications

- Annual inspection campaign I & II were modelled as one single Opex increase
- Replacement/repair costs are handled as Opex and are assumed to happen every 3/5/10 years and are spread over the operating lifetime as the timing of the event occurrence is unknown, the same holds for loss of income
- It is assumed that insurance covers 50% of the infield cable replacement cost
- After calculating the LCOE per seabed fishing impact scenario, the LCOEs are analysed and the effects compounded

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4. Financial analysis and results

LCOE impact of OWFs from additional accommodation costs – 1. Potential scenario

The below LCOE impacts are incurred due to the additional Capex and Opex in order to accommodate seabed fishing in future OWFs. The results are for the *Potential scenario* where additional WTG spacing is not taken into account

- The results indicate that the Opex costs related to the estimated additional annual inspections during the lifetime of the wind farm account for around 80% of the LCOE increase due to the additional cost to accommodate seabed fishing
- The LCOE impact of the 3 OWFs are rather similar, with a lower impact on the IJV project due to overall higher Capex and Opex levels due to the bigger size of the project

Individual LCOE impact[1] (EUR/MWh)	HKW			TNW			IJV		
	Low	Mid	High	Low	Mid	High	Low	Mid	High
1.a. Capex: Cable purchasing cost	N/A								
1.b. Capex: Cable laying cost	N/A								
1.c. Capex: Cable burial cost (due to add. length)	N/A								
1.d. Capex: Cable burial cost (due to depth)	-	0.02	0.04	-	0.02	0.04	-	0.02	0.03
2. Opex: Annual inspection campaigns	-	0.10	0.20	-	0.10	0.19	-	0.08	0.16
Total	-	0.12	0.24	-	0.12	0.23	-	0.09	0.19

[1] The underlying cost assumptions can be found on slide 10

The LCOE impact from the additional accommodation costs greatly depends on the implications related to deeper burial and the number of additional annual inspections

4. Financial analysis and results

LCOE impact of OWFs from additional accommodation costs – 2. Requested scenario

The below LCOE impacts are incurred due to the additional Capex and Opex in order to accommodate seabed fishing in future OWFs. The results are for the *Requested scenario* where additional WTG spacing is taken into account

- The additional cost related to the longer cables account for around 50% of the LCOE increase
- The LCOE impact of the 3 OWFs are rather similar, with a lower impact on the IJV project due to overall higher Capex and Opex levels due to the bigger size of the project

Individual LCOE impact[1] (EUR/MWh)	HKW			TNW			IJV		
	Low	Mid	High	Low	Mid	High	Low	Mid	High
1.a. Capex: Cable purchasing cost		0.10			0.10			0.08	
1.b. Capex: Cable laying cost		0.02			0.02			0.02	
1.c. Capex: Cable burial cost (due to add. length)		0.04			0.04			0.03	
1.d. Capex: Cable burial cost (due to depth)	-	0.03	0.06	-	0.03	0.06	-	0.02	0.04
2. Opex: Annual inspection campaigns	-	0.10	0.20	-	0.10	0.19	-	0.08	0.16
Total	0.17	0.29	0.42	0.16	0.28	0.40	0.14	0.24	0.34

[1] The underlying cost assumptions can be found on slide 10

Compared to the *Potential scenario*, around +0.15-0.20 EUR/MWh additional LCOE impact is expected in case the spacing between the WTGs is increased to 1 nm to accommodate fishing

4. Financial analysis and results

LCOE impact of OWFs from downsides – Both 1. Potential and 2. Requested scenarios

The below LCOE impacts are uncertain and/or are incurred additionally in case of a seabed fishing incident. For the different parameters, 3 types of downside scenarios (downside, material and significant) have been defined and analysed

- The parameter with the biggest impact on the LCOE is the additional insurance premium
- In case of any damage, the biggest LCOE impact driver is the cable replacement/repair cost

D1 = Downside
D2 = Material downside
D3 = Significant downside

Individual LCOE impact[1] (EUR/MWh)	HKW			TNW			IJV		
	D1	D2	D3	D1	D2	D3	D1	D2	D3
3. Additional insurance premium (PD & BI)	0.11	0.21	0.42	0.10	0.21	0.41	0.11	0.23	0.46
4.a. Infield cable replacement/repair cost[2] (incl. 50% insurance compensation	0.05	0.15	0.33	0.05	0.14	0.31	0.04	0.12	0.26
4.b. Infield cable replacement/repair cost[2] (excl. 50% insurance compensation)	0.10	0.30	0.66	0.10	0.28	0.62	0.08	0.23	0.52
5. Structure repair cost[2]	0.03	0.07	0.11	0.03	0.06	0.11	0.03	0.05	0.09
6. Loss of income[2]	0.01	0.09	0.28	0.01	0.09	0.26	0.01	0.09	0.27
Total (incl. 50% insurance compensation)	0.20	0.52	1.14	0.20	0.50	1.09	0.19	0.49	1.07
Total (excl. 50% insurance compensation)	0.25	0.67	1.47	0.24	0.64	1.40	0.23	0.61	1.34

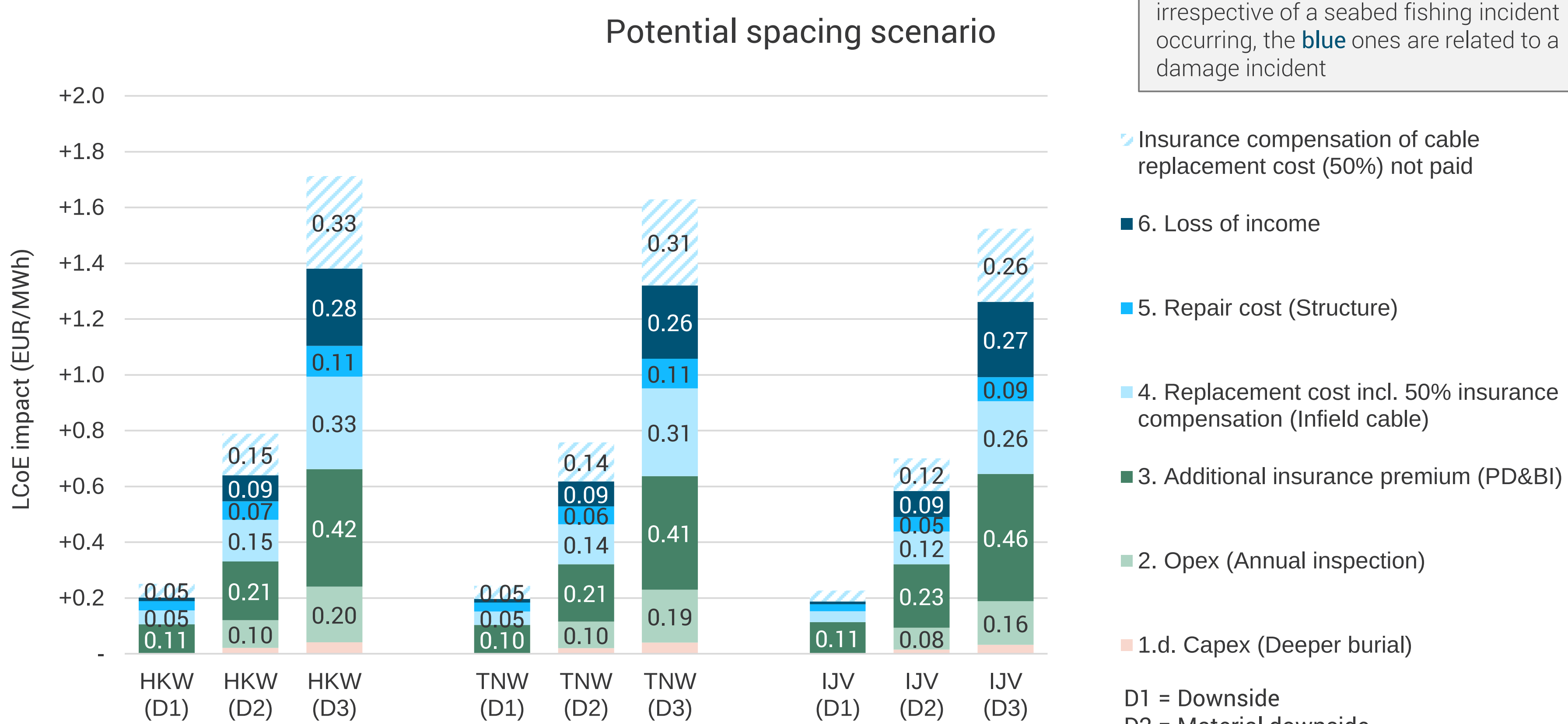
[1] The underlying cost assumptions can be found on slide 11 for the replacement/repair cost and loss of income and slide 12 for the insurance premium
[2] For the downsides, it assumed that damage to a structure with associated income loss occurs every 10, 5 and 3 years for D1, D2 and D3 respectively

The LCOE increase is strongly related to the additional insurance premium, frequency of incidents & impact on revenues due to damaged cables and # of affected WTGs

4. Financial analysis and results

Cumulative LCOE impact for downside case – 1. Potential scenario

The red/green LCOE impacts are irrespective of a seabed fishing incident occurring, the **blue** ones are related to a damage incident



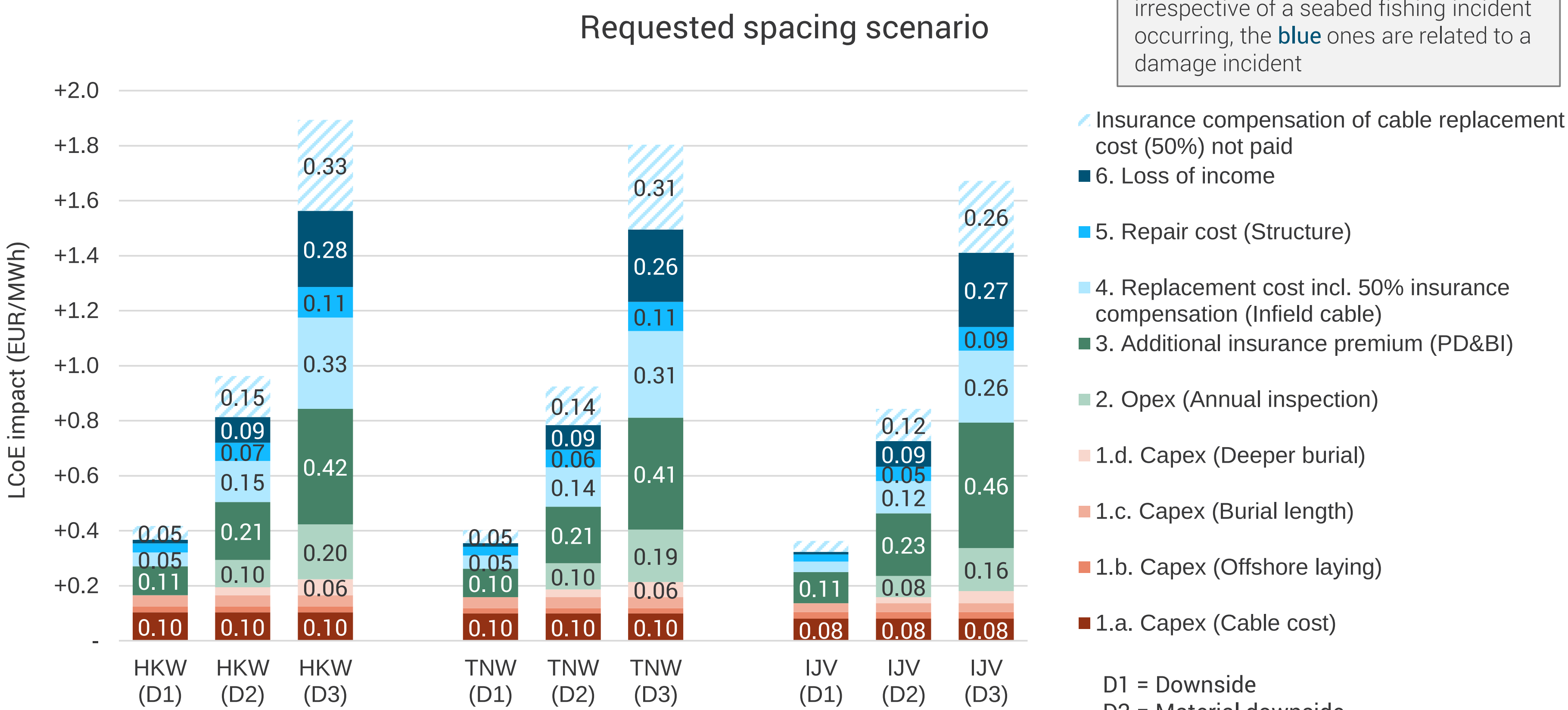
Only values displayed where LCOE impact is bigger than or equal to 0.05 EUR/MWh

The cumulative LCOE impact due to (i) costs for accommodating seabed fishing and (ii) downside case ranges between 0.2 and 1.7 EUR/MWh for the *Potential scenario*

4. Financial analysis and results

Cumulative LCOE impact for downside case – 2. Requested scenario

The red/green LCOE impacts are irrespective of a seabed fishing incident occurring, the blue ones are related to a damage incident



Only values displayed where LCOE impact is bigger than or equal to 0.05 EUR/MWh

The cumulative LCOE impact due to (i) costs for accommodating seabed fishing and (ii) downside case ranges between 0.4 and 1.9 EUR/MWh for the *Requested scenario*

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5. Conclusions

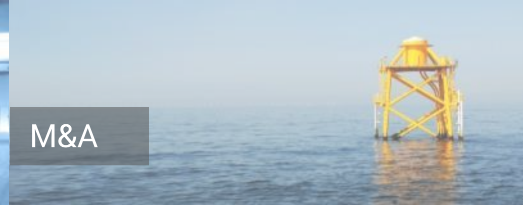
Conclusions of Study 2: LCOE impact analysis of allowing seabed fishing in OWFs (1/2)

I	The impact of allowing seabed fishing on the LCOE of 3 specific OWFs under the Dutch roadmap to 2030 (HKW, TNW, IJV) has been analysed in this report
II	It is not unlikely that the insurers will increase the premium and deductibles for the PD and BI insurances. However, there is uncertainty in how much this might be (p.12)
III	It is expected that there is no material impact on the finance terms and conditions provided the increased risk profile is mitigated through adequate measures (p.13)
IV	The LCOE increase only related to additional cost to accommodate seabed fishing is estimated to be around 0-0.2 EUR/MWh for the *Potential scenario* for all 3 OWFs (p.19)
V	The cum. LCOE impact strongly relates to the additional insurance premiums, incidents frequency & cost and ranges between 0.2-1.7 EUR/MWh for the *Potential scenario* (p.22)

5. Conclusions

Conclusions of Study 2: LCOE impact analysis of allowing seabed fishing in OWFs (2/2)

I	If expansion of the WFZ areas is not possible, it is unlikely that the WTG spacing can and will be increased to 1 nm to accommodate seabed fishing activities (p.10)
II	Compared to the *Potential scenario*, around +0.15-0.20 EUR/MWh additional LCOE impact is expected in case the spacing between the WTGs is increased to 1 nm (p.20)
III	The total LCOE impact due to (i) costs for accommodating seabed fishing and (ii) downside case ranges between 0.4 and 1.9 EUR/MWh for the *Requested scenario* (p.23)



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