Consider options for replacement ferries with lowest carbon technology

1. EXECUTIVE SUMMARY

1.1. The Isle of Man Steam Packet Company Limited owns two vessels, the Ro-Pax MV Ben-my-Chree and the HSC Manannan, providing a lifeline ferry service to the Isle of Man.

1.2. With effect from January 2020, the emissions from the Ro-Pax ferry MV Ben-my-Chree should be reduced, when the Company is required to comply with the International Maritime Organisation's requirement to reduce the sulphur content of fuels from 3.5% to 0.5%.

1.3. Under the terms of the Sea Services Agreement, the Company is required to provide a new Ro-Pax vessel by December 2022, and specification and commissioning have already commenced. The new vessel is required to have the capacity to operate with either marine fuel oil or liquefied natural gas (LNG).

1.4. Although a number of alternative fuel technologies are available for reducing the GHG emissions of shipping, they are either not currently available for use or not sufficiently advanced to power a new Ro-Pax. However, inclusion within the vessel design of the option for dual-fuelling would potentially future-proof the propulsion system. Careful specification of the engine will however be required if it is to avoid the potential risk of greater greenhouse gas emissions from methane slip, which is when gas leaks unburned through the engine. If methane slip is not controlled, environmental benefits of using natural gas are reduced and can cancel out the advantages over diesel or bunker fuel due to the high greenhouse effect of the methane.

1.5. Alternative fuel technologies may be more developed in the mid-2020s, to coincide with the replacement of the current fast craft vessel in 2026.

1.6. Consideration should also be given to accommodating future low carbon fuel options in the design of the new ferry terminal at Liverpool.

1.7. Renewable electricity is a good method of decarbonising the auxiliary power needed by vessels and to power the ships whilst a berth in ports, instead of fossil fuel generators.

1.8. An alternative method for reducing emissions from the Island's ferry services could be to reduce the number of sailings, whilst ensuring that this does not inadvertently increase air travel emissions.

2. THE CHALLENGE

2.1. The Isle of Man's lifeline ferry service to the Port of Heysham, a distance of 40 nautical miles, is provided by the Isle of Man Steam Packet Company Limited ("IOMSPCo").

2.2. The national importance of a secure and stable shipping service operating from and to the Isle of Man was confirmed by Tynwald in May 2018, when it voted to approve the purchase of IOMSPCo. At that time it was also agreed that a new sea services agreement would be signed between the Department of Infrastructure ("the DOI"), and IOMSPCo, within 12 months. Although now owned by Government, IOMSPCo operates as a private company, at arm's length from Government, with a governance structure lead by a Board of Directors. These Directors are appointed by the Isle of Man Treasury.

2.3. The Sea Services Agreement ("the Agreement") is a formal contract between the DOI and IOMSPCo, which obliges the Company to invest in new ships and guarantees minimum service levels. In return, the Agreement permits IOMSPCo almost exclusive use of the DOI's linkspans at King Edward VIII Pier and the Victoria Pier.

2.4. The Agreement was signed on 31st May 2019 and will replace the current User Agreement with effect from January 2020. The Agreement will remain in place until 2044, with variations to the Agreement being formally reviewed by the two parties every 5 years.

2.5. IOMSPCo owns two vessels; the Ro-Pax MV Ben-my-Chree, and the HSC Manannan, with a third, contract freight vessel, the MV Arrow, providing a back-up service. Further background information regarding the Island's strategic sea services, can be found in the 2016 Report commissioned from economic consultancy, Oxera LLP.

2.6. IOMSPCo has confirmed that 98% of the vessels' fuel is bought and delivered in the UK, with only a relatively small amount of fuel purchased in the Isle of Man from Manx Petroleums.

2.7. With effect from January 2020, emissions from the MV Ben-my-Chree should be reduced, when IOMSPCo is required to comply with the International Maritime Organisation's requirements that the sulphur content of fuels is reduced from a maximum of 3.5% to a maximum of 0.5%. This will result in a change for the MV Ben-my-Chree from Heavy Fuel Oil (HFO) to the cleaner, lower emission, Marine Gas Oil (MGO).

2.8. HSC Manannan already operates using Marine Gas Oil.

2.9. Under the terms of the Agreement, IOMSPCo is required at clause 5.2.2 to replace the MV Ben my Chree by December 2022 at the latest, and the specification and commissioning process have already commenced. The Sea Services Agreement specifies at Clause 5.2.7.2.1 that the new vessel is required to have the capacity to operate with either marine fuel oil or liquefied natural gas (LNG). LNG is a transition fuel, which could assist in reducing the emissions gap; however, bunkering facilities are currently very limited, with no bunkering available at Heysham Port.

2.10. Once the replacement Ro-Pax comes into service, the MV Ben-my-Chree will remain in service as the back-up vessel.

2.11. A number of alternative fuel technologies are available for reducing the greenhouse gas emissions of shipping. For alternative fuels and power sources, the technical applicability and commercial viability vary greatly for different ship types and trades, with deep-sea vessels having fewer options compared with short-sea segment vessels.

3. FUEL OPTIONS

Diesel /hybrid options

3.1. As in hybrid cars, an electric engine can be coupled to a diesel engine and power the same drivetrain. This allows a switch to zero-emission electric propulsion if and when required. The electric engine can be powered by a battery, but a fuel cell would also be able to provide zero-emission power when using a zero-emission fuel such as hydrogen from renewable electricity. However, the development of battery and fuel cell electric vessels is still at the demonstration phase and usually applied to smaller vessels due to the difficulty in reaching the power requirements of a large seafaring vessel. Another hybrid option injects hydrogen produced from renewable sources in a diesel engine alongside diesel and can yield considerable CO_2 emission reductions. This has been successfully demonstrated in vans by the British company ULEMCo105. It is currently being trailed by Cie. Maritime Belge SA with the Hydroville, a 14-meter passenger shuttle carrying passengers from Kruibeke to Antwerpen106.

3.2. In conclusion, this technology is currently unsuitable to be scaled-up to a RoPax operating across the Irish Sea.

Electricity

3.3. Electrification based on low carbon electricity production has been identified as a sensible pathway of decarbonisation for many transport sectors, including shipping. With an electrical propulsion system, the options are to generate the electricity on-board or to use electricity produced inland (e.g. from the grid). Both options require on-board battery storage. Due to reduced autonomy, the use of batteries in shipping is possible for short-range journeys or vessels with less power requirement from propulsion. It is therefore not suitable for the Irish Sea at this time. Aside from the propulsion, renewable electricity is a good method of decarbonising the auxiliary power needed by vessels and to power the ships whilst at berth in ports, instead of fossil fuel generators.

3.4. The world's largest all-electric ferry, E-Ferry Ellen, made its maiden voyage in August 2019, connecting the Baltic Sea island of Aero, to the rest of Denmark; a route of 22 nautical miles (CNBC, 2019). The vessel is capable of carrying 30 vehicles and 200 passengers and has been developed with support from the European initiative H2020 (E-Ferry, 2015).

3.5. Whilst E-Ferry Ellen represents a significant electric ferry development; it has a significantly smaller capacity than the MV Ben-my-Chree, a much shorter route, and very different sailing conditions between the Baltic and Irish seas. The E-Ferry Ellen is confirmation that electric ferry technology is not yet sufficiently developed to provide a Ro-Pax ferry powered by an alternative source that is capable of delivering the Island's lifeline service.

Figure 1 E-Ferry Ellen (Electrive, 2019)

3.6. In conclusion, electricity has potential as a zero-carbon alternative but technology is not currently sufficiently advanced for the Irish Sea routes/distances.

Liquefied Natural Gas (LNG)

3.7. In general, LNG can be used in spark-ignition engines, dual-fuel compression ignition engines and converted compression ignition engines. LNG is currently used most widely in dual-fuel engines. The boil-off gas from the LNG storage tanks is pumped to the engine where it is combusted with a proportion of conventional fuel (HFO, MDO or MGO) to aid ignition, as LNG has a higher ignition point and will not self-ignite. LNG carriers commonly use LNG in dual-fuel engines. However, there are now of the order of 100 LNG-powered vessels of other types. The technical readiness of these dual-fuel engines in LNG carriers is high, as they have been commonly used for these vessel types for many years. It is possible to convert some diesel engines to LNG.

3.8. A new Code of Safety for Ships using Gases or other Low-Flashpoint Fuels (IGF Code) came into force in January 2017 (International Transport Workers' Federation, 2017), initially focusing on LNG as an amendment to the International Convention for the Safety of Life at Sea (SOLAS). LNG storage can be located on-deck or below-deck. However, there are fewer safety requirements if the tanks are placed on-deck, according to the regulations surrounding the storage of gas used for marine fuel. For some vessel types, this would reduce cargo space and decrease the revenue of the ship. To minimise this loss of revenue, smaller storage capacity could be used. However, this would increase the bunkering frequency.

3.9. A disadvantage of LNG storage is that capital costs increase with tank size. This problem is compounded by the lower energy density of LNG compared to the incumbent diesel fuels, further increasing the need for larger fuel storage tanks. The required changes in refuelling infrastructure and subsequent costs are also barriers for widespread use of LNG as shipping fuel as conventional bunkering infrastructure and techniques cannot be used for this fuel, and these facilities are not available at Heysham or Liverpool. Some of the existing refuelling infrastructure used for HFO, MDO or MGO would need to remain if dual-fuel engines were used as the propulsion system.

3.10. The fuel cost of LNG is also lower than that of the incumbent fuels, approximately 25-50% of the price of MGO116. There are currently a small number of LNG ships being used in inland shipping, for example, the 'Greenstream' barge operated by Shell. In its 2019 Maritime Forecast, DNV GL reported that last year, 2.73 per cent of the global shipping order book was for LNG-powered ships, with another 3.07 per cent to be battery powered. DNV GL predicts that by 2050, LNG will be the single biggest source of fuel for the global shipping industry (Stenersen and Thonstad, 2017)

3.11. CMA CGM, one of the world's largest container operators, has recently taken delivery of its first LNG powered ultra-large container vessel. As the market moves to LNG and the international LNG infrastructure ramps up, this is seen as an interim fuel with ships that can run on both MGO and LNG and therefore a dual fuel ship to secure bunkers.

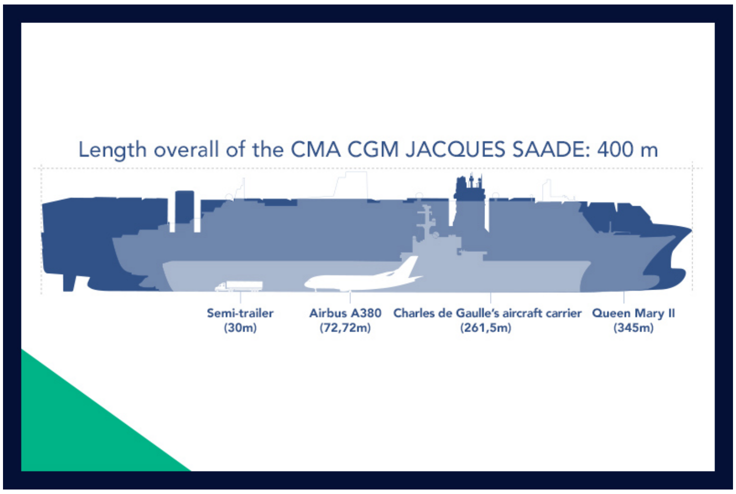

Figure 2 (CMA CGM Group, 2018)

3.12. Vessels using LNG propulsion can reduce CO_2 emissions when compared to the incumbent diesel fuels. However, when considering GHG emissions other than CO_2 on a lifecycle basis, methane slip from LNG needs to be taken into consideration.

3.13. Levels of methane slip vary significantly depending on engine type. In road vehicles, this can be so severe that it has led to an increase in greenhouse gas emissions since methane is c.25x worse compared to CO_2. Lean-burn gas engines and low-pressure dual-fuel engines suffer from methane slip due to incomplete combustion, while the high-pressure dual-fuel engine operates with almost zero methane slip.

3.14. In conclusion, recent research suggests only high-pressure dual-fuel engines reduce "well-to-wake" greenhouse gas emissions by 10%, compared with their heavy fuel counterparts. Lean-burn and low-pressure dual-fuel engines cannot reliably reduce greenhouse gas emissions, although they do emit 95% less sulphur oxides and 97% less particulates.

3.15. Methane slippage needs to be considered carefully if LNG is to be used by IOMSPCo as an alternative fuel for decarbonisation, and the research would suggest that the new IOMSPC vessel should be designed with a high-pressure dual-fuel engine if it is to avoid the risk of an inadvertent increase in greenhouse gas emissions as a consequence of methane slippage.

3.16. LNG bunkering facilities would be needed at Heysham or Liverpool that are not presently available.

Biofuels

3.17. Biofuels and carbon-based electrofuels are drop-in fuels requiring only limited or no modification to engines and fuel systems to replace or blend with traditional fuels used by internal combustion engines. Nitrogen-based electrofuels such as ammonia can also be produced from H_2, but to replace traditional fuels would require more moderate modification to engines, and to fuel storage and supply systems. While electrofuels have clear advantages with regards to technical application and greenhouse gas footprint, producing them is currently expensive and energy-intensive (IEA Bioenergy, 2017).

3.18. Global biofuel consumption in all sectors represents around one quarter to one-third of global bunker fuel consumption (estimated in the range of 10-12EJ), but biofuels are today almost entirely used in road transport, in particular in Europe, the USA and Brazil. Whilst biofuels in shipping are in the testing or early adoption phase, (for example via companies like GoodFuels that currently focus on diesel-type fuels such as HVO), the US Navy has developed a drop in fuel blend of 10% biodiesel, 90% petroleum diesel, that is fully compatible with the ships' petroleum power systems. The US Navy is using this biofuel to power its "Great Green Fleet." (Renewable Energy Magazine, 2016)

3.19. The limited use in shipping is a result of the policy focus on road transport to date (due to less overlap with the international arena), and the generally lower cost of shipping fuels and hence larger price gap compared to road transport fuels.

3.20. Biofuels include fuels produced from waste oils and fats (SVO, FAME, UCOME and HVO); alcohols (ethanol and bio-methanol); bio-LNG and synthetic diesel (FTdiesel and upgraded pyrolysis oil). The low sulphur characteristic makes many biofuels particularly attractive for reduced emissions.

3.21. The life cycle greenhouse gas equivalents of different fuels are measured from "well-to-wake" or "field-to-wake" for fossil fuels and biofuels, respectively. This includes the overall fuel chain from extraction/production of the feedstock at the source to combustion in the marine engine. The values can be used as relative indications of greenhouse gas emission levels, but as life cycle analysis may apply to different system boundaries, specific values for greenhouse gas emissions can be difficult to compare.

3.22. Fossil fuels have, on average, the highest life cycle greenhouse gas emission equivalents, and the numbers reported take into account emissions from extraction, refining, and distribution (well-to-wake calculation). Biofuel feedstocks capture CO_2 via photosynthesis during their lifetime, sequestering carbon until it is burned as a fuel, and thus the CO_2 from the biofuel combustion itself is not accounted for in life cycle greenhouse emissions. A field-to-wake calculation also includes feedstock and biofuel production processes (use of fertilizers, farming methods, drying, processing, etc.) and transportation. The actual life cycle CO_2 emissions for both fossil fuels and biofuels will depend on both the fuel production chain and the calculation method for greenhouse gas emissions. However, regardless of different emission estimates, the ranking of the fuels with regard to greenhouse gas emissions is believed to be valid. It is suggested that possibly the holistic environmental approach regarding life cycle emissions should be considered, rather than the calculation of pure Isle of Man combustion emissions.

3.23. In conclusion, if the supply was fully developed, this could bring about significant reductions in greenhouse gas emissions, but the cost remains high as not in full-scale production.

3.24. It may be worth considering the potential to include storage for biodiesel at the new ferry terminal at Liverpool, which is shortly due to commence construction by the Department of Infrastructure. This could provide an opportunity to future-proof the terminal should biodiesel become readily available.

Other Fuel Options

3.25. Consideration of different fuel options including compressed natural gas (CNG), Liquified Petroleum Gas (LPG), Methanol and Hydrogen is included within the Annex.

Barriers to Alternative Fuels

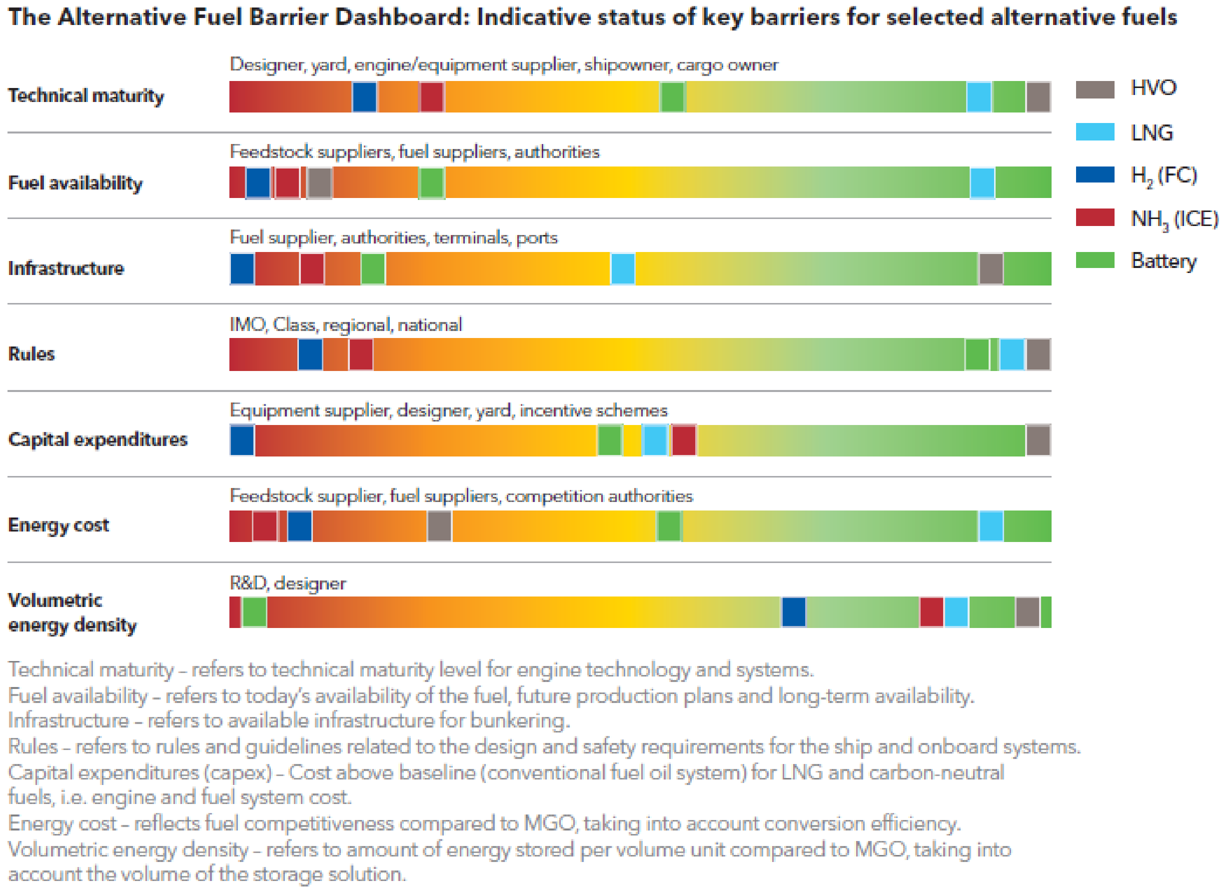

Figure 3 Illustration of the current status of barriers for alternative fuels. Taken from: The DNV GL Maritime Forecast to 2050

3.26. Alternative fuel costs:

The switch to MGO in 2020 to meet the international emission standards will result in an estimated uplift of USD 1.9 million. If the MV Ben-my-Chree was using biodiesel in the same quantity per year, the cost would be an uplift of over USD 3.5 million. Transference to biodiesel would, of course, depend on the availability of feedstock for first-generation biodiesel or non-feedstock biomass from second-generation.

[The above costs are based on average European costs for September 2019 taken from https://shipandbunker.com/prices

Biodiesel currently costs around USD1000 per metric tonne (Source https://www.neste.com/corporate-info/investors/market-data/biodiesel-prices-sme-fame).]

4. THE OPPORTUNITY

4.1. The reduction of non-greenhouse gas emissions in the shipping sector has been governed by air pollutant regulations for some time, and it is expected that international policymakers will also start to put in place de-carbonisation legislation. These legislative requirements will, in turn, influence the technical developments required to enable emissions reductions. As reported earlier in the report, a number of options are now starting to emerge which could be fully mature within the next few decades, which could enable the shipping industry to meet future decarbonisation targets.

4.2. The DOI plans to build a new ferry terminal at Liverpool, with the aim to be operational by Spring/Summer 2021. The design for the new terminal has been approved, and planning permission obtained. Provision for disposal of used fuel has been included within the design.

4.3. There is now an opportunity to equip the new Ro-Pax with the technology that not only meets the IMO requirements but has the potential to supersede these as these technologies emerge. Consideration should, therefore, be given to accommodating future fuel options which reduce carbon emissions in the design of the new vessels and the Liverpool ferry terminal, with the possibility that the allocated fuel disposal areas could be re-purposed.

4.4. A dual-fuel Ro-Pax vessel would require a large LNG tank to accommodate a fuel that could become available at Heysham Port in the future and would limit cargo space. A dual-fuel design would need to take into consideration the risk of methane slippage outlined above, and consideration could be given within the vessel design to fitting a tank at a later stage, which could potentially be a deck tank as the vessel would be able to bunker every day. Loss of space within such a design would be less of an issue but would aim to "future proof" the propulsion system.

4.5. The next opportunity with regards to a low emission power source will be for the HSC Manannan replacement vessel, around 2024. The Sea Services Agreement requires at Clause 5.2.3.3 that a further vessel will be required by December 2026, to replace the current fast craft vessel HSC Manannan, by which time the technology outlined in this report and associated bunkering infrastructure in our neighbouring jurisdictions may have evolved sufficiently to consider an alternative power source.

4.6. Clause 5.2.8.3 of the Sea Services Agreement requires IOMSPC to submit plans/specifications regarding the replacement vessel, to the DOI, and the DOI has the opportunity at this time, as specified in clause 5.2.8.3.2 to have an input into the plans. These clauses were specifically included within the Agreement with carbon reduction issues in mind.

Reducing emissions from off-Island Travel

4.7. A different, but possibly more effective way to reduce emissions from the Island's ferry service would be to reduce the number of sailings.

4.8. The Strategic Sea Services Policy, approved by Tynwald in December 2016, is that: *"The Department [of Infrastructure] will intervene in the ferry services market to the extent that is necessary to provide for the social and economic requirements of the Isle of Man."*

4.9. The following sailing schedule, formalised in the Sea Services Agreement, was agreed in the light of the above Sea Services policy, and the identification of the social and economic needs of the Isle of Man:

- 947 per year sailings to a Port in the North West of England. These sailings are required to include:
- daily sailings to Liverpool Sunday to Friday, and two sailings daily on a Saturday, from the last weekend in May to the first week in September, and;
- weekend sailings to Liverpool during the winter period.

4.10. Daily sailings are required for transporting perishable and time-sensitive goods, currently provided by the night-time Heysham service. This service brings in goods for store shelves the following day, in order to satisfy the wider logistics network which is set-up for just-in-time deliveries and operates throughout the year. Heysham sailings are provided by the Ro-Pax, MV Ben-my-Chree.

4.11. The service to Liverpool is provided by the HSC Manannan; essentially a passenger service providing easy access to the historic city, with which the Island has strong social and cultural links; a requirement which was recognised in July 2016 when Tynwald agreed to purchase land at Liverpool to build a ferry terminal (IOM Government, 2016).

4.12. The report commissioned by the DOI in 2016 from Oxera LLP reported that: *"the current ferry service to the Isle of Man can be characterised by significant excess capacity for freight and for passenger services in the off-peak season. Current vessels and service frequency are designed to address peak demand, and certain routes (e.g. Dublin) are unlikely to be economical on a stand-alone basis."*

4.13. Oxera reported that current available freight capacity is between four and six times larger than actual shipped volumes when passenger vehicle traffic is excluded, which would imply an actual capacity utilisation over the year of around 20–25%. However, given that the vessel vehicle space is interchangeable between freight and passenger vehicles, the actual utilisation of 'free cargo space' after passenger traffic is taken into account would be closer to 50% annually. This capacity would certainly suggest that there is scope to potentially reduce the number of sailings and thereby reduce emissions. This could potentially be achieved by either:

- a move away from the "just-in-time" delivery model, enabling a reduction in the number of daily sailings. Whilst existing and future vessel capacity suggests that this could be possible, there would be a requirement for new, on-Island food storage capacity. The Sea Services Agreement specifies that the new Ro-Pax must provide a similar freight capacity. Alternatively;

- a reduction in the number of fast craft sailings to Liverpool.

4.14. The above would, however, be contrary to the current social and economic needs of the Isle of Man, as confirmed by the Public Survey of Ferry Services conducted by the Department of Infrastructure in October 2018.

4.15. The survey, which received a total response of 4,962, was, at that time, the largest response to an Isle of Man Government public survey. The survey identified that frequency of services, sailing schedules and speed of journeys are important, and that two-thirds of respondents would prefer a fast ferry service to Liverpool seven months of the year, whilst one-third would prefer a slower ferry year-round.

4.16. It should be noted that reducing ferry services could potentially push passengers to travel by air, which produce higher level of emissions than ferries.

4.17. Identification and careful consideration of all the issues, together with the impacts on IOMSPCo, the economy, and the overall level of Isle of Man emissions, would be required should such a course of action be pursued.

5. THE ACTIONS

5.1. Necessary ambition

- Discussions should take place with IOMSPCo regarding the future potential of inclusion within the new vessel design the opportunity for conversion to a dual-fuel vessel.

- Re-visit the issue regarding the powertrain and associated infrastructure, for an Isle of Man ferry around the period 2024.

- Further consideration and analysis of the potential for, impact, and carbon savings of a reduction in the number of IOMSPCo sailings, together with the potential impact of increased emissions from increased air travel.

6. CONCLUSION

6.1. Given the essential nature of IOMSPCo's ferries in providing a lifeline service for the Isle of Man, the imminent commissioning of a replacement Ro-Pax, and the current status of the development of alternative fuel technology, there is limited opportunity at the present for direct intervention to require a reduction in IOMSPCo emissions.

6.2. Maritime industry developments as a consequence of the de-carbonisation agenda could, however, provide new and different options in the 2020s to consider alternative power sources.

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ANNEX A

Compressed Natural Gas (CNG)

Similar to LNG, compressed Natural Gas (CNG) can be stored on a vessel and can be burned in a gas-burning or dual-fuel engine. The lower energy density of the gas requires extra space for fuel storage compared to LNG. CNG also has much longer refuelling times. The cost of CNG as a fuel reflects the natural gas price, which is much lower than current incumbent diesel fuels (especially those needed to comply with SOx regulations). This is an advantage for the use of CNG. Estimates of the CO2 reduction potential from CNG range from modest savings of the order of 8-9%, relative to the incumbent diesel fuels, to a net increase in emissions. CNG use is currently being demonstrated in a Dutch ferry, between Texel and the mainland (TESO) and therefore a short route.

CONCLUSION: More research is necessary to explore the use of CNG or bio-CNG across a wider range of shipping classes, to determine the extent of its applicability before considering the Irish Sea routes.

Liquefied Petroleum Gas (LPG)

A maritime application of LPG could produce a 10-17% reduction in CO2 emissions on a well-to propeller basis when compared to the incumbent diesel fuels. The use of LPG also ensures compliance with NOx and SOx legislation, as the emissions of these gases is low for this fuel. LPG is available and readily transported, shown by its use in the domestic heating and cooking markets. For this reason, it is often mentioned as an alternative fuel for the shipping sector. However, the price of LPG is too expensive when compared to other alternative marine fuels. As LPG is heavier than air in gaseous form it also presents issues in safety on a vessel, any leaks would remain on the vessel at risk of ignition. When the high fuel cost is combined with the issues of safety, as well as the additional costs of retrofitting a gas or dual-fuel engine, then LPG looks relatively unviable as an alternative option for deep and large-scale decarbonisation in the shipping sector

CONCLUSION: Prohibitive cost and infrastructure issues.

Methanol

Methanol is a liquid fuel, easier to handle than LNG or CNG. It is currently mainly produced from natural gas. Conventional production from natural gas is estimated to increase GHG emissions from shipping by approximately 5%. However, CO2 capture and its reinjection into the synthesis loop is being implemented to improve methanol yield and reduce the CO2 footprint. Methanol engines are used in ships, though at the early stage of adoption. Several projects have worked on the development of engine conversions to methanol; these include Leanship, Methaship, SPIRETH and PILOT Methanol.

The PILOT Methanol project involved the conversion of an existing medium speed four-stroke Wärtsila engine on the passenger ferry Stena Germanica. Seven methanol tankers are in use today based on MAN dual-fuel two-stroke methanol (ME-LGI) engines, with four more on order (commissioned by Waterfront Shipping). These engines also allow the use of gaseous fuels like (Bio-)LNG.

In general, methanol can be used in spark-ignition engines, dual-fuel compression ignition engines and converted compression-ignition engines. Methanol contains oxygen which impacts energy density, ignition, combustion, emissions and other characteristics in comparison to conventional fuels. Methanol has a lower cetane number, which determines the ability to self-ignite, than diesel. It would not be able to be used in traditional marine diesel engines without a pilot fuel or ignition enhancer and adaptations to the engine, injection, fuelling system and storage. Methanol can be stored in non-pressurised tanks. Whether it requires a double barrier design for all parts in contact with methanol due to its low flashpoint is still under discussion.

In the case of the Stena Germanica ferry, a ballast tank was transformed into a methanol fuel tank. The low viscosity and corrosive nature increase engine wear and require redesigned engine parts or chemical additives. The toxic and corrosive nature of methanol requires specific design considerations and changes to the maintenance and risk assessment due to potential leakages. However, according to MAN these challenges have all been overcome in their ME-LGI engine. However, it is more difficult to ignite than diesel fuels and dilutes with water, both characteristics which reduce its fire risk. The risk is higher in a sealed compartment such as an engine room, but with the right measures, the risk can be mitigated. Methanol is classified as a Class 3 flammable liquid and solvent similar to gasoline and petroleum distillates. A new International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code) entered into force in January 2017 as an amendment to SOLAS, it currently covers LNG and Methanol.

The requirement for double-walled fuel tanks for alcohol fuels or possibility for single-wall tanks still remains under discussion. The infrastructure for methanol already exists in the chemical industry with train, truck and ship deliveries in a wide number of locations, and it can be introduced without too much difficulty to the marine sector. The actual bunkering facilities are the last missing element. Both mobile and land-based bunkering of methanol would come with limited additional cost for conversion or new build barges or terminals. The low energy density of methanol (20 MJ/kg) in comparison to diesel or HFO (42.7 and 40.9 MJ/kg) requires around twice the space on board for fuel storage or an increased bunkering frequency for the same storage capacity. A greater weight of the fuel storage system would impact the loading capacity of the ship, and the slightly higher energy efficiency of methanol only balances this out to a limited extent. One of the benefits of methanol is that it is a bio-degradable liquid. The cost of fossil methanol between January 2017 and March 2018 was 13.6-19.1 €/GJ142. This is the most expensive fuel cost out of the fossil fuel options, at approximately double the price of HFO cost and two to three times the fuel cost of LNG.

CONCLUSION: High cost but infrastructure mainly in place (bunkering excepted) and already in small scale use.

Hydrogen

The use of hydrogen in shipping is mainly considered through the use of electric propulsion and fuel cells. However, hydrogen can also be used in a gas turbine to provide propulsion or in a hybrid fuel mix. The use of hydrogen in fuel cells does not produce any GHG emissions, from tank-to-propeller. Instead, the GHG emissions from hydrogen depend on its production (well-to-tank). Most hydrogen produced in the world comes from fossil sources, including steam methane reforming and coal gasification. These production pathways generate high GHG emissions, although some of these might be captured at source in the future. Hydrogen may also be produced through an electrolyser powered by electricity. Based on whether the electricity comes from fossil, nuclear or renewable sources, the lifecycle greenhouse gas intensity of the outgoing hydrogen will vary. Therefore, the GHG emissions from hydrogen fuel cells would only be lower than conventional marine fuels if hydrogen is produced from low-carbon electricity (green hydrogen).

Currently, green hydrogen is not readily available, especially because of the difficulties to transport and store this fuel. Ammonia is also being investigated as an energy carrier for use in fuel cells and is deemed to have potential as an alternative marine fuel. It is currently being tested in a project by Proton Ventures.

The marine application of fuel cells requires a new electrical propulsion system, on-board fuel cell systems and new storage capabilities compared to existing marine engines. The storage of hydrogen on board requires a large space due to the low energy density of hydrogen, with an estimated tank size of 10-15 times larger than the required HFO tank and therefore loss of associated cargo space. A solution for this is to cool the hydrogen to ultra-low temperatures to store it as a liquid, but this requires more energy and more infrastructure to do, as well as specialised tanks to store, resulting in greater barriers to implementation. The storage and usage of hydrogen as a fuel also requires compliance with safety standards, resulting in modifications to ship equipment as well as other barriers. Therefore, it would require a highly modified vessel or a purpose-built vessel to make hydrogen as a viable fuel option. This can be implemented more easily into future ship builds but would be costly to retrofit. Additionally, like for LNG, the decreased energy density and need for increased fuel storage would favour inland and short sea shipping types, over deep-sea shipping as it requires less on-board fuel storage.

A feasibility study for the provision of hydrogen-powered ferries for the Scottish Western Isles was published in July 2019, which included the comparative cost of hydrogen produced from wind farm electricity (Point and Sandwick Trust, 2019).

Alternatively, carbon-neutral H2 can be produced from natural gas (with carbon capture and storage) or from nuclear energy. Using compressed or liquefied H2 in fuel cells is a realistic option for the short-sea shipping segment in the medium term.

CONCLUSION: Excellent for Zero carbon footprint but infrastructure supply on a large scale doubtful.

Nuclear

Nuclear powered vessels have the potential of reducing GHG emissions significantly and produce no other gas emissions due to the absence of combustion. The use of nuclear reactors as a fuel source for maritime applications is well developed through military uses in submarines. There is currently one merchant nuclear-powered ship operating called the SEVMORPUT, a Russian-built in 1988, which operates across arctic waters. Nuclear power offers extended range, limited need for refuelling and extremely high energy density of fuel, making nuclear suitable for large trans-ocean deep-sea shipping.

However, the safety to people and the environment, and geopolitical risks related to nuclear powered commercial shipping present many barriers to its uptake as viable main-steam technology in global shipping. It is not envisaged that nuclear will become a viable alternative in the near future

CONCLUSION: Excellent zero-carbon option but politically unacceptable and would most likely lose the Isle of Man its Biosphere status.