Life Cycle Assessment of Dieso to F-76 Specification in a UK Naval Context for the Purpose of Comparison with Alternative Fuels

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Synopsis

The IMO has stated its intention to reduce maritime carbon emissions by 50% by the year 2050. An ambitious target, this presents an opportunity and need for acknowledging the *lifetime* impact of marine fuels for meaningful comparisons between alternative fuels. This study attempts to produce such an assessment in the context of naval marine fuel oil from well-to-tank. It focusses on the impact of receiving crude oil from different nation states and considers the lifecycle impact of that fuel based on the nature of its extraction and transport. Through this process the well-to-tank lifecycle equivalent greenhouse gas emissions index of Diesel Fuel Naval Distillate to F-76 specification is calculated to be 12.2 gCO_2e/MJ. The vast majority of this number is produced by the extraction phase of the fuel, whose data is spurious at best. The large reliant of accurate data from nation states makes this a difficult process to undertake with integrity. Nations and oil extraction organisations are incentivised to under-estimate or obfuscate their environmental impact of extraction, leading to Green House Gas (GHG) indices whose accuracy is questionable. The reliability of the index is reliant on the measures of transparency present in the nations from which the data is taken.

Keywords: Alternative fuels, decarbonisation, GHG Index, Carbon Intensity

Biographies

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1. Introduction

The international maritime organisation (IMO) has stated that by 2050 maritime carbon emissions will be reduced by 50%. (International Maritime Organization, 2018) In order to achieve this, the IMO has suggested that alternative fuels will be needed to replace traditional crude oil-based hydrocarbon fuels. Although it may be easy to compare the emissions from the combustion of different fuels, this only tells part of the story. In addition to the emissions caused by burning, fuels also have an environmental impact caused by their extraction, transportation and processing. To this end, the IMO has released draft guidelines (International Maritime Organization, 2021) on the life-cycle analysis of fuels from well-to-wake. These guidelines include a preliminary default value for the well-to-tank emissions of various marine fuels (stating a value of 14.9gCO2e/MJ for Marine Gas Oil), to use in the assessment of GHG well-to-wake emissions.

A Life Cycle Assessment (LCA) to determine GHG emission index for the Diesel Fuel Naval Distillate to F-76 specification (herein referred to as Dieso F-76) is considered, based on the fuel production and distribution pathway for Dieso F-76 as embarked on Naval platforms in the UK, this includes pathways for crude oil originating in each of the top five oil suppliers to the UK. This paper summarises the results of the analysis conducted in order to estimate a baseline GHG index for Dieso F-76 for the purpose of comparison against alternative marine fuels.

2. Life Cycle Assessment Procedure

In order to provide a consistent methodology and terminology throughout this study, the guidance provided in the GHG Product Life Cycle Accounting and Reporting Standard (World Resources Institute, 2011)(herein referred to as the Product Standard), published by the World Resources Institute was used.

The Product Standard is an internationally recognised methodology, which has been specifically recommended for adoption by the Sustainable Defence Support Sub-Working Group (a joint MoD/ Industry working group) in their Roadmap for Sustainable Defence Support (UK Ministry of Defence/ KBR, 2020). The

Product Standard provides requirements and guidance for organisations to quantify and report an inventory of Life Cycle GHG emissions associated with a specific product.

Full details of how this study complies with the requirements of the Product Standard are contained outwith this paper, but the key bounds set in accordance with the standard are as follows:

a. Choice of Studied Product: Diesel Fuel Naval Distillate to F-76 specification

b. Choice of Unit of Analysis: GHG emissions, expressed in terms of gCO_2e using a 100-year Global Warming Potential (GWP) factor (Intergovernmental Panel on Climate Change, 2014) to the following six gasses:

   i. Carbon dioxide (CO_2),

   ii. Methane (CH_4),

   iii. Nitrous oxide (N_2O),

   iv. Sulphur hexafluoride (SF_6),

   v. Perfluorocarbons (PFCs), and

   vi. Hydrofluorocarbons (HFCs).

c. Expression of Impact Category of Unit of Analysis: Mega Joules (MJ) of final product, i.e. gCO_2e/MJ.

3. Production and Distribution of Dieso F-76

Dieso F-76 is a military grade distillate fuel. For use by UK Naval vessels, it is specified to Def Stan 91-4, although UK ships will also typically refuel from other sources which will use Dieso F-76 to NATO standards (STANAG 1385).

The well-to-tank lifecycle for the production and distribution for Diseo F-76 can be summarised as shown in Figure 1.

a. Crude oil is extracted and processed
b. Crude oil is transported to a refinery, typically by pipeline or tanker.
c. F-76 is created in the refinery process from a mix of distillate fractions and light cycle (gas) oil.
d. F-76 is transported to a bunkering terminal, where it is stored.
e. F-76 is loaded onto a ship, to its bunker tanks.

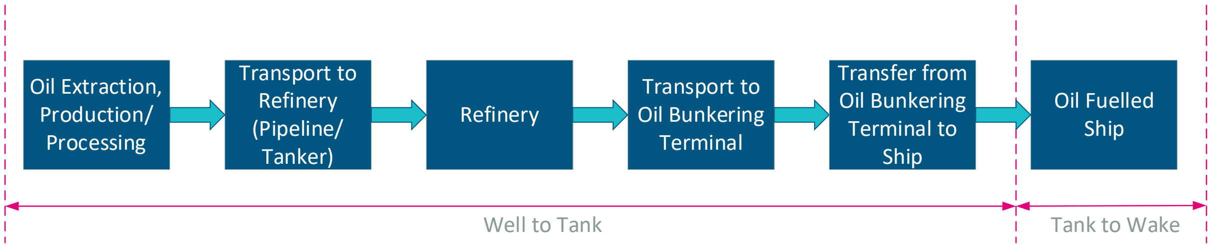

Figure 1: Well-to-Wake Lifecycle of Dieso F-76

Note that the final stage in the well-to-wake lifecycle (transfer from bunkering terminal to ship) is considered negligible when compared with the impact of the other stages in the lifecyle. Therefore any analysis of this lifecycle stage is omitted from this assessment and it is assumed that this stage represents zero carbon emissions.

In the draft IMO guidelines for completing a lifecycle assessment of a fuel the concept of a well-to-wake assessment is put forward. The carbon emissions are considered in each step of the oil lifecycle from the extraction at the well to the combustion on the ship (Figure 1). Each of the elements of the lifecycle has an associated environmental cost in terms of carbon emissions. In order to quantify the overall GHG emissions of Dieso F-76, it is necessary to understand each of these steps in the lifecycle. Throughout this paper the lifecycle assessment will be considered on a well to tank basis only. For context, based on the IMO preliminary default values for Marine Gas Oil the well-to-tank stage represents over 15% of the total well-to-wake carbon emissions.

3.1 UK Specific Production and Distribution of Dieso F-76

In order to determine a UK specific GHG emission index for Dieso F-76, details for each of the stages shown in Figure 1 must be established. This requires assumptions to be made based on refinery and oil bunkering terminal locations, to allow for estimates to be made for transport.

3.1.1 FLUBCON Analysis and Bunkering Terminals

In order to simplify the process of obtaining a meaningful GHG index for Dieso F-76, it is useful to know from where the majority of the UK Naval fleet receive their fuel. To this end, the Royal Navy provide a database, the Fuels, Lube Oil Consumption and Engine Usage (FLUBCON) database. This records monthly quantities of fuel consumed and engine running hours, as well as volumes of fuel loaded ono each ship as well as the locations from which it was loaded. From this database, an assessment of the 2020 refuelling locations was produced, the results of this showed that 70% of the fuel loaded onto many platforms was received in the UK or from a Royal Fleet Auxiliary (RFA) tanker, with the vast majority being loaded at one of the six Oil Fuel Depots (OFD) around the UK.

The largest of the OFDs are located in Gosport and Thanckes close to Portsmouth and Devonport Naval bases, respectively. From the FLUBCON analysis, these two OFDs were found to supply the majority of fuel. Due to its slightly more remote location with respect to UK oil refineries, OFD Thanckes was selected as the baseline oil bunkering terminal location for this assessment.

3.1.2 Refinery Analysis

The Department for Business Strategy, Energy & Industrial Strategy, Digest of UK Energy Statistics 2020 (Department for Business. Energy and Industrial Strategy, 2021) identifies that there are 6 refineries in the UK, the largest capacity of which is located in Fawley in Hampshire. On this basis, this refinery location is chosen as the baseline for assessment. This is the location crude oil is assumed to be shipped to, and F-76 is assumed to be delivered from.

4. UK Marine Oil Supply by Country

The life-cycle carbon intensity of a fuel oil is dependent on its origin. From varying transportation distances and methods to differing extraction technologies and regulations, there is high variability amongst oil imports with regard to carbon emissions.

In 2020 the UK produced 49 million tonnes of crude oil and exported 38.3 million tonnes of that. To supplement its exports, the UK imported a further 36.7 million tonnes of crude oil from overseas sources. This is shown in Figure 2 (Department for Business. Energy and Industrial Strategy, 2021).

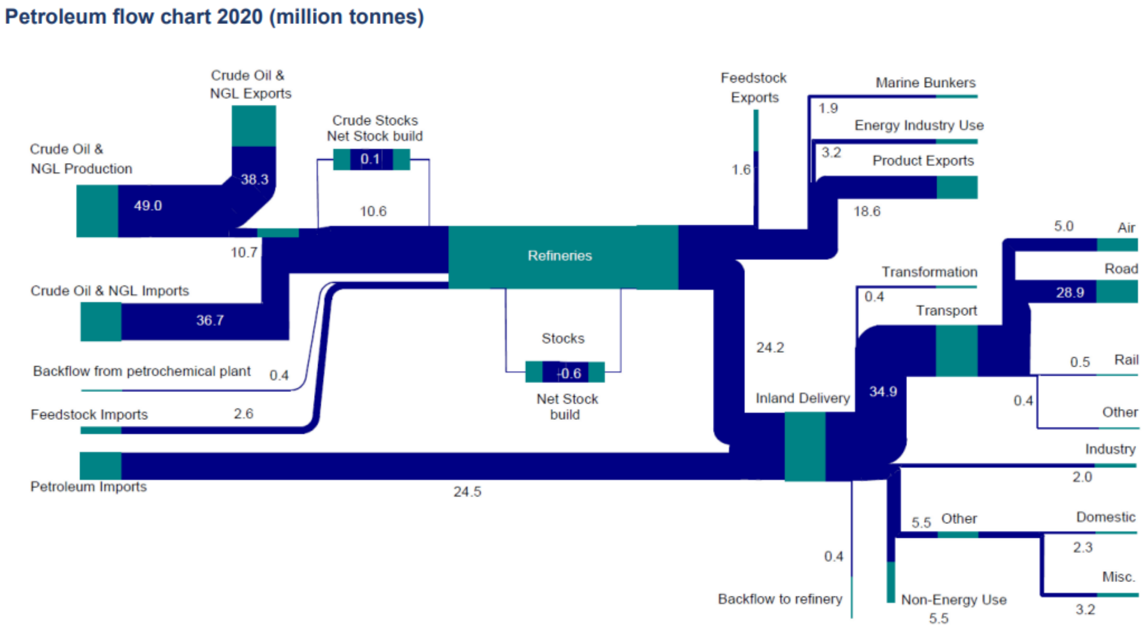

Figure 2 UK crude oil imports and petroleum production

Therefore in order to understand the true carbon impact of Dieso F-76 bunkered in the UK, it must be uderstood from where the additional crude oil is imported. The department for Business, Energy and Industrial Strategy in the UK provides data for this. According to the 2020 Digest of the United Kingdom Energy Statisics (DUKES), the following 5 countries are the largest suppliers of crude oil to the UK (Table 1), making up ~95% of the UK's crude oil.

Table 1: Top 5 suppliers of crude oil to the UK

Source Country (-)	Crude Oil Supplied (Thousands of Tonnes)	Normalised Percentage (-)
Norway	11,755	28
United States	11,359	27
United Kingdom	10,700	25
Russian Federation	3,948	9
Nigeria	2,965	7
Canada	1,642	4

The percentage of crude oil supplied into the UK from different countries, as identified in Table 1, can therefore be applied as a weighting factor when estimating the GHG emissions index for the oil production and transport top the refinery phases of Dieso F-76 production. This is shown in Figure 3.

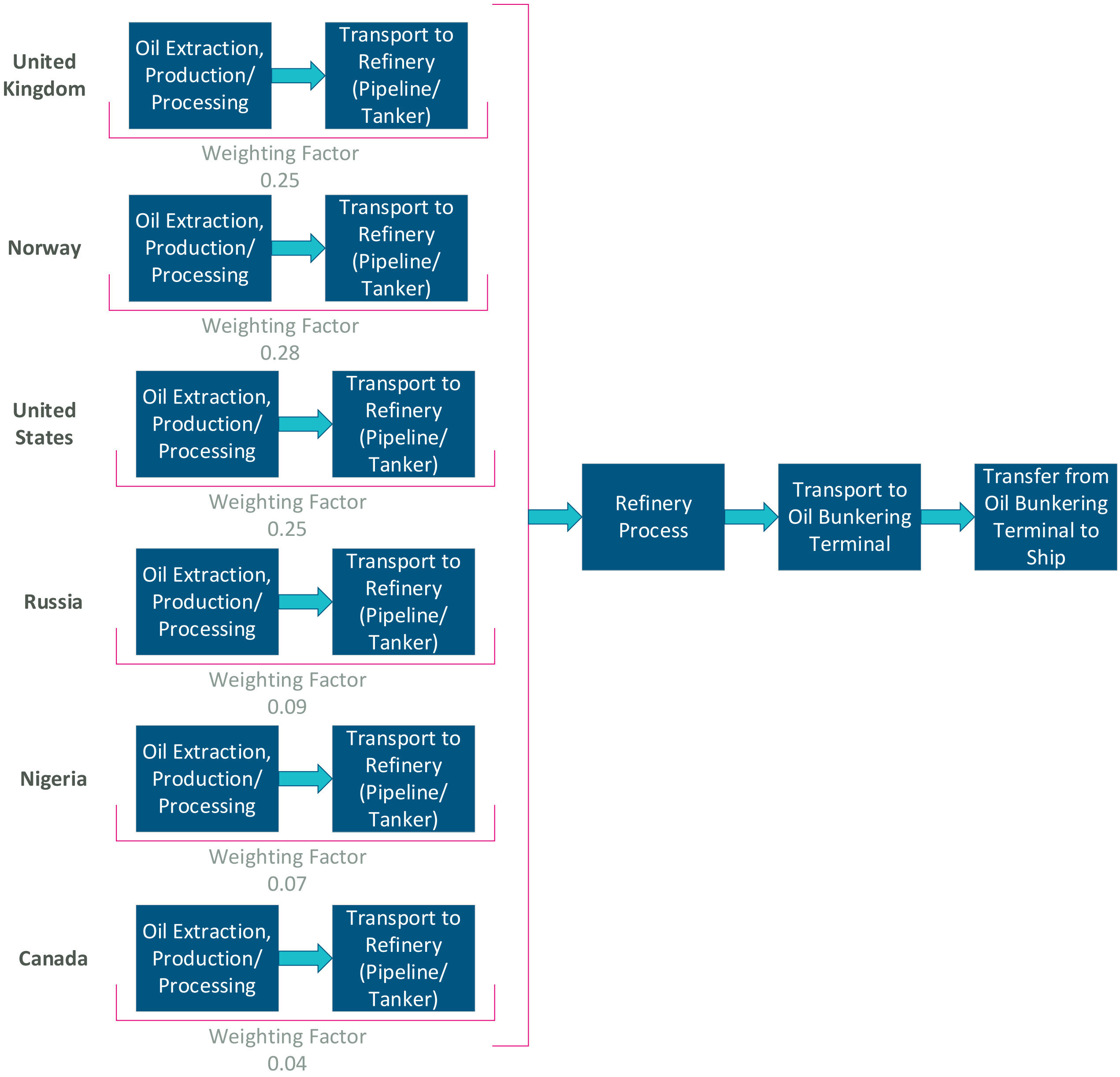

Figure 3 Well-to-tank lifecycle of UK produced Dieso F-76

5. Well-to-Wake Lifecycle of Dieso F-76

5.1 Extraction

The carbon intensity of crude oil extraction is dependent on the methods of extraction used as well as the government regulatory conditions in which it takes place. Variation in the carbon intensity of offshore oil extraction largely comes down to 2 factors: whether the source is conventional crude oil or tar sands, and whether and to what extent flaring is used. (International Council on Clean Transportation, 2010) (Mohammad & Masnadi, 2018) Flaring is the process of burning natural gas that is often trapped in crude oil reservoirs. Since natural gas is comprised of hydrocarbons, this process comes with a significant penalty to carbon emissions that is proportional to the quantity of natural gas burned (Ismail & Umukoro, 2012). Tar sands are oil rich sands which can be harvested for crude oil. Canada has one of the world's largest reserves of oil sands and as of 2020 63% of its crude oil came from this source. Despite being the country with the smallest import volume considered in this assessment, because of its unique oil extraction method, it still accounts for a significant proportion of carbon emissions in the well-to-tank lifecycle (CAPP, 2020).

5.1.1 UK

The United Kingdom extracts crude oil from the North Sea seabed which is transported directly to shore via a pipeline. The quantity of carbon emitted by this process has been studied in a variety of ways throughout the literature. Different studies produce different carbon emissions indices for UK oil ranging from 2.54 to 50 gCO_2e/MJ (International Council on Clean Transportation, 2010) (Mohammad & Masnadi, 2018) (Jacobs Consultancy for Alberta Energy Research Institute, 2009).

5.1.2 USA

The energy intensity of crude oil extraction in the USA varies from state to state with the most energy intensive methods occurring in California and lower energy extraction occurring in Texas (International Council on Clean Transportation, 2014) (Jacobs Consultancy, 2012).

5.1.3 Norway

The extraction of Norwegian oil is considered to be very similar to that of UK oil. Like the UK, Norway extracts oil from the North Sea. Despite this, there are differences which should be highlighted for completeness, namely: Flaring is more heavily regulated in Norway than in the UK and power is supplied to the oil platforms from onshore energy sources, which are likely to be more efficient than electricity generated by gas turbine/ diesel generator on UK oil platforms.

5.1.4 Russia

The primary regions producing oil which is exported to the UK are the Timan-Pechora, Western Siberia and Urals-Volga regions. These regions are all connected, via the Baltic Pipeline System to Primorsk or Ust-Luga, which are the main European export hubs for crude oil transported by ship. Various sources state that data quality for Russian oilfields is poor (Mohammad & Masnadi, 2018) (International Council on Clean Transportation, 2014). Although it is known that Russian oil fields flare a significant amount of gas, estimated to be the largest by volume of any country worldwide (Global Gas Flaring Reduction Partnership, 2020). A lack of published, field specific data does mean that estimates for carbon intensity likely have a large error margin associated with them.

5.1.5 Nigeria

Nigerian oil, similar to Russian oil, is produced with a significant amount of flaring. Statistics from the GGFR placed Nigeria as the 7th highest in the world by total gas flaring volume. Because of this, the carbon intensity index for Nigerian oil is expected to be relatively high. Additionally, many oil fields in Nigeria are deep water offshore fields which comes with a significant energy penalty, further adding to carbon emissions.

5.1.6 Canada

Due to the energy intensive process of extracting oil from oil sands as well as the trapped CO_2 released, Canadian crude oil has a large GHG emission index associated with it: approximately 17.5 gCO_2e/MJ (Mohammad & Masnadi, 2018).

5.1.7 Summary

Overall, this results in a country-by-country crude oil extraction GHG intensity shown in. Table 2. The information in this table comes from a variety of sources. For each country the mean of the presented values is taken as an estimate for GHG emissions. Of note is the significant variation of the data amongst the sources. For example, sources for Nigeria vary up between 11.3 and 22.1 and Canada between 7.5 and 17.5 gCO_2e/MJ. The reasons for this variation in the data is sometimes clear, such as in the case of Canadian oil where the GHG index is dependent on whether the oil is from oil sands or conventional drilled oil. Whereas estimates for Nigeria appear to vary depending on source data.

Table 2 Crude oil extraction GHG emissions by region (gCO_2e/MJ) by selected sources

Region	**GHG Emissions Index (gCO_2e/MJ)**						
	Masnadi, et al. (Mohammad & Masnadi, 2018)	**ICCT/ER** (International Council on Clean Transportation, 2014)	**TIAX** (TIAX for the Alberta Energy Resource Institute, 2009)	**Jacobs** (Jacobs Consultancy, 2012)	**NETL** (National Energy Technology Laboratory, 2008)	**IHS CERA** (IHS Cera, 2010)	**Mean Intensity**
Norway	5.6	2.5		3.6			**3.9**
USA	11.3				4	4.2	**6.5**
UK	7.9	3		3.6			**4.8**
Russia	11.3	5.9		6.8			**8.0**
Nigeria	12.6		16.8	11.3	22.1	14.1	**15.4**
Canada	17.5	13.0		7.5			**12.7**

5.2 *Transport to Refinery*

The process of moving oil from source to refinery can vary in its environmental cost in 2 ways, namely: by the method of transport and by the distance it has to travel.

5.2.1 *Pipeline Transport*

The majority of life cycle assessment sources which conduct a well-to-tank analysis of fuel types use the same source for the GHG emissions of piped oil. This comes from the U.S. Department of Energy’s Greenhouse gases, Regulated Emissions and Energy use in Technologies (GREET) model (Argonne National Laboratory/ U.S. Department of Energy, 2021). This model states that for crude oil transported in a pipe, the energy emitted per MJ of oil per kilometre of pipeline is: 4.38 J/MJ km. In order to convert this into a GHG emissions index it is necessary to know how much CO_2 is emitted per Joule of energy required to transport oil in a pipeline, which means making further assumptions as to the source of the energy used to pump the crude oil.

Pipeline lengths for each country have been estimated based on the available data for pipeline infrastructure in all the countries considered, as well locations within these countries where the majority of crude oil is known to be extracted.

5.2.2 *Tanker Transport*

A review of the available literature suggest that many well-to-tank analyses use industry average data for oil tankers. This doesn’t consider trade routes or tanker sizes. However, the work of Greene, et al (Greene, et al., 2020). has analysed journey data and cargo information to provide a trade route specific breakdown of emissions. This study shows that longer trade routes tend to use larger tankers and are therefore more efficient in terms of emissions on a per-volume basis. This explains the almost counter-intuitive observation that oil transport by pipeline to the UK from the north sea is more GHG intensive than by tanker from the USA and Canada.

Table 3 Emissions factors used for different trade routes

Source Country	**Equivalent Trade Route, Greene, et al.** (Greene, et al., 2020)	**Emissions Factor (gCO_2e/t-nm)**	**Comments**
Norway	Intraregional	5.0191	No specific inter-Europe data provided, therefore use generic "Intraregional". Expected to be small DWT tanker, therefore higher emissions factor.
USA	Other International	4.3602	No specific transatlantic data provided, therefore use generic "Other International". Expect to be large DWT tanker for long distance journey, therefore relatively low emissions factor

Source Country	Equivalent Trade Route, Greene, et al. (Greene, et al., 2020)	Emissions Factor (gCO_2e/t-nm)	Comments
UK	Intraregional	5.0191	No specific inter-Europe data provided, therefore use generic "Intraregional". Expected to be small Deadweight Tonnage (DWT) tanker, therefore higher emissions factor.
Russia	Russia - Europe	4.8260	
Nigeria	West Africa - Europe	4.0596	
Canada	Other International	4.3602	No specific transatlantic data provided, therefore use generic "Other International". Expect to be large DWT tanker for long distance journey, therefore relatively low emissions factor

Tanker transport distances have been estimated based on the known locations of oil distributions terminals within the countries under consideration and the assumed refinery location in the UK.

5.3 Refinery

There exist a number of challenges to allocating a quantitative carbon emissions index for the refining of crude oil to Dieso F-76. Single processes within a refinery produce many different products. If the carbon intensity of the process of a whole is known, it is difficult to assign a value to an individual distillate. Additionally, the quality and origin of the crude oil result in discrepancies between the constituent hydrocarbons of the oil. This means that carbon intensity for a specific distillate can vary. Finally, sulphur content of crude oil can have a large impact on the energy intensity of the refinery process, since the desulphurisation process is very energetically expensive.

It must also be noted that Dieso F-76 is a distillate to a very specific standard which is primarily used in military applications. Since it is not widely used, no specific data for the refinement of Diesel F-76 from crude oil is found to be available. The closest commercial equivalent is Marine Gas Oil (MGO) specified to Distillate Marine Grade A (DMA). Although not preferable, use of DMA MGO is allowable in naval applications as a next best permissible source if refuelling is absolutely necessary. Although they do have different properties, the refinement process for the two fuels is considered to be broadly similar. As a result, carbon intensity figures for the refinement of MGO are used in this study.

As a result of the above challenges, this paper will use a refinery carbon intensity index of 4.4 gCO_2e/MJ taken from a study by Sphera Solutions GmbH (formerly Thinkstep), who have developed an estimate based on use of their GaBi Life Cycle Assessment software and databases (Thinkstep AG, 2019) that attempts to account for the above challenges. This value is calculated based on a sulphur content by weight of 1.05-1.43%, which is considered to be a conservatively high estimate, and is calculated on an energy allocation basis, i.e. carbon intensity of different products in the refinery process is allocated based on the relative total energy content of all the different products produced.

It should be noted that the maximum sulphur content for Dieso F-76, when defined in accordance with Def Stan 91-4, is 0.1%, whereas DMA MGO to BS ISO 8217:2017 has a maximum allowable of 1%. This does highlight that the carbon intensity assumed for this stage of the lifecycle may be an underestimate for Dieso F-76.

Despite the additional energy used to remove sulphur during the refinery process, the wider environmental impact, outside of GHG emissions may also be considered. Not only does the reduction in sulphur from fuel reduce the emissions of sulphur dioxide when the fuel combusts, the sulphur that is removed can be converted into useful by-products such as elemental sulphur or sulphuric acid, therefore lowering the carbon intensity for the refinery process..

5.4 Transport to Bunker

Since it is assumed in this paper that all oil in the UK ends up in Fawley for refinement, the relevant distance for estimating the GHG emissions for transport to bunker is the distance from Fawley to the chosen bunker.

For the purposes of simplicity, the bunker selected for this paper is Thanckes Oil Fuel Depot. This is justified on the basis that Thanckes has the largest storage capacity of any of the OFDs in the UK and of the two major OFDs (Gosport and Thanckes) it is further away from Fawley refinery, therefore presents a more pessimistic outlook.

It is assumed transport between Fawley and Thanckes will occur by sea, with a distance of approximately 127 nm. The GHG index for intraregional tanker transport can be used from section 5.2.2. Using the average grams of CO_2 per tonne nautical mile as 4.4030 gCO2e/t-nm, the 127 nautical mile journey from Fawley to Thanckes will result in 559.181 gCO_2/t. Using the Lower Heating value of Marine Diesel Oil of approximately 40 MJ/kg or 40000 MJ/t. This results in a total GHG emissions index of $1.5\text{x}10^{-2}$ gCO_2e/MJ.

6. Dieso F-76 GHG Emissions Results

With the above sections considered, an estimate for the overall GHG emissions index of Dieso F-76 can be produced. This is achieved by using the weighted sum of the extraction and transport indices on a country-by-country basis and adding the refinery and bunker transport penalties. Overall, it is estimated that the GHG emissions index for Dieso F-76 as produced and bunkered specifically in a UK Naval context is 12.2 gCO_2e/MJ.

Table 4 Summary of GHG emission index assessment

Oil Origin		**GHG Emissions Index (gCO2e/MJ)**						
	Extraction	**Transport from Well to Refinery**	**Weighting Factor**	**Weighted Average Transport and Extraction**	**Refinery**	**Transport From Refinery to OFD**	**Transfer from OFD to Ship**	**TOTAL GHG Emissions Factor**
Norway	3.9	0.56	0.28	7.77	4.4	0.015	0	**12.2**
USA	6.5	0.35	0.27					
UK	4.83	2.03	0.25					
Russia	8	3.85	0.09					
Nigeria	15.38	2.03	0.07					
Canada	12.67	1.35	0.04					

7. Consideration of Alternative Fuels

With the calculated lifecycle GHG index, it is useful to try to draw a comparison between other marine fuel options such as methanol-based fuels, biodiesel or synthetic fuels which may, in the future, become appropriate and available for sue in a naval context.

By understanding the baseline GHG index of the fuel currently in use, any figures quoted for alternative fuels can be put into context. The process for establishing a GHG index value for Dieso F-76 for use in UK also indicates the high level of variability that will also be present in the assessment of any alternative fuels and the likely variability on a country-by-country basis.

8. Opportunities to Reduce Well-to-Wake Emissions

As noted in Section 3, well-to-tank GHG emissions consist of approximately 16% of the total well-to-wake GHG emissions, according to the preliminary default values stated by the IMO. Whilst this is by no means insignificant, it does show that there is greater potential to achieve overall GHG emissions reductions from naval platforms by focussing on the actual fuel consumption of naval platforms, rather than working to reduce emissions in the processing of their fuel.

In reality this is considered to be achievable through two broad means:

a. The application of Energy Saving Technologies (ESTs) to reduce energy and therefore fuel consumption.

b. Behavioural changes in operation, including slower steaming and increased use of shore power when alongside.

It is acknowledged that the above elements only have the ability to reduce fuel consumption and therefore GHG emissions by a limited amount. Therefore, any further reduction in GHG emissions must be achieved through the use of alternative fuels, which have a combined well-to-wake emissions factor less than the Dieso F-76 currently in use.

9. Conclusion

The aim of this study was to go through the process of determining the lifecycle impact of a specific marine fuel and in doing do, ascertain the difficulties and shortcomings of that process, with the aim to lead to further studies looking into overcoming some of these concerns. The GHG emissions index of Dieso F-76/ Marine Gas Oil is heavily determined by the extraction and refining of the fuel. In fact, the majority of the lifecycle emissions of that fuel come from these two parts of the lifecycle. This in itself poses a challenge to the shipping industry in its quest for reducing its environmental impact.

Currently, it is challenging to obtain accurate and meaningful data when considering the environmental impact of crude oil extraction even within countries considered transparent. For example, the crude oil extraction GHG estimates for Canada vary from 7.5 – 17.5 gCO_2e/MJ.

Further examples of this are clear in Table 2. The data for Nigeria for instance has a range of 9.5 gCO_2e/MJ and a mean of 15.4 gCO_2e/MJ. So much variation compared with the mean makes it almost meaningless to draw an accurate conclusion for oil extraction in Nigeria. The overall lifecycle assessment GHG index is so reliant on accurate data which simply doesn’t exist at the moment. Without a reliable and possibly centralised source of agreed-upon data, marine companies and government agencies are incentivised to use the most lenient figures available to them, irrespective of their reliability or merit. This makes it near to impossible to use a GHG index to accurately draw precise comparisons between fuels.

It is considered that conducting a sensitivity analysis and/ or establishing appropriate tolerances to apply the GHG emissions index figures established as part of this assessment would be a worthy future activity. Understanding the tolerances involved would mean that the accuracy of comparison between different fuel types could be better understood.

The draft IMO guidance (International Maritime Organisation, 2021) presents a preliminary default factor for the GHG Index of Marine Gas Oil of 14.9 gCO_2e/MJ to be used in well-to-wake GHG emissions calculations. This figure is based on a single value taken from a single study (sphera, 2021) which was developed in order to provide a global average for GHG emission index for Marine Gas Oil. The Sphera study actually shows a significant regional difference in GHG emission index, ranging from 13.4 gCO_2e/MJ in Europe, to 17.9 gCO_2e/MJ in North America, which is not captured in the IMO draft guidelines.

Whilst the results of this paper largely agree with the European regional figure from the Sphera study, this still serves to demonstrate the issues with presenting a single figure as a representative GHG emissions index for any one fuel type, even though more region-specific data is available, this has not been used by the IMO, presumably in the interest of minimising complexity of the calculation process.

It is acknowledged in the draft IMO guidance that emissions index values should be kept under review by a “scientific fuel expert panel”, but a periodicity for this review has not been established. As noted, the results for this paper align well with the European regional figure from the Sphera study which forms the basis of the IMO preliminary figure, however, whether they will still closely match in upcoming years is dependent global trade climates. The source of crude oil imports into the UK will vary year-on-year, meaning that the GHG index for Dieso F-76 from this study will not necessarily be correct for following years.

The use of alternative fuels clearly represents an important factor in the future reduction of GHG emissions from naval platforms and whilst a move away from fossil fuels is essential, it is crucial that the full lifecycle emissions for any alternative fuels are appropriately considered to ensure that an accurate understanding of the benefits which might be realised can be obtained.

9.1 Addendum

At the time of writing this paper, Europe's oil and gas industry has been turned on its head with the war in Ukraine impacting gas pipeline supplies from Russia. In addition to this, Russia has threatened to cut Europe completely off from its gas supply. The UK has made commitments to phase out all Russian oil by the end of 2022. The UK will therefore need to supplement its traditionally Russian oil supplies with those from another nation. Depending on the source nation chosen, this could result in a meaningful change to the lifecycle GHG index for Dieso F-76 in the UK.

10. Acknowledgements

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