# REPORT $CO_2$ AND $NO_x$

*Report $CO_2$ and $NO_x$ emission of helicopter operations from Den Helder Airport compared with Offshore vessel movements from Port of Den Helder.*

*Impact of the negotiation agreement Dutch North Sea*

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# TABLE OF CONTENTS

# INTRODUCTION

*This report has been initiated after a negotiators agreement had been reached about the North Sea agreement for the Netherlands. This agreement included several articles that would reduce the usage of helicopters for the transport of passengers and goods for the offshore industry Overlegorgaan Fysieke Leefomgeving, 2020). One of the articles states that due to the reduction of helicopters, the spatial use of the North Sea will be reduced. The other articles that this report will look into, is that the North Sea agreement states that future offshore rigs will be produced without landing decks for helicopters. This report investigates whether the assumption made in the North Sea agreement is valid. This study does this by investigating what the emissions of helicopters are compared to the alternative, which are ships. In this study the transport of passengers and goods will be considered, as well as taking into consideration the total emissions of the logistics of Den Helder.*

The transport of passengers and goods done by Den Helder Airport and the Port of Den Helder is strongly dependant of the offshore industry. Historically this offshore industry mainly consist of the oil and gas industry. More recently the offshore wind industry has also started playing a larger role in this. The operations of the oil and gas industry is relatively stable currently, but the locations of offshore wind parks are growing strongly. The expectation is that this growth will continue, especially following the Dutch Climate Agreement that states that the generation of offshore renewable energy will need to increase to 49 TWh and the generation of energy on land only to 35 TWh (Rijksoverheid, 2019). This agreement makes it almost a certainty that the construction and maintenance of offshore wind parks will increase tremendously the coming years. The current constructed Dutch wind parks have a generated capacity of 957 MW. To increase this amount to the required 49 TWh, an estimated extra amount of 10411 MW generated capacity will need to be constructed. Next to this amount for 2030, for 2050 the amount of generated capacity will need to increase to 60 GW (Wiebes, 2018).

Due to this increase, it is expected that there will also be an increase to the transport of goods and passengers to these offshore wind parcs. Currently, this transport is being done by ships and helicopters. With the introduction of the Dutch North Sea agreement it is likely that the intend of the agreement will be to reduce the share of helicopters in this transport. Therefore, this report has been set up. To research whether the transport of passengers and goods can better be done by helicopters or ships, for the case of emissions.

In this study the locations as shown in Table 1 are used for the calculation of the travel distance. The centre of these locations is used for the calculation of the distance, and this is calculated from Den Helder Airport. The distance is shown in Nautical Miles (NM). Following from the locations, the average distance is taken. This average distance is 78.6 NM, which is the same as 145.6 km. This has a flight time of 0.5980 hours (35 minutes and 53 seconds) and a shipping time of 7 hours, 51 minutes and 36 seconds. The following calculation is used for the calculation of the flight time:

$$\frac{Distance_{nm} - LTO_{nm}}{Cruising\ speed} * 60 + LTO_{minutes}$$

**$Distance_{nm}$ = Distance from Den Helder Airport to location**

**$LTO_{nm}$ = Distance traversed with Landing and Take-off. Totalling to 8.3 nm**

**Cruising speed = Cruising speed of helicopter. Defined as 140 knots**

*** 60 = conversion to minutes**

**$LTO_{minutes}$ = Minutes required for LTO**

This calculation shows that for the average flight without LTO the flight time is 0.5021 (30 minutes and 8 seconds). This is of importance because this flight time is used for the calculation of the amount of the fuel used, and which the emissions are based on.

**Table 1** *Distances of the different offshore locations with flight and shipping times..*

| Location | Distance (NM) | Flight time | Shipping time |
|---|---|---|---|
| BORSELLE 3/4/ | 101 | 0.76 | 10.1 |
| Hollandse kust zuid | 45 | 0.36 | 4.5 |
| Hollandse kust noord | 22 | 0.19 | 2.2 |
| Hollandse kust west | 38 | 0.31 | 3.8 |
| Ymuiden ver | 64 | 0.49 | 6.4 |
| Ten noorden van de Waddeneilanden | 67 | 0.52 | 6.7 |
| BLOCK A | 152 | 1.12 | 15.2 |
| BLOCK B | 143 | 1.06 | 14.3 |
| BLOCK E | 106 | 0.79 | 10.6 |
| BLOCK F (short) | 77 | 0.59 | 7.7 |
| BLOCK F (long) | 115 | 0.86 | 11.5 |
| BLOCK G | 71 | 0.54 | 7.1 |
| BLOCK K | 69 | 0.53 | 6.9 |
| BLOCK L | 53 | 0.42 | 5.3 |
| BLOCK P | 56 | 0.44 | 5.6 |

For the $CO_2$ emissions of jet fuel two figures are available from different sources (Table 2). The first is based on the US Energy Information Administration (2016), that states that 9.57 kg of $CO_2$ is emitted by using one gallon of jet fuel. This adds up to 2033 g/kg when converted. Next to this Klein et al. (2019) state an emissions equivalence of 3110 g/kg of jet fuel. This is based on the report 'Methods for calculating the emissions of transport in the Netherlands 2019'. For this study, the second figure has been selected as this is the official figure used by PBL and thereby the Dutch Government. It has to be mentioned that these figures are derived from data from planes at Schiphol. This prevents the usage of this source for the amount of $NO_x$. The $NO_x$ content is based of Rindlisbacher & Chabbey (2015).

**Table 2** *Emission data with different types of fuel. These are the figures that are used in this study.*

| Type | Source | Amount | Unit | Type of fuel |
|---|---|---|---|---|
| Heli | $CO_2$ (U.S. Energy Information Administration) | 2033 | g/kg | Jet fuel |
| Heli | $CO_2$ (Klein et al., 2019) | 3110 | g/kg | Jet fuel |
| Heli | $NO_x$ (Rindlisbacher & Chabbey, 2015), figures derived of this | 7316 | g/hour | Jet fuel |
| Ship | $CO_2$ (Klein et al., 2019) | 3121 | g/kg | Diesel |
| Ship | $NO_x$ (Klein et al., 2019) | 52.3 | g/kg | Diesel |
| Ship | $NO_x$ in port/DP (Klein et al., 2019) | 31 | g/kg | Diesel |

Table 3 gives an overview of the different helicopter types that are regularly used at Den Helder Airport. What is of importance for the calculation of emissions from these types is the amount of fuel used per hour and the fuel used for each LTO (Landing Take-off). Next to this the passenger and goods capacity is shown. This will be used for the calculation of the optimal emissions scenario's.

**Table 3** *Different types of helicopters used, with the fuel usage and carrying capacity..*

| Heli | Brandstofverbruik per LTO (kg) | Brandstofverbruik (kg/uur) | Passagier Capaciteit | Goederen Capaciteit (kg) |
|---|---|---|---|---|
| AW189 | 67 | 440 | 16 | 460 |
| AW139 | 58 | 420 | 12 | 300 |
| AW169 | 42 | 298 | 8 | 250 |
| EC-175 | 72 | 490 | 16 | 300 |
| EC-155 | 48 | 330 | 10 | 300 |
| EC-145 | 37 | 261 | 8 | - |
| EC-135 | 30 | 209 | 5 | - |

The current fleet in use at Den Helder Airport is shown in Table 4. This shows that the current fleet consists of 13 helicopters with the AW139 being a large part of the fleet. The emissions of each helicopter trip is taken from this fleet using the emissions data derived from Klein et al. (2019) for $CO_2$ and Rindlisbacher & Chabbey (2015) for $NO_x$.

**Table 4** *The composition of the current helicopterfleet on Den Helder Airport with the emissions per flight based on this fleet.*

| Amount | Type | Average $CO_2$ per flight (kg) | Average $NO_x$ per flight (kg) | Passenger capacity | Goods capacity (kg) |
|---|---|---|---|---|---|
| 8 | AW139 | 1015 | 2.22 | 12 | 300 |
| 2 | AW189 | 1101 | 2.57 | 16 | 460 |
| 1 | EC175 | 1211 | 2.63 | 16 | 300 |
| 2 | EC155 | 813 | 1.75 | 10 | 300 |
| Emissions for an average flight from Den Helder Airport | | $CO_2$ (kg): 1012 | | $NO_2$ (kg) 2.24 | |

Table 5 shows the current composition of the shipping fleet. This fleet consists of nine different ships, where some ships have different roles. Examples of these roles are suppliers and walk-to-work vessels. To get the average emission per shipping trip, the average is taken from the total emissions of all vessels. The emissions data is derived from Klein et al. (2019). Next to this, an assumption had to be made regarding the amount of time the ships spent in Port and Dynamic Positioning (DP). The time assumed for this in this study is one hour in Port and one hour Dynamic Positioning. Although in reality the amount of time a ship spent on this is longer, for this study that only looks at the travel time this is considered a realistic assumption. The remaining time in Port and DP can be considered to contribute to the emissions offshore or in Port. This ensures that this study is most comparable and only takes into account actual travel emissions. When a more realistic amount of time in Port and DP is taken into account of 24 hours, emissions will likely be a multitude of 4 higher than the found emissions in this study.

**Table 5** *The composition of the Offshore Supply Vessel fleet used for offshore logistics.*

| Ship | Fuel use in Port (kg/hour) | Fuel use DP (kg/hour) | Fuel use (kg/hour) | Passenger capacity | Goods capacity on deck (ton) |
|---|---|---|---|---|---|
| OSV1 | 29.17 | 175 | 375 | 8 | 1600 |
| OSV2 | 29.17 | 175 | 321 | 6 | 1600 |
| OSV3 | 29.17 | 88 | 204 | 12 | 1500 |
| PSV1 | 29.17 | 175 | 306 | 2 | 1600 |
| PSV2 | 29.17 | 117 | 204 | - | - |
| PSV3 | 29.17 | 175 | 318 | 38 | 1500 |
| PSV4 | 29.17 | 175 | 321 | 38 | 1500 |
| W2W1 | 29.17 | 204 | 292 | 60 | - |
| W2W2 | 29.17 | 204 | 292 | 60 | - |

The last part that contributes to the logistics of the offshore operation in Den Helder are the Crew Transfer Vessels. These are mainly used for the transport of passengers and goods, and are interesting to look at taking into account the current development on the North Sea considering wind parks. The current types that are used in the Port of Den Helder are built by Damen. For this study the DAMEN Fast Crew Supplier 2610 (DAMEN, 2019), DAMEN Fast Crew Supplier 2610/24 pax and the DAMEN Fast Crew Supplier 2008 are used. Table 6 shows this composition with the specifications of those vessels.

**Table 6** *Composition of the CTV fleet with specifications.*

| Ship | Speed (kn) | Fuel use (kg/hour) | Travel time (Hours) | $CO_2$ (kg) | $NO_x$ (kg) | Passenger capacity | Goods capacity on deck (ton) |
|---|---|---|---|---|---|---|---|
| DAMEN Fast Crew Supplier 2610 (2019) | 21 | 291 | 3.74 | 4006 | 67.13 | 12 | 15 |
| DAMEN Fast Crew Supplier 2610/24 pax | 21 | 291 | 3.74 | 4006 | 67.13 | 24 | 15 |
| DAMEN Fast Crew Supplier 2008 | 19 | 233 | 4.14 | 349 | 58.5 | 12 | 4 |

# RESULT CURRENT EMISSIONS LOGISTICAL OPERATION DEN HELDER

Following from the analysis using the current data available from the helicopter and shipping fleets used in the logistical operations around Den Helder the emissions are now known. For helicopters, during an average flight of 78.6 NM, 1012 kg $CO_2$ and 2.24 kg $NO_x$ are emitted. For the same distance Offshore Supply Vessels emit 7782 kg $CO_2$ and 130.41 kg $NO_x$. For CTVs this is 3402 kg $CO_2$ and 57.00 kg $NO_x$. This data shows that for a similar distance helicopters have a lower amount of emissions. It needs to be taken into account though, that ships have a bigger capacity for goods. For the current analysis this is not of importance because this is a first inventory of the total emissions of the logistical services of Den Helder Airport.

**Table 7** *Emissions per type of transport, per trip.*

| Type | $CO_2$ (kg) | $NO_x$ (kg) |
|---|---|---|
| Helicopters | 1012 | 2.24 |
| Offshore Supply vessel | 7782 | 130.41 |
| Crew Transfer Vessel | 3402 | 57.00 |

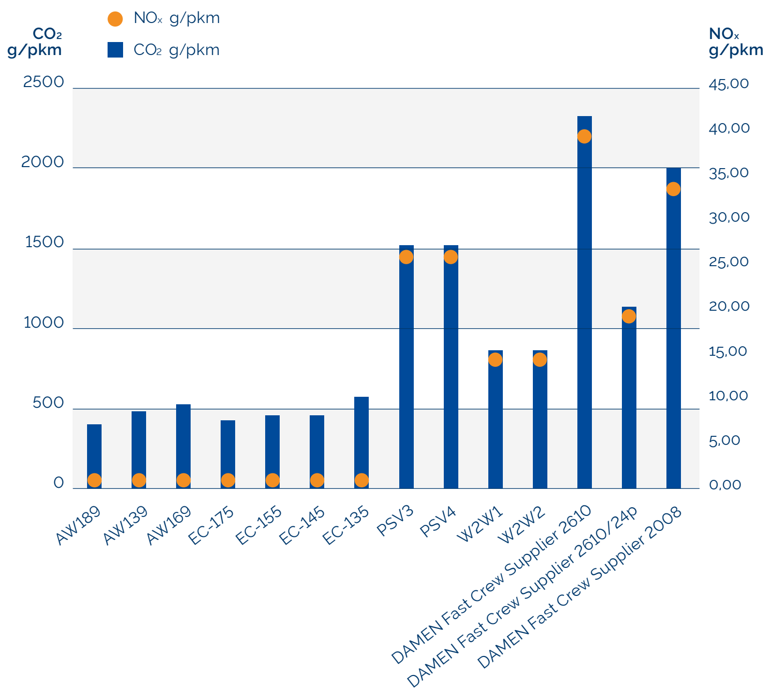
From the data from Table 7 the total emissions are calculated. For this the amount of flight as stated by Den Helder airport are taken in combination with the amount of passengers transported. This totals to 15232 flights for 2019. For each flight one LTO is taken into account and the previously mentioned flight time. With the current fleet the emissions for flights are 15416 Ton $CO_2$ and 34.05 Ton $NO_x$. Next to this, the amount of shipping movements are based on statistics from the Port of Den Helder. From this it was found that the offshore sector has 1752 movements in the Port of Den Helder. DHSS accounts for 300 of these movements. This study assumes that the amount of movements by ships is 80% offshore supply vessels and 20% CTVs. Using these figures the total amount of emissions from shipping are 12251 Ton $CO_2$ and 205.30 Ton $NO_x$. Meaning that the total logistical operation in Den Helder totals to 29017 Ton $CO_2$ and 243.78 Ton $NO_x$.

**Tabel 8** *Het totaal aantal bewegingen van helikopters en schepen met daarbij behorende uitstoot in Tons.*

| Type | Movement | $CO_2$ (Tons) | $NO_x$ (Tons) |
|---|---|---|---|
| Helicopters | 15232 | 1012 | 2.24 |
| Ships | 1752 | 7782 | 130.41 |
| Totals | 16984 | 3402 | 57.00 |

Next to the current it has also been calculated what the emissions are per transport method for the transport of passengers or goods per kilometre. For passengers all helicopter types taken into account and the following OSVs are taken into the study: PSV, OSV en W2W. These are the OSVs that are also suited for the transport of passengers. Next to this, the following CTVs are included in this study: DAMEN Fast Crew Supplier 2610, DAMEN FCS 2610/24 pax en DAMEN FCS 2008. For this analysis the maximum passenger capacity is taken. In Figure 1 it is shown that all helicopter types have lower $CO_2$ and $NO_x$ per passenger kilometre compared to all types of vessels. This is especially the case for $NO_x$, as helicopters have relatively low nitrogen emissions. The two Walk-2-Work ships are the most favourable ships for transporting passengers, but this takes into account the assumption of optimal passenger load. This passenger load for W2W1 and W2W2 is 60 passenger. There are not a lot of real world scenarios where 60 passengers are needed at a distance of 78.6 NM in one location, but this shows that when efficiently used the Walk-2-Work vessels can be the least emitting vessel. For the CTVs the emissions per passenger kilometre are high. The only vehicle that is in the same range as the others ships is the DAMEN 2610/24 pax, this is because it has a capacity of 24 passengers.

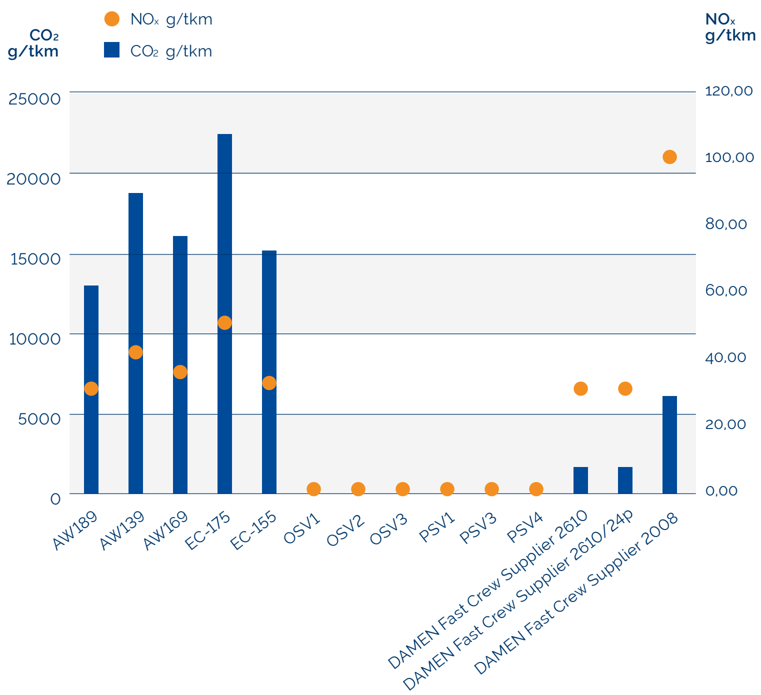
**Figure 1** *Emissions in gram per passenger kilometre for all available helicopters and vessels. The left axis is $CO_2$ g/pkm and the right axis is $NO_x$ g/pkm.*



Along with the transport of passenger, the good transport has also been taken into account in this study. For this the helicopter types AW189, AW139, AW169, EC-175 and EC-155 have been included because these types have payload data available for the luggage compartment. Helicopter are able to take more goods in the cabin which would allow  for a higher capacity of goods taken. However, in reality this is hardly ever done and therefore it has been chosen to only take into account the luggage compartment.  The data for this comes from the Technical Pilot for these helicopter types. For the ships the following vessels have been included: PSVs and OSVs. These are the OSVs that mainly transport goods. Next to this, all previously mentioned CTVs are included in this analysis.

In Figure 2 it can be seen that vessels in general are better for transporting goods in the optimal case. Because of the high maximum capacity of OSVs the emissions per amount of weight transported is low. Again, this is assumes the maximum amount of goods transported which is not always a correct depiction of reality. One exception was found which has a higher $NO_x$ emissions than helicopters and this is the Fast Crew Supplier 2008. As this ship can only carry 4 ton and has high emissions $NO_x$ compared to helicopters it will emit more for passengers and good transport. Still, as a general rule it can be stated that vessels are more efficient for transporting goods in optimal scenarios.

**Figure 2** *Emissions in gram per ton kilomtere for all available helicopters and vessels. The left axis is $CO_2$ g/pkm and the right axis is $NO_x$ g/pkm*




These results are based on a 100% optimal usage of helicopters and vessels. In reality this optimal usage will hardly occur. Therefore the numbers used in Figure 1 and Figure 2 are indicative only. The conclusion that transport of passengers by helicopter and transport of goods by vessel can be drawn from this though. For a realistic calculation of the amount of $CO_2$/$NO_x$ g/pkm and g/tkm it is necessary to make a method that takes into account the actual payload of every movement. This data is currently not available.

# SCENARIOS

To evaluate the impact of the proposed North Sea Agreement it is necessary to establish a number of scenarios. In these scenarios an estimate will be made taking into account the consequences of the proposed measures. For this study the scenarios for business as usual and the North Sea Agreement are of the highest importance as these will impact the sector directly. Nonetheless, two other scenarios have been made that look into ways of reducing emissions. The focus of the scenarios is put into the amount of flights, as that is the focus of the North Sea Agreement. For the scenarios the flight are replaced with ship movements. The total emissions of vessels will not be taken into account because the focus is on the flights.

### Scenario Business as usual

This scenario is the baseline. All variables will stay the same, expect for a light grow in the amount of flights. The number of flights will increase by 2 percent yearly. This assumption is made by taking into account the expected growth of offshore wind parcs and a stabile amount of flights for the oil- and gas industry.

### Scenario: Impact by the North Sea Agreement (four variations)

*Variation 1:*
Increase in OSVs due to a reduction of flights.

A reduction of the amount of flights by 5% each year. These flights will have to be compensated by ships. It is assumed that there will be one more shipping movement with every two of flight reductions.

*Variation 2:*
Variant 1 + Increase in the amount of hoisting operations due to the decrease in available flight decks.

This variant also takes into account the increase in the amount of hoisting. This is a consequence of the North Sea Agreement that states that new platforms will be constructed without helideck.

One hoist operation takes into account the average amount of passengers for each flight. This average is found to be 5.57 passenger for each flight. To hoist this amount of passenger it has been assumed that the operation takes 14 minutes, as each hoist cycle takes 2.5 minutes. In these 14 minutes 139.25 kg of fuel is used which adds up to 433 kg $CO_2$ and 1.71 kg $NO_x$. For one LTO the emissions is 182 kg $CO_2$ and 0.351 kg $NO_x$.

The amount of LTO starts at 100%. This is not in line with the current real situation, as currently there are already hoist operations going on. Still it can be used to establish the impact of the increase of hoisting. The 5% increase in hoisting will also mean a 5% reduction in the amount of LTOs in this scenarios.

*Variation 3+4:*
These scenarios are the same as 1 and 2, but for this scenario the helicopters will be replaced by CTVs instead of OSVs.

### Scenario Autonomous platforms

With current developments, platforms are starting to be operated more autonomously or from onshore locations remotely. This means that less flights are required for the transport of passengers. In this scenario this reduction has been established at 3% yearly. This means a reduction in flights, fuel use and thereby emissions.

### Scenario: Optimizing operations and technologies (three variations)

*Variation 1:*
Change the rotation of crew. Switch from 2 weeks on, 2 weeks off to 3 weeks on, 3 weeks 3 off and optimize routes.

Due to changing the rotation of crew the amount of flight will be reduced by roughly a third. This will mean a reduction in the amount of flights from 15232 to 10155. It has to be taken into consideration that in reality not every flight is a crew change. Still, in this scenario the assumption is made that this is the case and thereby assessing what the maximum impact of this change will be. The amount of flights will in reality reduce less than the amount stated here. This is because of the internal transport between unmanned installations that is still required.

Next to this adjustment, this scenario also takes into account an optimisation of the flights. It will be assumed that flights can be combined more efficiently by sharing flights between oil and gas and the offshore wind industry. It is defined in this scenario as 3% yearly.

*Variation 2:*
*Sustainable Aviation Fuels*

Currently, there are ongoing development regarding to the production of Sustainable Aviation Fuels. One company that is currently active in the Dutch market is SkyNRG (SkyNRG, n.d.). SKyNRG has already been supplying KLM and Leeuwarden airport has stated they also use the Sustainable Aviation Fuel. This fuel is made using a renewable source, such as used oil, fats or other biomass that currently is regarded as a waste product. A side note to this product is that currently it still has to be mixed with traditional jet fuel, and can't be used as fuel in itself.

This scenario assumes a yearly increase of biofuels in the fuel mix. This means that there will be yearly increase of the share of biofuels with 5% and the share of fossil jet fuel decreases by 5%. Biofuels still have a emissions in the use phase, but due to the source being renewable the share of $CO_2$ in the atmosphere will increase less. Therefore, the emissions caused by Sustainable Aviation Fuel are reduced by 80% according to SkyNRG.

*Variation 3:*
Autonomous platforms + Variation 1 + Variation 2

This variation is the most optimal variation as this will take into account all scenarios that decrease the emissions previously mentioned.

# RESULT FOR THE SCENARIOS ON THE $CO_2$ AND $NO_x$ EMISSIONS OF THE LOGISTICS OF DEN HELDER AIRPORT

In Table 9 the impact $CO_2$ can be seen for the different scenarios. The business as usual scenario that assumed a growth of 2% yearly shows that this will result in 24% more emissions in 2030 compared to 2019. However, the impact of the North Sea Agreement more than doubles the amount of emissions when using Offshore Supply Vessels. When using the CTVs as a replacement for flights it can be seen that there is only a slight increase compared to business as usual. The increase of hoist operations due to a reduction of platforms to land on will cause an increase of 1195 Ton of $CO_2$. Although this is not the biggest impact, it still shows that it will increase emissions.

**Table 9** *Results of the scenarios on the emissions of $CO_2$*

| Scenario | 2030 | $CO_2$ 2030 compared with 2019 |
|---|---|---|
| Business as usual (ton) | 19168 | 124 |
| North Sea Agreement - Offshore Supply Vessel | 34326 | 223 |
| North Sea Agreement - Offshore Supply Vessel + Increase hoisting | 35521 | 230 |
| North Sea Agreement - CTV | 19940 | 129 |
| North Sea Agreement - CTV + Increase hoisting | 21135 | 137 |
| Increase Autonomy platforms | 11027 | 72 |
| Crew change scenario + Optimization routes | 7579 | 49 |
| Scenario sustainable aviation fuels | 8633 | 56 |
| Scenario Crew change + sustainable aviation fuels | 4244 | 28 |
| Scenario optimisation – Increase autonomy, crew change, sustainabale aviation fuels | 3343 | 22 |
| Emissions in 2019 (ton $CO_2$): | | 15416 |

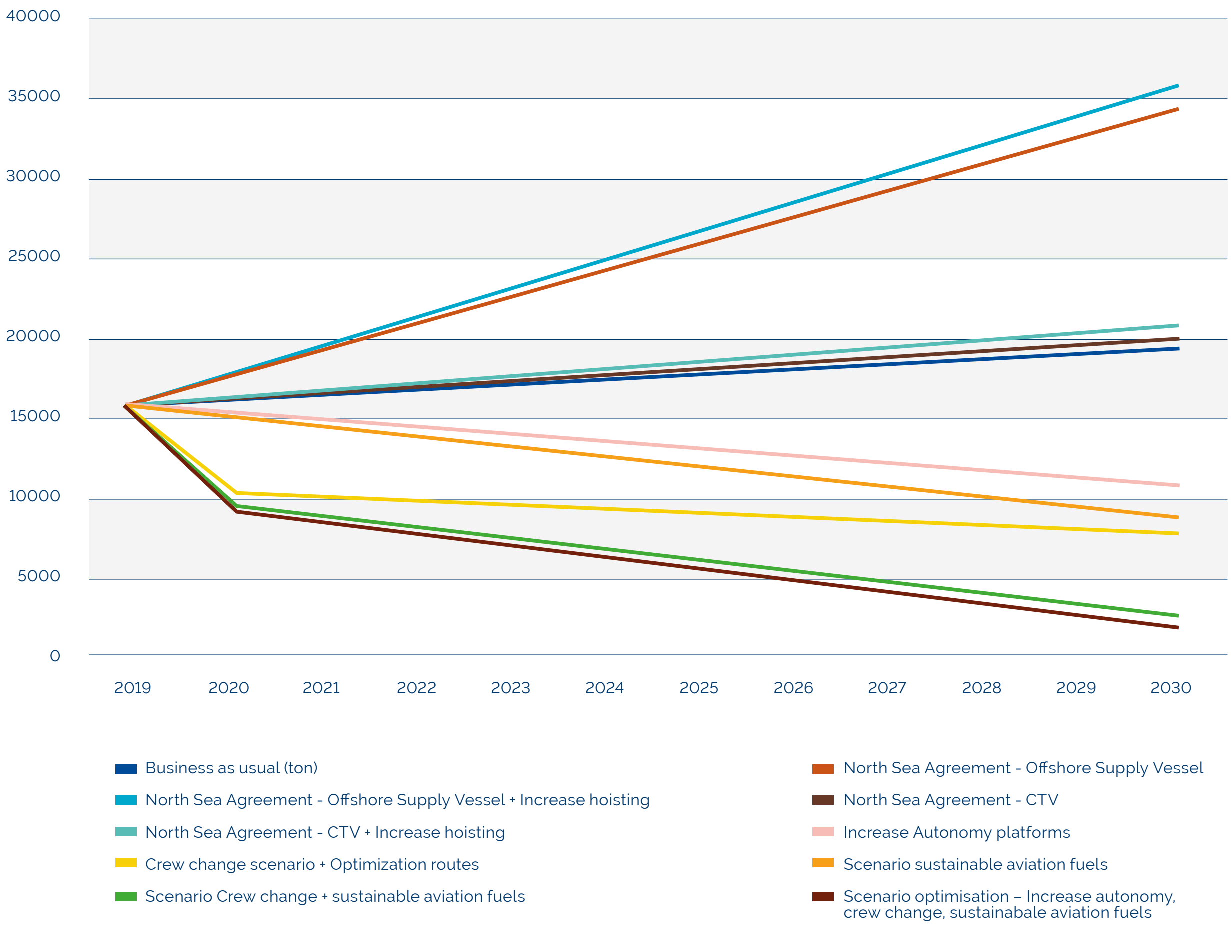
For the $NO_x$ emissions the only scenarios that show a difference with the $CO_2$ emissions of Table 8, are the ones that are impacted by the North Sea Agreement. This is because of the increase in Nitrogen emissions that are involved by using ships. Nitrogen emissions for passenger transport using OSVs will increase a factor of 10 when following the North Sea Agreement. In this case it also becomes clear that transport using CTVs will have more of an impact than previously suggested looking at $CO_2$ emissions.

**Table 10** *Results of the scenarios on the emissions of $NO_x$*

| Scenario | 2030 | $NO_x$ 2030 compared to 2019 |
|---|---|---|
| Business as usual (ton) | 42.3 | 124 |
| North Sea Agreement - Offshore Supply Vessel | 447.6 | 1315 |
| North Sea Agreement - Offshore Supply Vessel + Increase hoisting | 454.1 | 1334 |
| North Sea Agreement - CTV | 206.6 | 607 |
| North Sea Agreement - CTV + Increase hoisting | 213.0 | 626 |
| Increase Autonomy platforms | 24.36 | 72 |
| Crew change scenario + Optimization routes | 16.7 | 49 |
| Scenario sustainable aviation fuels | 19.1 | 56 |
| Scenario Crew change + sustainable aviation fuels | 9.4 | 28 |
| Scenario optimisation – Increase autonomy, crew change, sustainabale aviation fuels | 7.4 | 22 |
| Emissions in 2019 (ton $NO_x$): | | 34.05 |

Figure 3 shows the scenarios over time. An interesting finding is the strong drop in emissions that follows from the change in rotation of crew. This causes a direct decrease in the amount of flights, and with that also the amount of emissions. What does not come across clearly from this graph is the difference between flights and CTVs in emissions. Although CTVs still have higher emissions than helicopters, the difference in nitrogen emissions are not shown in this graph. Next to this, it is assumed that for every 2 flight, one ship movement is used. Which, in reality will be hard to manage.

**Figure 3** *$CO_2$ emissions related to the logistical operations of Den Helder Airport in Tonon*



# CONCLUSION

### 1. Emissions of the logistics from Den Helder

The emissions of flights and shipping in Den Helder to 27667 Ton $CO_2$ and 239.35 Ton $NO_x$. For this it an average distance of 78.6 NM with 5.57 passengers was assumed. For the same distance, the emissions per type of transport differ. For helicopters it has been found that an average trip emits 1012 kg $CO_2$ and 2.24 kg $NO_x$. For OSVs this same trip emits 7782 kg $CO_2$ and 130.41 kg $NO_x$. While for CSVs this trip emits 3402 kg $CO_2$ and 57.00 kg $NO_x$.

Furthermore, after having looked into the capacity for passengers and goods there are big differences between the types of transport when assuming an optimal case. Helicopters are more efficient for transporting passengers, and OSVs are more efficient for transporting goods. It has to be stated that this is valid for optimal conditions.

### 2. Impact of the North Sea Agreement on emissions

The scenarios used for the North Sea Agreement clearly show an increase in the total emissions. Replacing passenger transport by vessels is necessary, as the agreements states that the number of flights by helicopter should be reduced. This analysis shows that with the agreement there will be an increase in total emissions. As can be seen in Figure 1 helicopters are more efficient for transporting passengers. This will not be the case in any situations, because ships can combine passenger and good transportation. However, with the increase of offshore wind parcs the transport of passenger is likely to increase the coming years. It is unlikely that this increase will make transport of passenger by vessels more better in most cases than transport by helicopters. Next to this,  is that vessels in this study have a very short time in Port and DP contributed to them. For a full analysis the operations at sea, in Port and at the Airport have to be added. This will likely make the situation for transporting passengers using vessels worse.

### 3. Potential for reduction of emissions.

In this report several opportunities for emissions reduction have been introduced in the scenarios. Several of these solutions reduce the amount of flights by optimizing the logistics, and other solutions reduce emissions by adjusting the fuel itself. There are still gains to be made on both types of solutions, and with knowledge of the Dutch Climate Agreement and Paris Climate Agreement it is to be expected that there will be an expectation for Den Helder to look into ways to reduce emissions. Further opportunities are suggested in the recommendation section. Furthermore, this study is a first indication of the impact of the flights and movements of vessels. This does not provide an overview of the full supply chain such as energy and material usage in and around Den Helder Airport and the Port of Den Helder. Another issue that is not included is maintenance, and materials required for that, offshore.

# RECOMMENDATIONS

> The main recommendation of this study is to abandon the section in the North Sea Agreement that states that helicopter usage will have to be reduced. From this study it is found that introducing this, will lead to more emissions of $CO_2$ and $NO_x$. By removing this section more time can be spend to the optimal use of the resources that are already in place in the industry, and work towards an actual reduction in emissions. Eventually, this can lead to actual solutions in which all the variables are taking into account that could impact the impact of the operation.

> Following from recommendation 1 it has to be analysed whether it possible to optimise the operations in order to reduce emissions. Options that could be looked at are combining flights between the oil and gas industry with the wind industry. Next to this options are to increase autonomy on the platforms, change rotations schedules. A guideline with this would be that for every flight or kilometre reduced, the emissions are likely to reduce.

> Another subject that can be looked at is that of alternatives to fuels. For aviation this a difficult issue as electrification is not really an option due to the added weight. One solution would be the Sustainable Aviation Fuels mentioned in this report. Another option would be to research hydrogen production. With the increase in hydrogen production from renewable offshore energy from the North Sea it is possible to research hydrogen gas as a base for fuel. With hydrogen it is possible to produce syngas, and with that produce synthetic kerosene (van der Burg, 2019). Development for this is still ongoing, and currently it is not a competitive option. However, it might become an option in the near future. Before switching fuels, it will always be necessary to also research what the impact of this fuel will be on the wear on the machinery.

> To bridge the gap from fossil fuels to a climate neutral fuel, it could be an option to research the options for $CO_2$ compensation. One well-known method is the planting of trees, but there are also other options available in the form of energy efficient cooking sets for developing countries or investment in energy saving technologies.

> To provide a total overview of the impact of the complete offshore industry on the North Sea (Oil, gas and wind) it will be necessary to execute a Life Cycle Assessment or a Material Flow Analysis. This will provide an overview of not only the emissions in the use phase, but will give an overview of the Life Cycle of the whole operations, and will be able to give more detailed overview of which parts of the operations there are major gains to be found. Next to this, a Material Flow Analysis would provide detail on where the materials go to, and how these could later be recycled to contribute to the circular economy. With these insights it can then later be established how this will develop over 2030-2050 and what the impacts will be for the industry.

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