Short overview of aviation and shipping decarbonisation

Briefing note prepared for Isle of Man Government

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Author: Eunomia Research & Consulting

1.0 Introduction

Island states and dependencies are reliant on trade and visitors reaching them by sea or air and may incur difficulties in mitigating such emissions due to their geography. The issue's difficult nature is well recognised and requires specific exploration, exemplified by the Pacific Small Island States raising funds to explore decarbonisation.[1] Communities on any island state risk economic isolation if air and sea connections are cut off or reduced, therefore exploring sustainable alternatives is paramount. The option of major reductions in usage of this transportation (rather than replacement by alternative technologies) is therefore not viable.

Whilst options to fully decarbonise aviation and maritime emissions are still in the early stages of development, there are currently commercially available technologies and strategies to improve efficiencies, which can provide short-term reductions in ongoing greenhouse gas emissions. These include both hard (physical changes such as retrofits) and soft (behaviour changes) interventions.

This briefing note provides a summary of publicly disclosed innovations currently being explored or implemented within the aviation and maritime industries. It is not a comprehensive insight into the future trajectory of technological development, but instead a collation of the best information at present around these technological challenges.

As pressure on the climate mounts and governments, industries and individuals place higher importance on finding solutions to mitigate environmental impacts, we expect to see further progress being made, and the rate of progress accelerate.

[1] https://www.theguardian.com/environment/2019/sep/24/pacific-islands-seek-500m-ocean-shipping-zero-carbon

2.0 Aviation

2.1 Options to Reduce Emission and Impacts

The IPCC's special report on aviation suggests a number of policy options that can be taken to reduce emissions from aviation. While many of the specifics of the report from 1999 are now outdated, the policy options remain a good starting point for further research. The policy options are:

- Changes in aircraft and engine technology;
- Fuel;
- Operational practices; and
- Regulatory and economic measures.

2.1.1 Changes in Aircraft and Engine Technology

Electric Power and Alternative Fuel Technology. The Highlands and Islands regions of Scotland recently announced that it aims to be the world's first net-zero aviation region. This will involve full decarbonisation of flights and airports in the region by using electric aircraft to carry out short haul flights between the islands and the mainland. The technologies for electric passenger flights are not yet in place – the only aircraft to currently use the technology are very small and lightweight – but Scotland hopes to carry out test flights by 2021.

Norway also has intentions of converting all short-haul flights that are leaving its airports to electric power by 2040. They say that they expect technologies to develop quickly, with companies such as Airbus already researching into this topic. They hope to introduce a small number of 25-30 seat electric motor planes into service as soon as 2025. For many domestic flights, this number of seats is adequate.

Scotland's aim is only feasible due to the nature of flights taken between the Highlands and Islands region: they are typically short haul flights and will, therefore, be more feasible to transition to alternative fuels or electric power. The relevance of this to the Isle of Man is partial, as there are a variety of destinations accessible from the airport, some of which would be commensurate distances to those in the Highlands and Islands. Where distances are similar, there will clearly be opportunities to learn lessons from Scotland and Norway. Longer-distance journeys will require other approaches.

Biomimicry: In 2019 Airbus unveiled a thought-provoking bird-like conceptual airliner design. The concept showed a hybrid-electric, turbo-propeller aircraft for regional air transportation. Taking inspiration from the efficient aerodynamics of birds, it showed wing and tail structures and featured individually controlled feathers to provide active flight control. Whilst only a concept, it is based on realistic ideas such as a blended wing-to-fuselage joint that mirrors the graceful and aerodynamic arch of an eagle or falcon.[2]

[2] https://www.airbus.com/newsroom/news/en/2019/07/airbus-conceptual-airliner-to-inspire-new-generation-engineers.html

This is not the first time biomimicry (the design and production of materials, structures and systems inspired by nature) has been used in the aviation industry.

Traditionally aircraft surface design was smooth to assist them to cut through the air. However, studies of sharks, which are known for their speed through water, suggest that aircraft could benefit from mimicking sharkskin, which is covered in small, tooth-like riblets. The Frauenhofer Insititut in Germany has designed a paint modelled on sharkskin that incorporates grooves similar to those of these riblets which can be applied to the surfaces of aircraft. It is believed that if this paint were to be applied to every aircraft in the world it could save 4.48 million tonnes of fuel annually[3]. Since 2016 several Airbus jetliners have been fitted with small 'riblet' textured surfaces applied to the fuselages and wings. The drag-reducing surface of this sharkskin mimicry is particularly effective during high-speed cruise flight which implies that the concept is highly suitable for long-range aircraft. Further research is needed to identify its potential on short haul flights.[4]

Dayna Baumeister, co-founder of the Biomimicry Guild, believes that by examining lightweight materials found in nature, there is a potential of many opportunities to cut the weight of an aircraft and thereby creating savings on fuel and emissions.[5]

2.1.2 Fuel Efficiency and Alternative Fuels

Improving fuel efficiency and using alternative fuels is the preferred solution by the industry. However, the research on fuel efficiency is often overstated. Estimates frequently show an annual reduction in energy consumption per seat-kilometre, which ignores the fact that the annual reduction rate is beginning to tail off, since aircraft cannot possibly reach zero fuel consumption.

Biofuels and synthetic fuels are not a solution for the aviation industry as a whole. They still contribute to global warming through GHG emissions and non-CO_2 warming and are not available at the scale required by the aviation industry. Increasing production of biofuels would entail detrimental social and environmental impacts. Research into sustainable alternative fuels is ongoing and might present a better solution in the future, particularly for the smaller scale of emissions that the Isle of Man faces.

2.1.3 Regulatory and Economic Measures

Regulatory and economic measures can be used to manage passenger demand for aviation through a reformed taxation regime. In 2015 The New Economics Foundation proposed the repeal of an Air Passenger Duty and its replacement with a Frequent Flyer Levy (FFL), the rate of which would vary depending on the frequency of flights taken by the individual. The

[3] https://www.flightglobal.com/aircraft-engineers-turn-to-biomimicry-for-greener-designs/95210.article
[4] https://www.airbus.com/newsroom/news/en/2018/01/biomimicry--engineering-in-nature-s-style.html
[5] https://www.flightglobal.com/aircraft-engineers-turn-to-biomimicry-for-greener-designs/95210.article

report estimates that just 15% of the UK's population takes 70% of the flights. On a small island like the Isle of Man this statistic might differ, as flights will presumably be a necessary mode of transport across all residents to leave the island. Nonetheless, there is scope to explore the potential impact of a FFL on flights into and out of the Isle of Man, though this analysis should also explore the broader societal and economic impacts to determine the manner in which this could best align with an island economy.

In the paper linked above, it is proposed that would-be passengers are ranked based on their income, as income is found to correspond with the average number of flights taken. Therefore, the paper proposes a nine-stage tax, with no taxes for the lowest-income band.

For business flights, there are two proposed options:

- Businesses should face the same marginal taxation rates as flights taken for leisure. The taxation bands could be calculated on the ratio of total flights taken by the business to total employees.
- Alternatively, businesses could be exempt from the tax regime and the increase in business passengers would need to be offset by a further decrease in leisure passengers.

The latter would seem to be counterintuitive, as many of the most frequent flyers are flying for business travel.

The report concludes that "if the aviation industry were to take the same responsibility for emissions reductions as all other industries must (on average), this would imply an annual reduction in aviation emissions of 7-11%". This reduction in emissions would contribute towards achieving an acceptable change of not exceeding 2 degrees warming.

In addition to a frequent flyer levy, the report recommended that governments cease to fund airports and airlines through taxes. Like most airports, the Isle of Man's Ronaldsway Airport runs at a loss (£3.7m annually) though the social and economic impact would have to be added to any decision over removal of subsidies.

In the short term, regulatory measures may be the most effective approach to reducing the Isle of Man's emissions from aviation, but would need to be analysed in the broader context of the Isle of Man as an island community.

3.0 Maritime Emissions

For the Isle of Man, domestic navigation emissions (including internal shipping and boating emissions) encompass all maritime movements within the Isle of Man and between the UK and the Isle of Man. These account for 8% of the country's transport emissions, which was

0.013 MT CO_2 eq in 2017.[6] Fishing emissions are separately categorised, account for 2% of the country's transport emissions, which was 0.003 MT CO_2 eq in 2017.[6]

3.1 Options for emission reductions

- **Electric ferries**. Technology has advanced so far that electric ferries that are routinely operational in Norway have cut emissions by 95% and costs by 80%.[7] Electric ferries also reduce NO_x, water and noise pollution. The first all-electric ferry in Norway, the Ampere, carries people and vehicles on the 5.7km Sognefjord crossing which takes 20 minutes. The ferry has a capacity of 120 cars and 360 passengers. Its 1MWh battery and electric motor save an estimated 570 tonnes CO_2 eq per year.[8] The ferry is charged during the 10-minute loading period at either end of the crossing, and then fully re-charged overnight, with power from a hydro-electric microgrid.

- **Alternative fuels**. Changing fuels can lead to emission reductions, for both smaller boats and larger ships. This is a major focus for the international shipping industry. Container ships operate on much longer journeys and therefore have mostly looked towards alternative fuels rather than batteries. Liquified natural gas (LNG) has already been proven as a commercially viable option, with 125 LNG fuelled ships operating across the world today.[9] New rules from the International Maritime Organisation (IMO), entering force in 2020, may encourage more ships to adopt LNG as a fuel in an attempt to limit emissions.[9] It is estimated that the use of LNG as a fuel in the shipping industry can lead to a 10-20% CO_2 reduction. There are indications that this market will grow in the coming years, as the number of LNG fuelled ships on order continues to grow.[10] Other shipping fuel sources that are being developed include hydrogen, biofuels (ethanol and biodiesel) and ammonia. Ammonia, or Green Ammonia in particular, seems to be gaining momentum. A recent Ricardo report[11] suggests that Green Ammonia will be central to current decarbonisation targets of the shipping industry, especially as it can be generated with renewable energy.

- **Shipping efficiency improvements**. The lifespan of a cargo ship is roughly 25-30 years. This implies that there is a huge stock of ships that are operating, and will continue to operate, with conventional fuels and engines. Options for improving the

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[6] Aether, Guide to the Isle of Man Greenhouse Gas Inventory
[7] https://electrek.co/2018/02/03/all-electric-ferry-cuts-emission-cost/
[8] https://www.ship-technology.com/projects/norled-zerocat-electric-powered-ferry/
[9] https://www.reuters.com/article/us-shipping-fuel-lng-analysis/new-fuel-rules-push-shipowners-to-go-greenwith-lng-idUSKBN1L01I8
[10] http://production.presstogo.com/fileroot7/gallery/dnvgl/files/original/124feddb807045969b3071a55f73c80b/124feddb807045969b3071a55f73c80b_low.pdf
[11] https://ricardo.com/news-and-media/news-and-press/new-shipping-fuels-can-cut-pollution-and-boost-clean-energy-economy-in-developing-countries

efficiencies of this stock are therefore very important, and there are a number of possibilities. While some options include retrofitting or physical amendments, others are simply improvements to the scheduling and optimisation of speed and weight.

- **Tonnage deployment** through modelling systems to optimise tonnage of different journeys. These models will help ensure that capacity can be allocated to where it is needed most.
- **Speed and scheduling** can be optimised for improving efficiencies. Sailing at a slow steady pace and reaching port on time is far more fuel-efficient than sailing quickly, arriving too early and being forced to wait. This creates a potential of 2% in fuel savings.[12]
- **Hull cleaning and paint** options.[14] One method to reduce skin friction is to alter the way flow velocity grows through the boundary layer and/or the way the boundary layer grows along the hull. In general, a smooth hull surface is considered to be conducive of best performance, and, to a large extent, this is the case when the alternative is a fouled hull as a consequence of marine growth. The collation of "sea gunk" on ship hulls can increase a ship's drag by up to 15%, reducing its hydrodynamic efficiency and making it travel slower, consume more fuel and cause more pollution[13]. Similarly to what is found in the aviation sector, biomimicry is starting to play an increasingly important role in the maritime industry. Studies show that sharks do not pick up bio-fouling irrespective of their speed. This shows that further benefits can be achieved by adopting particular types of surface texturing in place of a uniformly smooth hull.
- **Air lubrication** can achieve up to 10% reductions in fuel consumption, where air is blown between the hull and water, to reduce friction.[14] The technology is yet to be commercially proven, and optimal system design is debated. The two most advanced options are Air Cavity Systems or Micro-bubbles.
- **Wind technologies** which help to propel the ship are being considered by many shipping firms, with potential savings of up to 30%.[14] While technologies are not currently commercially available, there are several in development. Towing kites are used in tailwinds, launched from the hull to pull the ship. Other options include Flettner Rotors, Rotor Sails and Windmills.

- **Fishing fleet efficiency**. As an island state with a small fishing industry, there are options to improve fuel efficiency of the Isle of Man's fishing fleet. These include[15]:
  - changing towing patterns, avoiding going to sea in bad weather;

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[12] https://www.2wglobal.com/news-and-insights/articles/features/5-ways-to-improve-efficiency-in-the-shipping-industry/
[13] https://www.chinadialogue.net/article/show/single/en/5566-Biomimicry-sharkskin-ships-and-whale-flipper-wind-turbines
[14] https://ww2.eagle.org/content/dam/eagle/advisories-and-debriefs/ABS_Energy_Efficiency_Advisory.pdf
[15] https://www.seafish.org/media/Publications/options_improving_fuel_efficiency_in_UK_fleet.pdf

- improving efficiency of gear, reduce towing speeds
- fishing closer to mainland; and
- engine replacements.

There are varying uptake and efficiency savings of each of these methods, though the Sea Fish report, referenced above, suggests that awareness of efficiency savings has increased.

The potential of each and all of these measures to impact upon the maritime emissions of the Isle of Man would need to be examined in detail, specifically assessing the current fleets and associated operation patterns to determine the interventions with greatest impact and/or those that are most cost-effective.