Scottish ferries: sailing towards greater energy efficiency and decarbonisation?

Nishatabbas Rehmatulla, UCL Energy Institute

Abstract

The Paris Agreement, UK and Scotland Climate Change Acts provide a clear direction of travel for greenhouse gas (GHG) emissions. Scotland's climate targets would require that the domestic transport sector be nearly completely decarbonised. Existing analysis shows that there are inefficiencies in the procurement of ferries, both in Scotland and the rest of Europe, which mean that energy efficiency and decarbonisation opportunities may be forgone in certain situations. The age of ferries has a direct impact on their efficiency and the analysis shows that, whilst Scottish ferries are younger than their counterparts elsewhere, when disaggregating by operator, there seems to be some correlation between public and private operators with regards to age of the ferries. Implementation of incremental energy efficiency technologies and measures in ferries may be hindered due to market failures, and total decarbonisation may be hindered by non-market failures.

I Introduction

The UK and Scotland have both agreed to reduce CO2 emissions by 80% below 1990 levels by 2050 through the UK Climate Change Act 2008 and Climate Change (Scotland) Act 2009. Scotland's Climate Change Act 2009 contains an interim target of a 42% reduction by 2020 and a 50% reduction by 2030, on 1990 levels. Emissions from domestic transport accounted for just over 20% (13 MtCO2e) of total Scottish GHG emissions in 2014, whilst international aviation and shipping account for a further 5% of total emissions (CCC 2015). Given these climate change targets, the domestic transport sector will require to be almost totally decarbonised. Reductions in emissions, from road transport for example, are being made through various initiatives and strategies incentivising the uptake of electric vehicles and changing behaviours, thus helping to meet the sector's challenging targets.

Decarbonisation in ferries can begin from implementation of measures to improve energy efficiency (design related measures, hydrodynamic measures and machinery measures) for both existing ships (through retrofits) and new ferries. Thereafter, weaning off from fossil fuels through greater use of low carbon fuels (e.g. bio-diesel and liquid natural gas) and eventually shifting towards renewable forms of energy (e.g. wind and solar) and synthetic fuels (e.g. hydrogen), will be required to reach decarbonisation. For a complete list of technologies applicable to ferries refer to the appendix. There are several examples of ferries in operation that have already achieved zero emissions, for example the Ampere, a fully electric car ferry owned and operated by Norwegian operator Norled. CalMac already owns three hybrid ferries (lithium ion batteries), which has resulted in 20% reduction in emissions and is already carrying out feasibility studies to evaluate the role of hydrogen and fuel cells, under EU funded projects.

The implications of Brexit on procurement of ferries remains unclear. EU policies impacting the procurement of ferry services is covered by three key pieces of legislations; EU council regulation No. 3577/92 (the Cabotage regulation) regulates the transportation of passengers and goods by sea between two points within Member States of the EU; Directive 2014/25/EU of the European Parliament and of the Council of 26th February 2014 on procurement by entities operating in the water, energy, transport and postal services sectors repealing Directive 2004/17/EC and Directive 2014/24/EU of the European Parliament and of the Council of 26th February 2014 on public procurement, repealing Directive 2004/18/EC. These directives determine when an undertaking incurring a Public Service Obligation (PSO) has to be selected using a public procurement procedure and what the terms of this procedure can be.

This aim of this paper is to review the literature on the impact of tendering on delivering an environmentally friendly ferry service, comparing the current state of Scottish ferries with other European nation ferries, and assess whether there are barriers that could hinder Scottish ferries achieving greater energy efficiency and near decarbonisation.

II Procurement of ferry services

Tendering has been suggested as a means to induce cost efficiency and thus reductions in the costly public subsidies (Sunde 1999) by replacing market competition with ‘access to’ market competition. For a review of the European ferry sector procurement policies refer to Rehmatulla, Smith & Tibbles (2017). Baird, Wilmsmeier & Boglev (2010) and Baird & Wilmsmeier (2011) show that ferry subsidies in EU member states have been rising despite the competitive tendering of ferry services introduced in many EU member states. Tendering procedures that are thought to improve the prevalent ferry services in terms of value for money for the consumers and public agencies is not yielding the desired or expected results. Førsund (1993), Minken & Killi (2001), Bråthen et al. (2004) and Odeck & Bråthen (2007) show that there may be cost efficiency gains in the range up to 30% in the EU ferry links analysed. Even in the case of Norway, which is free from the EU procurement regulations but adopts similar approaches to procurement as EU, Bråthen et al. (2004) show that tendered ferry links did not outperform non-tendered ferry links and that the subsidising authorities do not seem to impact on the performance of ferry links.

Rehmatulla, Smith & Tibbles (2017) analysis of the EU ferry sector using agency theory suggests that split incentives (associated with the different entities and their conflicting interests) are pervasive in the public procurement of ferries and can stymie attempts to improve the energy efficiency of ferry services. Their findings suggest that there is a need to devise procurement policies that can address the split incentives in public procurement through tendering under EU regulations. Baird (2012) and Baird, Wilmsmeier & Boglev (2010) show that, uneconomic routes offer reduced return for operators, despite being subsidised. The reduced returns for operators act as a disincentive to them investing in energy efficiency. These findings have important implications on the efficacy of the public procurement of ferry services through tendering, as they suggest production costs (e.g. labour, capital and fuel) are not minimised, therefore suggesting that energy efficiency savings may be forgone in certain situations.

Research by Odeck & Bråthen (2007) indicates that the age of ferries has a direct impact on their energy efficiency. The most likely explanation is that newer ferries are more fuel efficient than older ones. Using age as a proxy for energy efficiency this section attempts to distil the case using quantitative data on the ferry fleet within Scotland and the EU to show whether there are any trends on energy efficiency that may be occurring due to procurement procedures.

Table 1 shows a comparison of Scottish ferry companies and other major European private publicly-owned and operated and privately-owned and operated ferry companies. The average age of Scottish ferry operator ferries is higher (just over twenty-one years on average), than the major route operators in other parts of the EU (fifteen years on average). The table also shows that the average age of the privately-owned operators' fleet is approximately seventeen years compared to publicly-owned operators whose average is twenty-one years.

Figure 1 shows the average age of vessels owned by public and major private operators. One third of UK flagged ferries is over 25 years of age (Figure 2) which is lower than that of all EU flagged ferries, where almost half of the fleet is over 25 years of age (Rehmatulla, Smith & Tibbles 2017). The average age of UK flagged fleet is 23 years compared to the EU average of 29 years.

It has been suggested that if the Scandinavian (mainly Norwegian) approach to ferry operation were adopted in Scotland in terms of vessel and terminal design, operating practices and PSO policy (e.g. provide-and-operate contracts), substantial savings could be made in terms capital and operating costs (Pedersen 2015). A comparative analysis shows that Norway actually has a higher proportion of its fleet that is beyond the expected ferry life of twenty-five years compared to the UK, as is shown in Figure 4. Figure 5 confirms the strategy employed in Norway in the past couple of decades, of smaller sized vessels and faster services (using catamarans) and increased frequency compared to the UK, which has been deploying generally larger ships at slower speeds. From an environmental view point, larger ships (assuming high capacity utilisation) and slower ships result in significantly lower emissions than smaller, faster ships. A 10% reduction in speed results in nearly a 30% reduction in power requirements, thus speed reduction as an operational measure is considered to have one of the highest impacts on energy efficiency and emissions. The reduction in speed can translate into significant cost savings in fuel for the ferry operator and therefore travel costs and fares for passengers, if fuel cost savings are passed on. It is estimated that in a large car and passenger ferry, a reduction of 0.5 knots would result in 20% reduction in fuel consumption and CO_2 emissions whilst only adding five minutes to a two-hour journey or an extra 4% on transit time (Scottish Government 2011).

Table 1: Average age of vessels owned by public and private companies[1] (2014 data)

Company	Headquarters location	No. of vessels	Average age	Ownership
Tallink Group	EU	11	13	Private
Blue Star Ferries SA	Greece	10	14	Private
Compagnia Italiana	Italy	10	14	Private
Brittany Ferries	France	9	14	Private
DFDS A/S	Denmark	11	15	Private
Ustica Lines SpA	Italy	28	15	Private
Acciona Trasmed.	Spain	10	15	Private
Wightlink Ltd.	UK	13	18	Private
Stena Line AB	EU	19	18	Private
Transtejo-Transp.	Portugal	12	20	Private
Western Ferries	Scotland, UK	5	15	Private (unsubsidised)
Pentland Ferries	Scotland, UK	2	25	Private (unsubsidised)
John O'Groats	Scotland, UK	1	28	Private (unsubsidised)
CalMac	Scotland, UK	29	20	Public
Northlink Ferries	Scotland, UK	2	12	Public
Orkney Island Council Ferries	Scotland, UK	7	24	Public
Shetland Council Ferries	Scotland, UK	11	22	Public
Highland Council	Scotland, UK	3	33	Public
Argyll and Bute Council	Scotland, UK	1	13	Public

[1] Data obtained from Clarksons World Fleet Register. This data set does not have good coverage of ferries, especially small sized vessels.

Figure 1: Average age of vessels owned by public and major private operators (2014)

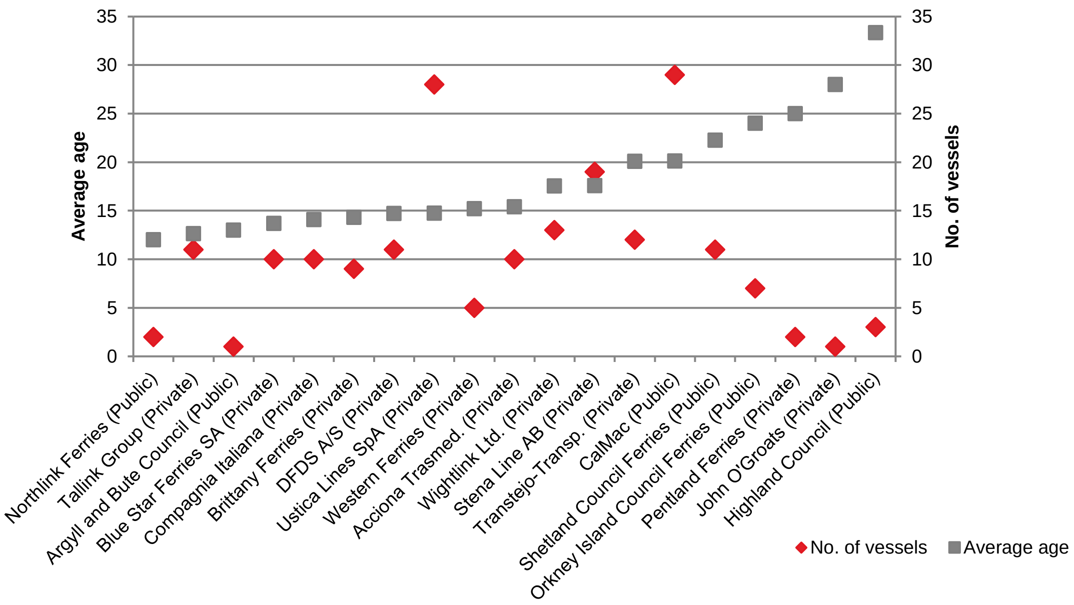
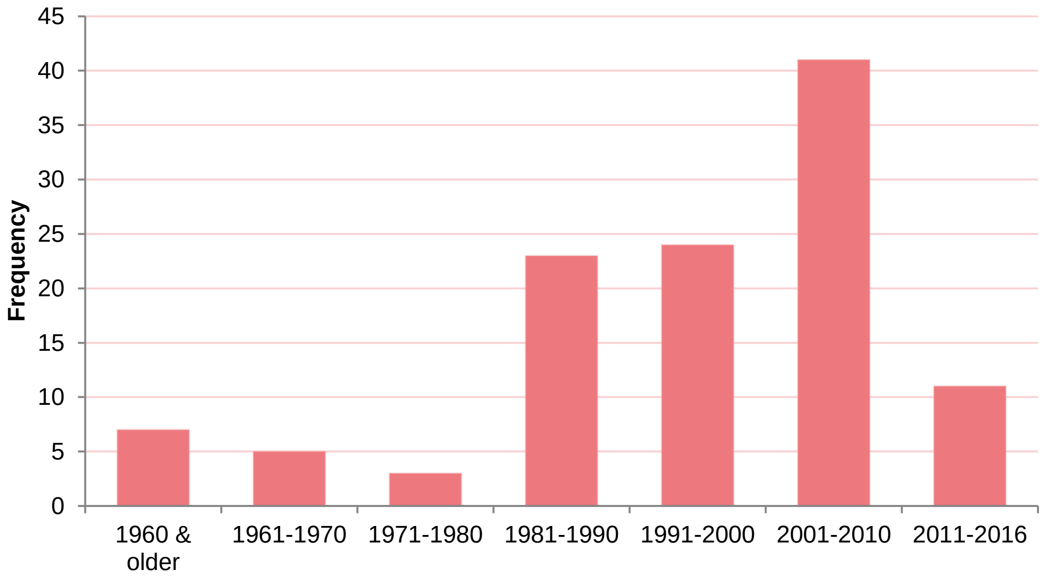


Figure 2: UK ferries by age distribution (2016)



The analysis above shows that Scottish ferries are in general younger compared to other European nations, including Norway. However when one disaggregates by operator, there seems to be some correlation between public and private operators with regards to age, both in the Scottish and EU context. If the data is considered a representative sample, then it points towards differences across nations that are supposed to be using a Europe-wide procurement framework. The analysis presented here should not be construed as final, but as preliminary findings and should be read with caution. Further work is required for a thorough analysis.

Figure 3: Norwegian ferries by age distribution (2016)

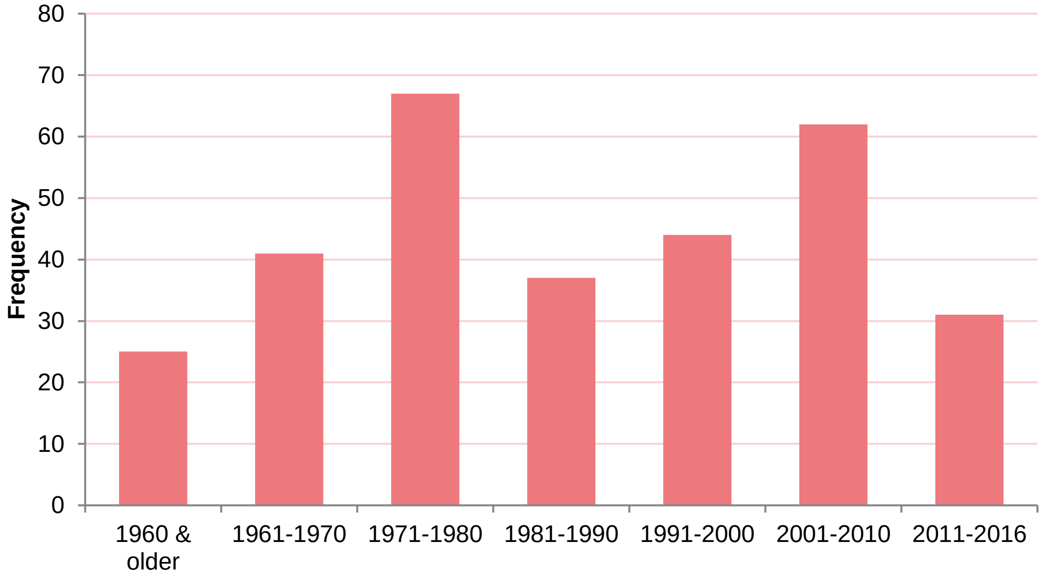


Figure 4: Relative comparison of UK and Norwegian ferry fleet by age (2016)

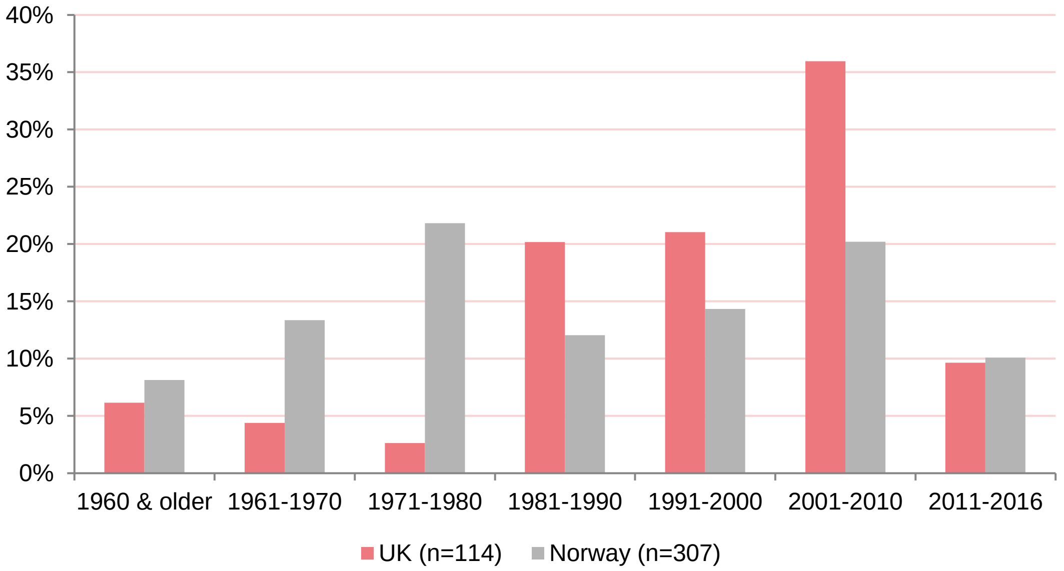
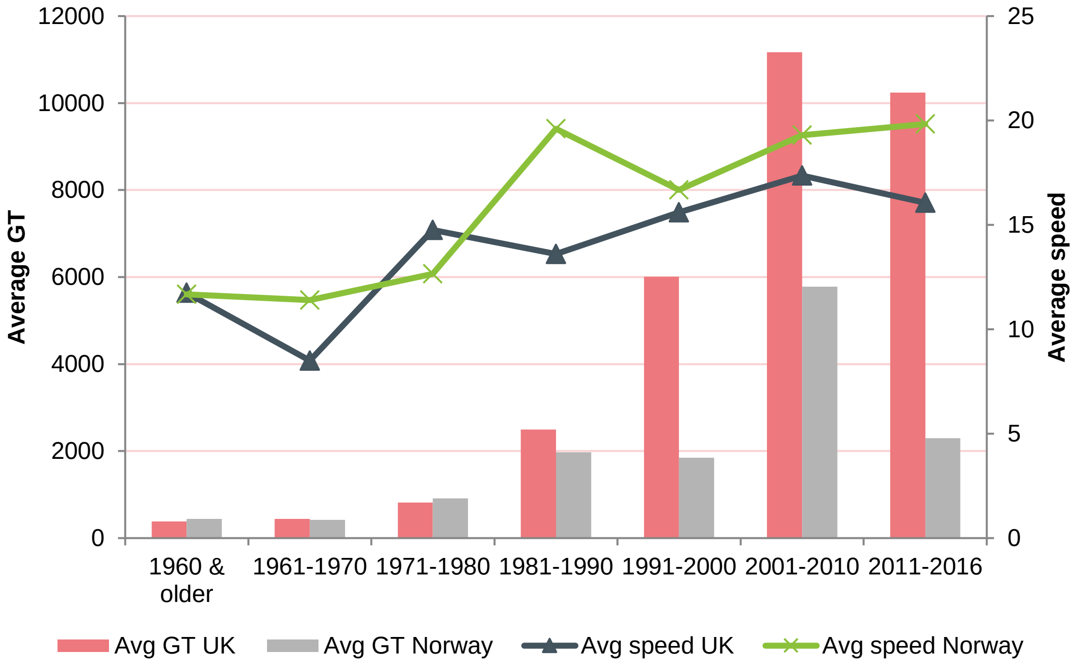


Figure 5: Relative comparison of UK and Norwegian ferry fleet by average Gross Tonnage and speed (2016)



III Barriers to decarbonisation of the Scottish ferry sector

The previous section discussed several factors that show that the provision of ferry services under the different procurement strategies are not optimal. Rehmatulla, Smith & Tibbles (2017) suggest these can be linked to whether; the contract is an operate-only or provide-and-operate contract; the contracts are based on gross or net cost; the operator is publicly, privately or community owned; and, the investor can recoup higher investment costs through higher charter rates.

A large number of energy efficiency measures, especially operational ones, are cost-effective and tend to have substantial emissions abatement potential when implemented in ferries, yet their implementation is not at the level that would be expected from an economist's economic potential and technologist's economic potential (Jaffe & Stavins 1994). This leads to an 'energy efficiency gap', the difference between the actual low levels of implementation of energy efficiency measures and the higher level that would appear to be cost-beneficial or cost-effective from the consumers' or firm's point of view based on techno-economic analysis (Rehmatulla & Smith 2015a). A plausible explanation for the gap is the existence of energy efficiency barriers, which may be defined as postulated mechanisms that inhibit investment in technologies that are both energy efficient and economically efficient (Sorrell et al. 2000). Barriers to energy efficiency can stem from organisational (power, culture etc.), behavioural (bounded rationality, values etc.), market failures (split incentives, information asymmetry, imperfect information) and non-market failures (access to capital, risk etc.). For a full explanation of these in context of shipping refer to Rehmatulla & Smith (2015b).

Market failures

Implementation of incremental energy efficiency technologies and measures may be hindered due to market failures, such as lack of information and split incentives (Adland et al. 2017; Agnolucci, Smith & Rehmatulla 2014; Prakash et al. 2016). Going beyond a certain emissions reduction level would most likely require use of alternative fuels with lower carbon content (e.g. biofuels and synthetic fuels, such as hydrogen) and the implementation of such step-change technologies is impacted by non-market failures, such as access to capital (Grant Thornton 2010), and different forms of risks (Rehmatulla et al. 2017). Analysis by Aquatera (2016), commissioned by Orkney Islands Council, suggests a number of alternative fuels options are available for low carbon ferries, but conclude that whilst moving towards cleaner technologies will have, across all the alternative options, on average 50% reduction in emissions compared to marine diesel, their implementation will have significant cost implications and will depend on the priorities of the decision makers. It is therefore interesting to note that, whilst the Vessel Replacement and Deployment Plan (VRDP) includes energy efficiency and emissions as part of its priorities, it places fuel efficiency and emissions reduction as the seventh and lowest priority (Transport Scotland 2015).

Split incentives

Improvements in energy efficiency and decarbonisation of the Scottish ferries may be impacted by split incentives of the various entities involved in the system. The delivery of ferry services is thus impacted by various recursions of principal-agent relationships, for example, between the ferry operator and the ferry owner, the government and the operator, the local authority and the government, ferry users and ferry operators. The implication of multiple principle agent relationships is that energy efficiency may not be a priority for different entities in the principal-agent chain as a result of different cost responsibilities, energy price shielding and other constraints. For example, the previous section showed the impact of marginal speed reduction on GHG emissions, yet the Scottish Ferries Review consultations showed that consultees were not supportive of reductions in speed with a preference for technological solutions mainly in newbuilds compared to retrofitting the existing fleet (Scottish Government 2011). It is encouraging to note that the Expert Ferry Group has revisited the issue of speed reduction and will continue to investigate further with quantitative analysis (Transport Scotland 2016).

Given that the majority of ferry routes in Scotland are under operate-only contracts (i.e. the Scottish Government or public bodies, for example councils who own and/or provide vessels) one would expect to see a higher level of implementation of energy efficiency and low carbon solutions in Scottish ferries. Such investments are viewed over a long-term investment horizon and the lifetime of vessels, which should lead to higher implementation of energy efficiency measures, since several technologies have a payback generally ranging from a couple of years to ten years (Wang et al. 2010). Operate-only contracts provide further certainty that a vessel will be on a particular route for its life and as a result the investment in the port and harbour infrastructure and the ship-port configuration leads to further efficiency gains, as such ferries save energy and emissions on manoeuvring and speed. The long-term vested interest in such ferries, should result in better maintenance, for example, appropriate hull coating and hull cleaning regime, which could save a significant amount of fuel and emissions.

However, operate-only contracts also have their drawbacks in context of GHG emissions and energy efficiency and this can also be witnessed in the Scottish ferries sector. During the tendering process, bidding firms may be prevented from offering vessels which may be more energy efficient and instead have to accept existing vessels that may not be the most efficient, which in turn will affect the bidding as increased fuel costs need to be taken into account. The central government or the public body has to find the capital to procure newer vessels and under existing circumstances this is a challenging task (Grant Thornton 2010). This affects the fleet turnover and as a result some very old ships continue to operate in Scottish waters. Also of importance in operate-only contracts is the ability of the ferry provider to recoup the higher investments in energy efficient ferries, through higher bareboat charter rates. Empirical evidence to date shows that in the drybulk shipping time-charter market only around 15-40% of energy savings are recouped by higher charter rates (Agnolucci, Smith & Rehmatulla 2014; Adland et al. 2017). However, the structure and provision of ferry services (lower frequency of chartering and longer lead time in the contracting process) may mean that energy efficiency is well scrutinised. Further work in this area is required to estimate the extent to which the fuel cost savings by operators are passed back to the ferry owner through a higher charter rate.

IV Concluding remarks

The Paris Agreement, UK Climate Change Act and the Climate Change (Scotland) Act all provide a clear sense of direction and a long-term objective for all sectors, including ferries. Given the average economic lifespan of ferries, investment decisions made today would need to account for an evolving emissions landscape and manage decarbonisation. This paper highlights several issues with respect to energy efficiency and low carbon ferry services. From the quantitative data, it is not evident that competitive tendering within the Scottish context, has led to improvements in energy efficiency of ferries and the problems that competitive tendering seeks to overcome appear to be present from a principal-agent perspective. Whilst, EU procurement policies have made some progress to incorporate energy efficiency and GHG issues by incorporating life-cycle costing and environmental externalities into procurement directives, Member States still enjoy considerable flexibility in determining how much emphasis should be placed upon these. Procurement policies have yet to overcome the issue of split incentives, which as understood is pervasive in the provision of ferry services in most cases. Most important is the priority that is accorded to energy efficiency and emissions by different entities in the ferry sector. This need not be a costly exercise, as shown for some measures (e.g. speed reduction, other operational measures and maintenance strategies) there could be significant savings in monetary terms for ferry passengers as well as overall GHG emissions from the sector. For measures that require significant capital outlay (e.g. alternative fuels) alternative and newly emerging forms of financing, such as green bonds, should be considered. This work has used secondary data sources to try and unpack the issues and barriers to energy efficiency and decarbonisation of the Scottish ferries sector. However, further work could collect data using participatory approaches such as interviews and focus groups with the industry stakeholders to better understand and provide solutions and recommendations to improve the energy efficiency and emissions of the ferry sector in order to meet Scotland's challenging climate targets.

Author details
Nishatabbas Rehmatulla
UCL Energy Institute,
Central House,
14 Upper Woburn Place,
WC1H 0NN.

Appendix

Energy efficiency and low carbon solutions for ferries

Design based technologies	Hydrodynamic technologies
Aft waterline extension Skeg shape/trailing edge optimisation Optimisation of hull openings Shaft line arrangement Bulbous bow Lightweight construction Air lubrication Design speed reduction - smaller engine Design speed reduction - engine derating Superstructure aerodynamics	Propeller modifications (advanced blade sections, winglets/Kappel,prop section optimisation) Propeller/rudder integration (propeller rudder bulb, propeller rudder matching/combination, asymmetric rudder) Pre/postswirl devices (boss cap fin, vane wheel, presswork ducts, mews duct, stator fins) Pods/thrusters (wing thrusters, pulling thrusters, wing pod, pulling pod) Contra-rotating propellers Other hull streamlining (low profile openings, optimisation of water flow openings)
Machinery technologies	Alternative energy sources and energy carriers
Common rail Diesel electric drive Combined Diesel/electric & Diesel mechanical drive (CODED) Hybrid shaft generator Engine tuning Low loss power distribution Variable speed electric power generation Power take off/shaft generator Speed control of pumps and fans Waste heat recovery Energy saving lighting Efficient boiler	Solar power Wind power – kites, sails and Flettner rotors Batteries and fuel cells Biofuels Liquid Natural Gas (LNG) Cold ironing/shore power Hyrdogen Ammonia Methanol
Maintenance strategies	Operational measures
Propeller condition based maintenance Regular/interval based propeller maintenance Advanced propeller coating and paints Hull cleaning Hull surface coating - biocidal Hull surface coating - foul release	Weather routing Autopilot upgrade/adjustments General speed reduction Advanced fuel consumption monitoring Trim/draft optimisation Speed reduction due to port efficiency – Just in Time arrival Raising crew awareness & energy efficiency training Efficient voyage execution -Voyage planning & DWT utilisation Optimisation of ballast voyages

References

Adland, R, Alger, H, Banyte, J & Jia, H 2017, 'Does fuel efficiency pay? Empirical evidence from the drybulk timecharter market revisited', *Transportation Research Part A: Policy and Practice*, vol 95, pp. 1-12.

Agnolucci, P, Smith, T & Rehmatulla, N 2014, 'Energy efficiency and time charter rates: Some evidence quantifying the extent of split incentive problem in the panamax drybulk market', *Transportation Research Part A: Policy and Practice*, vol 66, pp. 173-184.

Aquatera 2016, *Low carbon ferries feasibility study*, <http://www.localenergyscotland.org/media/99677/G3068-Low-Carbon-Ferries-Feasibility-Study-Final.pdf>.

Baird, A 2012, 'Comparing the efficiency of public and private ferry services on the Pentland Firth between mainland Scotland and the Orkney Islands', *Research in Transportaion Business & Management*, vol 4, pp. 79-89.

Baird, A & Wilmsmeier, G 2011, 'Public tendering of ferry services in Europe', *European Transport*, no. 49, pp. 90-111.

Baird, A, Wilmsmeier, G & Boglev, Y 2010, *Scottish Ferries Review, Part A: Methods of ferry delivery and operation, competition and procurement, and environmental issues*, viewed 2 April 2014, <www.scotland.gov.uk/resource/doc/935/0105632.doc>.

Bråthen, S, Hervik, A, Odeck, J & Sunde, O 2004, 'Competitive tendering versus subsidy schemes in public transport services: Comparing efficiency in the provision of ferry services', *European Transport Conference*, 10th April 2004, Association for European Transport, Strasbourg.

CCC 2015, *Reducing emissions in Scotland - 2015 progress report*, <https://www.theccc.org.uk/wp-content/uploads/2015/01/Scotland-report-v6-WEB.pdf>.

Førsund, F 1993, 'Productivity growth in Norwegian ferries', in H Fried, C Knox, S Schmidt (eds.), *The measurement of productive efficiency: Techniques and applications*, Oxford University Press, New York.

Grant Thornton 2010, *Small Ferries Project - Outline Business Case*, viewed 16 April 2014, <http://www.smallferriesproject.com/study.html>.

Islands Commission 2005, *Maritime and air transport in the islands of the EU*, viewed 14 August 2014, <http://www.commissiondesiles.org/pub/docs2/58_eng_-_conclusions_seminar_on_transports_western_isles.pdf>.

Jaffe, A & Stavins, R 1994, 'The energy-efficiency gap What does it mean?', Energy Policy, vol 22, no. 10, pp. 804-810.

Minken, H & Killi, M 2001, 'Productivity growth in Norwegian ferry links 1988-1996, and implications for regulation', *Thredbo: International Conference Series on Competition and Ownership in Land Passenger Transport*, Molde.

Odeck, J & Bråthen, S 2007, 'How efficient are ferries in providing public transport services? The case of Norway', *10th International Conference on Competition and Ownership in Land Passenger Transport* , 12th - 17th August, University of Sydney, Sydney.

Pedersen, R 2015, *Scandinavian/Scottish Ferry Comparisons*, <http://www.transport.gov.scot/system/files/documents/tsc-basic-pages/Expert%20Ferry%20Group%20-%20Scandinavian%20-%20Scottish%20Ferry%20Comparisons%202015.pdf>.

Prakash, V, Smith, T, Rehmatulla, N, Mitchell, J & Adland, R 2016, *Revealed preferences for energy efficiency in the shipping markets*, viewed 07 September 2016, <http://www.lowcarbonshipping.co.uk/files/ucl_admin/Revealed_preferences_for_energy_efficiency_in_shipping_markets.pdf>.

Rehmatulla, N, Parker, S, Smith, T & Stulgis, V 2017, 'Wind technologies: Opportunities and barriers to a low carbon shipping industry', *Marine Policy*, vol 75, pp. 217–226.

Rehmatulla, N & Smith, T 2015a, 'Barriers to energy efficiency in shipping: A triangulated approach to investigate the principal agent problem in shipping', *Energy Policy*, vol 84, pp. 44-57.

Rehmatulla, N & Smith, T 2015b, 'Barriers to energy efficient and low carbon shipping', *Ocean Engineering*, vol 110, pp. 102-112.

Rehmatulla, N, Smith, T & Tibbles, L 2017, 'The relationship between EU's public procurement policies and energy efficiency of ferries in EU', *Marine Policy*, vol 75, pp. 278–289.

Scottish Government 2011, *Environmental assessment (Scotland) Act 2005 Scottish Ferry Services draft plan for consultation strategic environmental assessment: Environmental report addendum*, viewed 28 July 2014, <http://www.transportscotland.gov.uk/report/j210731-00.htm>.

Sorrell, S, Schleich, J, O'Mallye, E, Trace, F, Boede, U, Ostertag, K & Radgen, P 2000, 'Barriers to energy efficiency in public and private organization', SPRU—Science and Technology Policy Research, University of Sussex, Brighton.

Sunde, Ø 1999, *Tendering ferry services in Norway: Ratchet effects?*, viewed 04 April 2014, <http://www.thredbo-conference-series.org/downloads/thredbo6_papers/Thredbo6-theme1-Sunde.pdf>.

Transport Scotland 2016, *Expert Ferry Group meeting minutes*, <http://www.transport.gov.scot/system/files/documents/tsc-basic-pages/Expert%20Ferry%20Group%20-%206%20October%202016%20-%20Minutes%20-%20final.pdf>.

Trasnport Scotland 2015, *Vessel Replacement and Deployment Plan - Annual report 2014*, <http://www.transport.gov.scot/system/files/uploaded_content/documents/tsc_basic_pages/Water/VRDP%20Annual%20Report%202014%20-%20final%20-%202%20October%202015.pdf>.

Wang, H, Faber, J, Nelissen, D, Russel, B & St Amand, D 2010, 'Marginal abatement costs and cost-effectiveness of energy efficiency measures', Submitted to IMO MEPC, 61st Session, 23rd July 2010.