What is the likely future demand for shipping?

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Abstract

A key driver for future emissions from the sector must be the demand for shipping – both local and global. Predictions of shipping flows underpin forecasts of their likely environmental impacts, and policy debates to develop technologies and operational strategies to manage and regulate emissions. To evaluate policy strategies designed to deliver low carbon shipping requires realistic forecasts of future movements of different types of ships. This paper focuses on the socio-economic drivers, and particularly those with a Low Carbon future perspective.

This paper aims to clarify the risk attached to the realisation of future demand scenarios, rather than to create certainty. Future scenarios for energy use to 2050 help to contextualise the path to decarbonisation of marine transport, from technology creep-driven 'slow and steady' energy use reduction scenarios, to the posited 'very low carbon future' scenario. This analysis considers the impact of these scenarios on shipping, as well as the impact of the industry's reaction to emerging socio-political drivers. The paper summarises analyses of patterns of wet and dry bulk flows involving the UK, and forecast flows to 2050. Drivers of future shipping flows include economic growth, market changes, haul lengths and energy demands. Container flows, and drivers related to supply chain optimisation, port configuration and choice, technological development, ship operations, and policy and regulation are also discussed.

Recognition, and effective monetisation, of the social and environmental costs of key activities associated with shipping may serve to deliver a different future energy scenario, one where external costs are properly incorporated into the decision making. Assuming that a key driver would be the reduction of emissions to address climate change, then behavioural shifts would focus around reduction of fossil fuel-derived energy use and harmful emission capture. Any successful attempt to significantly and quickly reduce the emissions from shipping would result in a very different global fleet to today, and reduction of global trade quantities, meaning fewer journeys by fewer ships. A full version of this paper will be presented at the LCS 2013 Conference in September 2013 in London.

1. Introduction

Within the context of Low Carbon Shipping, a key driver for future emissions from the sector must be the demand for shipping – both local and global. Predictions of shipping flows underpin forecasts of their likely environmental impacts, and policy debates to develop technologies and operational strategies to manage and regulate emissions. To evaluate policy strategies designed to deliver low carbon shipping requires realistic forecasts of future movements of different types of ships. In the Low Carbon Shipping: A Systems Approach project, WP1 modelled global flows and drilling into the detail of particular flows and commodities as required; WP4 studied UK wet and dry bulk flows and links between bunker prices and spot freight rates; and WP3 concentrated on box trades, links with inland and port logistics and the detail of UK flows. An initial study collated global transport demand for different ship types (dry and wet bulk, general cargo, and containers) and examined historical relationships with GDP (Gross Domestic Product), using GDP forecasts to project out to 2050, but this approach did not define the trade flows required for more disaggregated model analysis.

This paper focuses on the socio-economic drivers, and particularly those with a Low Carbon future perspective, primarily of the wet and dry bulk trades. Other publications by the *Low Carbon Shipping* consortium address more completely other major trades, in particular containerised goods, and drivers related to supply chain optimisation, port configuration and choice, technological development, ship operations, and policy and regulation. Predictions of shipping flows underpin forecasts of their likely environmental impacts, and policy debates to develop technologies and operational strategies to manage and regulate emissions. This paper summarises analyses of patterns of wet and dry bulk flows involving the UK, and forecast flows to 2050. Drivers of future shipping flows include economic growth, market changes, haul lengths and energy demands identified in trade press articles which fashioned a Delphi instrument to build consensus regarding future market trends. This paper looks at the socio-economic, political, institutional, and market-based drivers, and particularly considers those with a Low Carbon future perspective or impact, and primarily related to the wet and dry bulk trades.

2. Data Sources & Assumptions

NEA (a transport research organisation and member of the Panteia group) data for inter-region trade flows and port volume flows was aggregated to quantify the tonnes traded by sea and tonne-km of maritime transport demand for a range of commodities (disaggregated using NSTR [EUROSTAT Standard Goods Classification for Transport] codes) for all country pairs. This data was then aggregated into regional and commodity group transport demands to generate a 2005 base year database of historical data. Using NEA's agent-based model which simulates trade and maritime transport demand over time, calibrated to the IPCC SRES A1B scenario used as representative of a central scenario in the IMO 2nd GHG study, forecasts were generated to 2050, along with data describing UK imports and exports for a range of commodities. The growth and evolution of the global fleet is determined by the evolution of global trade; figure 1 characterises the trends used by WP1 to 2050 for the three main ship type's freight (aggregations of trends for individual commodities, in billion tonne.km).

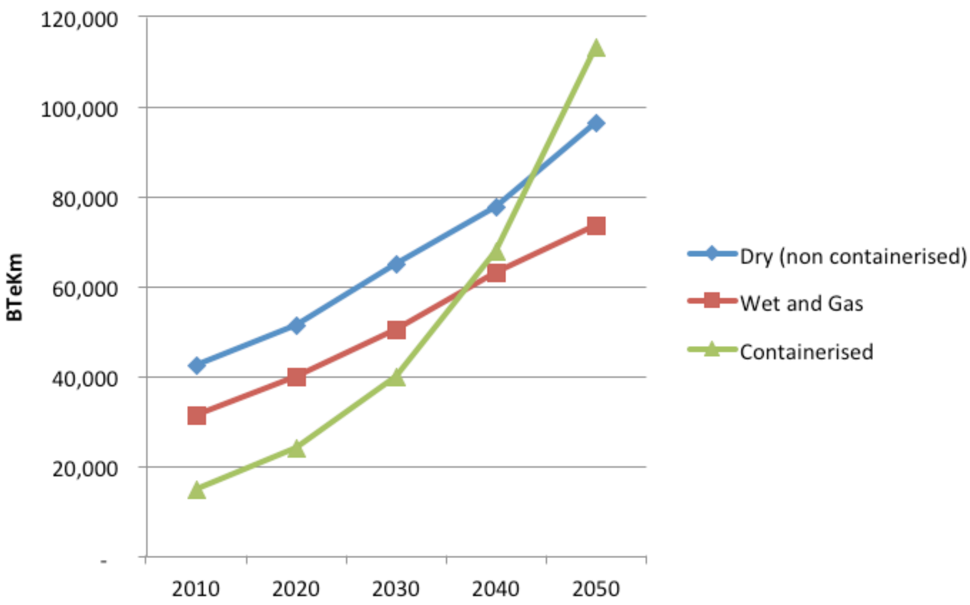

Figure 1 Projections of global transport demand in BteKm. Transport demand is based on estimated average hauls for each trade (LCS, 2013)

Current mitigation policy, for example the ambitious GHG reduction targets set out by the UK's Climate Change Act, is expected to fundamentally change the mix of commodities flowing into and out of the UK. The UK CCC undertook analysis to develop a coherent set of transport demand projections for the UK incorporating this target (CCC, 2011), which were used to calibrate UK specific trade flows in GloTraM. The scenarios deployed within the global transport demand dataset can be seen in figure 2. Its notable that even in the high demand scenario, UK demand is expected to grow at a substantially lower rate than demand growth globally, primarily due to the UK's position as a developed economy (LCS, 2013).

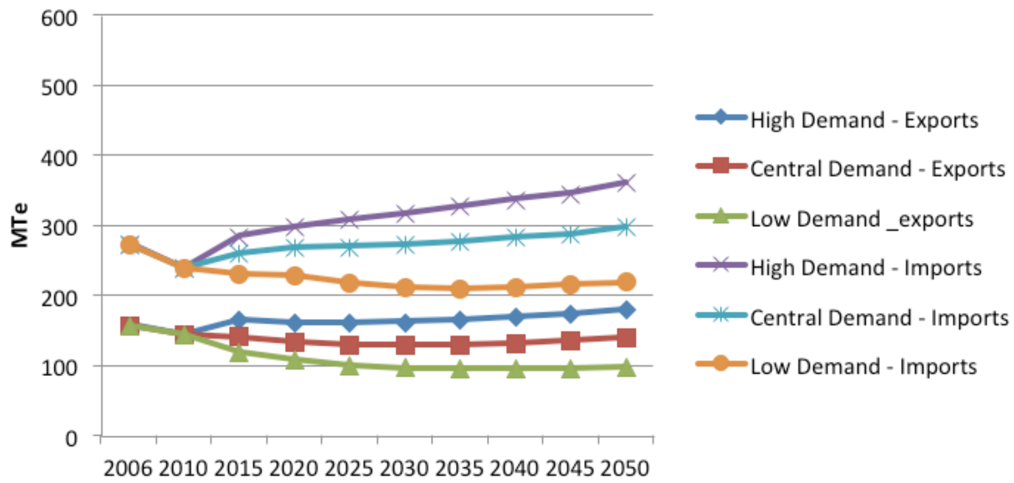

Figure 2 UK specific transport demand (source: UK CCC Review of UK shipping emissions)

Economic research in WP4 of the Low Carbon Shipping Project has concentrated on the fleets which represent the greatest total volume of emissions, wet and dry bulk (Figure 3; See IMO 2nd GHG Study: Buhaug et al, 2009 for more information). The availability and comparability of secondary maritime statistics is problematic, with global and national data emanating from both official and private sources (e.g. UNECE, UN, BP, EIA, DfT, Dukes, MDS Transmodal Ltd). Changing trade classifications may frustrate serial commodity comparisons, where for example official UK oil products flow data incorporated liquefied gas until 2000. Varying aggregated spatial units are a perennial problem complicated by volatile commodity sourcing policies and political changes which redefine trading boundaries including perhaps China and/or Hong Kong, and individual EU accessionary states. Northern Ireland is the principal exclusion when comparing data collations for Great Britain with the UK. Further, port commodity arrivals data which does not identify transhipment flows or an ultimate source or destination, hampers maritime flow reporting and denies end-to-end supply chain mapping.

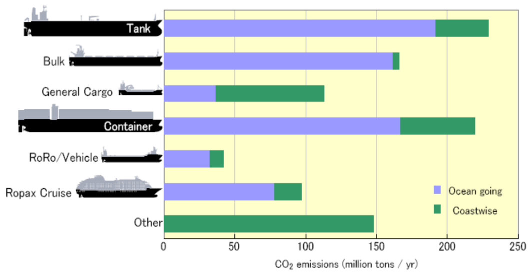

Figure 3 Annual total fleet emissions by ship type (Buhaug et al, 2009)

Published UK maritime commodity flow data is limited and secondary statistics are often incomparable (Glen and Marlow, 2009). Subject to inevitable measurement errors (Dinwoodie and Bhatia, 2004), global flow data emanate from official (e.g. EC, 2008) and private sources including BP's Statistical Review and Energy Outlook (www.bp.com), Exxon Mobil's Outlook for Energy (www.exxonmobil.com) and Shell's Energy Scenarios (www.shell.com), as do national data (e.g. EIA, 2011; DfT, 2009; Dukes, 2009; MDS Transmodal Limited, 2007). In addition aggregate trade flow data is available but changing classifications may frustrate serial commodity comparisons, where for example official UK oil products flow data incorporated liquefied gas until 2000 (DfT, 2009). Aggregations of spatial units vary, commodity sourcing policies are volatile and political changes redefine trading boundaries perhaps as new states accede to the EUs. Data collated for Great Britain (GB; MDS Transmodal Limited, 2007) differs from the UK (e.g. DECC, 2009) principally excluding Northern Ireland which receives one-fifth of UK arriving tanker dwt (Dft, 2009, table 3.6). Port commodity arrivals data which typically fails to identify transhipment flows or an ultimate source or destination further hampers flow reporting and thwarts end-to-end supply chains mapping.

Demand for tankers originating in, destined for, or visiting UK ports varies with the UK supply and demand for crude oil and products. UK crude oil imports peaked in 1973, before declining as North

Sea production transformed the UK into a net exporter. By 2010, the UK was again a net importer. Eventually UK flows to Europe will decline as North Sea production diminishes. As UK refineries age, UK crude imports will reduce and as new long range products tankers transport supplies from modern refineries in producing countries, UK products imports, LNG and biofuels will rise. The distribution of ports which handle major oil products reveals outflows dependant on the location of refining capacity. Reducing numbers of smaller regional distribution centres exist as policy changes to tax oil ex-refinery rather than ex-distribution centre coupled with scale economies which favour larger coastal tanker fleets closed many smaller port facilities and increased mean road haul lengths.

The historical trend in transport demand in the shipping industry shows that for globally aggregated commodity flows, there is a high level of correlation between GDP and transport demand. There are a number of problems associated with extrapolation of these historical trends (LCS, 2013), in particular where correlation with GDP forecasts is used (e.g. those available for IPCC scenarios, SRES) which can lead to dramatic growth rates. Buhaug et al. (2009) attempted to apply wider mitigation scenarios to estimate the transport demand in 2050, as a function of different SRES scenarios (see table 1; the values are indexed to the 2007 transport demand=100). The range of values shows an expectation that total maritime transport demand will increase by between a factor of 3 and 5.4 over the next 40 years.

Table 1 Transport demand in 2050

SRES scenario	A1B	A2	B1	B2
Ocean-going shipping	320	240	220	180
Coastwise shipping	320	270	220	220
Container	1230	960	850	690
Average (all ships)	540	421	372	302

The modeling undertaken by LCS WP1 deployed transport demand scenarios consistent with A1B, whereas the specific routes and scenarios discussed here looked at alternative perspectives and scenarios, particularly evolutions of the UK's transport demand.

3. Energy Scenarios

Predictions under a "business as usual" scenario predict the growth of shipping's share of global anthropogenic CO_2 emissions from the current 2.7% to between 12-18% by 2050, meaning shipping emissions will become much more visible, and are likely to present a significant political target, even if little action has been taken or required previously. The impact of global energy scenarios on the future demand for shipping is a key consideration, and will be presented in greater depth at LCS 2013 in London. The global trade effects associated with the different forecasts can significantly impact upon the supply and demand drivers for shipping. A large percentage of wet and dry bulk cargoes are to meet energy demand, and shipping's energy input is currently met almost exclusively by fossil fuel sources.

Three potential energy demand scenarios have been considered; the first two can be characterised as 'do nothing' and 'slow & steady', they encompass those considered by oil majors, such as in BP's Statistical Review and Energy Outlook 2030 (www.bp.com), Exxon Mobil's 2012: The Outlook for Energy 2040 (www.exxonmobil.com) and Shell's Energy Scenarios to 2050 (www.shell.com), and also the 'very low carbon future' scenario as put forward by the Tyndall Centre as the minimum required to meet 2050 global warming targets set out in the Kyoto agreement (Saltmarsh, 2010). The energy scenarios examined by these 3 major oil producers address the question of where can we go from today, how far and how fast? Shell's Energy Scenarios to 2050 are categorised as falling under one of two extremes, *Blueprint* and *Scramble*. In the 1990's Shell's global energy scenarios encompassed the idea of there being no alternative – dilemmas underpinning development, trust and industrialisation must be considered and we must reconcile ourselves to an approach. This has developed into an offshoot idea *there are no ideal answers*. Neither the blueprint nor scramble scenario for the development of the global energy system over the next 50 years is perfect, but both are feasible, and they do aid the identification of shifts in the ways of working with and thinking about energy. They help us to consider plausible interactions between different perspectives and possibilities. The focus of work by the Tyndall Centre for Climate Change Research (Bows & Gilbert, 2012) however, considers where we need to get to, and therefore how that could be achieved, and what actions are therefore necessary. UNCTAD's (2009) Expert Meeting on Maritime Transport and the Climate Change Challenge highlighted that timeframe was a real concern:

> "Current trends in terms of energy consumption and carbon path suggested that if no action were taken within the following two years … the world would forever miss the opportunity to stabilise emissions at "manageable" levels [and] a global and concerted solution was urgently required. … [N]egotiations towards regulation of CO2 emissions from international shipping should be pursued with all due speed."

The difference in approach is striking: one says "this is where we are and what we know, what level of change is acceptable to industry, and particularly to society as a whole?" Against this is the Tyndall Centre Approach, typified by projects such as that described in Anderson et al (2006): *Decarbonising Modern Societies: Integrated Scenarios, Process and Workshops*, and *Behavioural Response and Lifestyle Change in Moving to Low Carbon Transport Futures* (Pridmore et al, 2003). Indicative longer term forecast techniques span statistical time series and growth models, scenarios, and Delphi methods. Twenty-year quantitative meta-models typically highlight baseline, high growth and low growth scenarios, perhaps with a range of oil price assumptions, focused on interdependencies between exogenous input and resulting output, expressed primarily as elasticities. To construct alternative plausible futures, scenarios may draw on objective, quantitative forecasts or qualitative behavioural foresight amongst experts. The available energy scenarios and outlooks and their potential impact on shipping demand can be summarised as:

- All scenarios predict global oil demand peaks with varying timing;
- e.g. Shell's *Scramble* scenario: climate shocks necessitate oil substitution post-2020;
- ExxonMobil's forecast of no oil demand decline pre-2040, as GDP growth in developing countries exceeds 240% of European rates;
- Longer term forecasts predict reducing European GDP growth and energy consumption and EU demand for freight transport decoupling from GDP growth as economies dematerialise;
- European oil production will decline;
- Given that shipping costs comprise small proportions of crude oil import values, worldwide demand for maritime transportation of oil and freight rates have been relatively inelastic to bunker price changes.

4. Demand Drivers

Shipping activity is a derived demand, it exists in order to service the flow of goods, commodities and passengers from their origin to their destination. The drivers of this demand, and therefore shipping, are a combination of the location of natural resources, centres of population, their relative size and needs, relative wage rates in different economies, and the costs of transport. Shipping's historically low transport costs, enabled by available economies of scale and logistic efficiency, have in turn been enablers of the globalised society in which we live. Rigorous determination of the future evolution of each and every driver and its interactions with trade patterns was beyond the scope of the study, and so trade data and projections from a number of different sources were used to build detailed GloTraM datasets both for current and future trade flows (LCS, 2013). The primary drivers of demand for shipping overall can be defined as:

- Economic Growth
- Market Changes
- Haul Lengths
- Energy Demands
- Requirement to meet CO_2 emissions targets
- *Market volatility*
- *Legislative uncertainty*
- *Behavioural change*

The discrete dry and wet bulk flows described here are the result of detailed studies undertaken by LCS WP4.

4.1 Wet Bulk

Discussion of the results of a Delphi survey to predict likely trends in oil tanker flows to 2050 highlights volatility, and legislative and behavioural uncertainties, which is used to explain the conservative predictions of the experts, and conversely supports the use of holistic systems research when addressing the problem (Dinwoodie et al, 2012). Table 1 shows selected drivers identified which may underpin future demand for shipping wet bulk.

Table 2 Selected drivers which may underpin future demand for shipping wet bulk

Socio-economic effects	
SE1	How responsive is worldwide demand for maritime transportation to shipping cost changes?

SE2	How significant are transport costs per unit weight for imports into different regions?
SE3	Spatially differential rates of population growth will proportionately redistribute oil demand.
SE4	Spatially differential rates of industrial output growth will proportionately redistribute oil demand.
SE5	Reducing oil or energy intensities (oil or energy used per unit output) in industrial nations will persist
Ships and shipping markets	
S1	Will tankers be re-deployed as water carriers as drought risks increase with global warming?
S2	Will world oil tanker tonnage continue to remain constant whilst dry bulk tonnage trebles?
S3	Will large tankers be used for carbon storage and smaller ones transport liquid CO_2 to storage sites?
S4	Will regionalisation of oil supplies shorten supply chains and reduce demand for shipping? Will pipelines from Russia oilfields supply NE Asia and Canadian tar sands/ Brazilian oilfields the US?
S5	Will technical optimisation of ships reduce CO_2 emissions by 20% with scope for retrofitting?
Political and institutional changes	
P1	Will damage to BP's reputation and exposure to unlimited liability post *Deepwater Horizon* oil spills deter offshore exploitation in the US and stimulate re-sourcing of supplies?
P2	Will new trading relationships in the Russian Arctic reconfigure oil supply chains?
P3	Will droughts induced by global warming create more failed states causing piracy to proliferate; sub-optimal ship routing to avoid trouble spots; longer maritime hauls, and tie up more tonnage?
P4	Will scope to cut EU GHG emissions by up to 90% by 2050 create pressure to reduce emissions?

Oil tanker movements vary with the supply and demand for crude oil and oil products, dependent on demand for transport, traditionally related to GDP. All scenarios predict global oil demand peaks with timing varying from Shell's *Scramble* scenario in which climate shocks necessitate oil substitution post-2020 to ExxonMobil's forecast (op. cit.) of no oil demand decline pre-2040, as GDP growth in developing countries exceeds 240% of European rates. Longer term forecasts predict reducing European GDP growth and energy consumption and EU demand for freight transport decoupling from GDP growth as economies dematerialise. European oil production will decline (EC, 2008; EIA, 2011). Given that shipping costs comprise small proportions of crude oil import values, worldwide demand for maritime transportation of oil and freight rates have been relatively inelastic to bunker price changes (UNCTAD, 2010).

Perceptions of how particular developments will affect total demand are crucial. As global warming heightens drought risks, will more tankers be deployed as water carriers (Hammer, 2009)? Similarly, how will shorter sea routes arising from Arctic ice-melt (Ho, 2011), or an enlarged Panama Canal (Stott and Wright, 2012) impact tanker tkm? How will new Energy Efficiency Design Index (EEDI; IMO, 2012; MEPC.1/Circ.681) ship design regulations to encourage improvements in new ship fuel consumption affect demand or rising demand for new fuels including LNG and nuclear power? How will pipeline investments impact oil import mode splits as more pipelines link supply routes (Hammer, 2009)? Regulation of the type of fuel that ships may consume in particular areas and undefined future ECA designations may promulgate ship re-routing to avoid them (IMO, 2012). To reduce carbon emissions, an Energy Efficiency Operational Index for ships in operation or Ship Energy Efficiency Management Plan imply shorter hauls to reduce tkm (IMO, 2012). However, multi-sourcing strategies to ensure secure energy supplies may impact haul lengths (Dinwoodie et al, 2012).

Oil products tanker movements involving the UK depend on demand for various oil products, the capacity and location of refineries, export demand and the availability of other modes such as pipeline networks. In 2010, UK consumption of oil products comprised mainly transport fuel including petroleum and increasingly diesel by road users, dependent on car ownership levels and use; kerosene for air travel; and some heating kerosene (Dukes, 2011). Dinwoodie et al (2012) analysed patterns of oil tanker flows involving the UK to forecast flows to 2050 for this ship type. Largely because of the sheer size of the fleet, wet bulk carriers (primarily oil tankers) generate the highest volumes of carbon dioxide emissions (Buhaug et al., 2009). The demand for shipping crude oil and oil products derives from macro-economic demands for shipping which fluctuate with global economic activity and the dynamic role of shipping in moving raw materials, semi-processed or finished products in fluctuating supply chains (Stopford, 2009). Further, because measures of shipping demand combine tonnage lifted (t) and distance hauled (km), changes in both affect demand in tonne-kilometres (tkm) creating equifinalities. Tanker flows remain concentrated but increasing ship sizes have necessitated more offshore terminal developments of loading and discharging facilities. In the North Sea, offshore oil production has generated offshore transfers from production vessels or an undersea oil production facility. Near urban areas atmospheric emissions may influence decisions to establish Emissions Control Areas (ECA; IMO, 2012).

Dinwoodie et al (2012) identified diverse stakeholders spanning the supply chain. International Shipping is a complex, holistic interconnected system, requiring a range of stakeholder inputs. Panellists' predicted increased total global demand (tkm) solely due to increased demand for water carriers, an enlarged Panama Canal and rising demand for LNG. Demand would reduce due to EEDI regulations, nuclear power and shorter Arctic sea-routes, implying 4% net growth from the drivers listed. They also expected oil pipelines to reduce the proportion of US, European and Chinese oil imports moved in ships. Taken individually, no single driver would radically impact voyage lengths globally, but cumulatively their impacts mount. By 2050, predicted shortening of tanker haul lengths to counter rising bunker costs, ocean routing, multi-sourcing to ensure secure energy supplies and ECA-avoidance impacts imply cumulative reductions of 22%.

4.1.2 Impact on wet bulk flows

Overall, expected global tanker demand to 2050 will rise only modestly despite increasing demands to ship more water, avoid pirates and ECAs, and satiate rapidly developing economies. Perceptions of modest global change coupled with reducing energy intensity of UK industrial output imply a rapidly diminishing UK tanker market share. Perceptions of accelerating global preferences for pipelines over maritime flows and increasing demand for nuclear power, combined with reducing tolerance of fossil fuels in UK energy production may signify that as an advanced industrial nation, the UK will lead on systemic post-oil dependence behavioural shifts. However, based on this evidence, Kuznets curve concepts remain speculative stated intentions. Longer term, tanker movements in UK waters may vary with unknowns such as ice-strengthened hull availability, the incidence and political fall-out of oil spills incidents in Arctic waters, and the accessibility and cost of pipelines from Russia and MEG (Dinwoodie et al, 2012).

4.1.3 Wet bulk global demand drivers

It is predicted that we will see increased total global demand up to 2050 (measured in tkm) solely due to:

- increased demand for water carriers
- an enlarged Panama Canal
- rising demand for LNG

Key drivers which are predicted to reduce likely demand in the wet bulk fleet are:

- EEDI regulations
- nuclear power
- shorter Arctic sea-routes

Overall, the fleet is predicted to display a net 4% global increase from the balance of these drivers.

4.1.4 Wet bulk voyage length drivers

Overall, it is predicted that the impact of drivers for voyage length will be cumulatively significant; results (Dinwoodie et al, 2012) suggest that we will see a 22% reduction in overall voyage length within the global wet bulk fleet. The headline impact categories contributing to this will be:

- Oil pipelines will reduce the proportion US, European and Chinese oil imports moved in ships;
- Arctic ice melt will shorten NE Asia-W Europe hauls – e.g. the Canadian NW Passage and Russian NE passage;
- Shortening of tanker haul lengths will be seen to counter rising bunker costs;
- There will also be impacts associated with ocean routing, multi-sourcing to ensure secure energy supplies, and ECA-avoidance.

4.2 Dry Bulk Flows

Some of the uncertainties in predicting flows of coal, the current main UK dry bulk flow (and second globally) include assessing the likelihood and possible effects of changes in:

1. Regulation – EEDI, EEO1 and market based measures.
2. Supply chain resourcing?

3. Piracy including costs of sub-optimal re-routing and re-sourcing supplies using less vulnerable routes?
4. Shipping networks such as opening of a NE passage due to climate change?
5. Technological efficiency such as reduced transport intensity?
6. Technical relationships in advanced economies such as dematerialisation or Kuznets curves (exponential reduction in acceptance of major pollutants)?
7. Industrial structure including new ones (carbon capture and transfers, biofuels) or decline of e.g. coal?

All these unknown factors will act together to shape future demand for shipping. A key challenge is to establish what constitutes 'foreseeable' future transport demand scenarios ranging from 'Business As Usual', through varying degrees of mitigation, to assess the implications on the emissions of the shipping industry. Dinwoodie et al (2012) presents an independent prediction of maritime dry bulk movements to 2050 based on a Delphi survey, finding that even though the tonnage of goods moved is expected to grow substantially, this is partially offset by expectations of shorter hauls. Realistic forecasts of future ship movements for different types of ships underpin policy formulation and evaluation in maritime logistics, including strategies to deliver low carbon shipping.

Chowdhury and Dinwoodie (2011) assesses the effect of bunker fuel prices on spot dry bulk freight rates, principally coal, and how a carbon tax on bunker fuels could affect spot freight rates for these dry bulk markets. They take a top down approach, probing some of the assumptions regarding market structure and competition on routes. In 2010, the transportation of dry bulk cargo comprised more than one-third of all international seaborne trade (approximately 3.3 billion tonnes). Iron ore is the largest dry bulk trade by volume, and coal is second with imports of 904 million ton in 2010. As a major input to the shipbuilding process, supply of coking coal to produce steel has the potential to affect shipping markets as both a supply and demand driver. Since 2005 China and India have capitalised on the sharp increase in oil and gas prices to build new power plants that utilise coal, resulting in significant growth in the steam coal trade. In the global market for steam coal, China is a major importer and Australia is the largest exporter (Chowdhury & Dinwoodie, 2011). Australia, South America, southern Africa and Eurasia are expected to expand their international coal trade by 2030. Coal will continue to play a key role in the world's energy mix, with demand in certain regions set to grow rapidly. Growth in both the steam and coking coal markets will be strongest in developing Asian countries, where the demand for electricity and the need for steel in construction, car production, and demand for household appliances will increase as income rises. The estimates of UK coal production for the period 2005-2030 show that production will fall from about 22 million tonnes in 2005 to over 2 million tonnes in 2030. Therefore coal fired power stations will have to depend on imported coal (Chowdhury & Dinwoodie, 2011).

Table 3 Steam Coal Requirement in the UK up to 2030

	2010	**2015**	**2020**	**2025**	**2030**
Steam Coal required (tonnes)	45.8	29.8	27.4	27.4	27.4
UK coal production	21.2	14.3	6.9	2.2	2.2
Import requirement for power generation	24.7	15.5	20.5	25.2	25.2

Source: Adapted from MDS Transmodal (2007)

Predictions of global shipping movements to 2050 underpin forecasts of their likely environmental impacts, and hence policy debates to develop technologies and operational strategies to manage and regulate emissions. However, Stopford (2009) spurns long-term forecasts noting that prediction should aim to clarify risk rather than create certainty. Predicted likely trends in dry bulk shipping movements (DBSM; Dinwoodie et al, 2012), the second greatest GHG-emitting ship-type (by trade volume; Buhaug et al, 2009) to 2050 are presented here. These are based on secondary data sources including UK government, supranational and private statistical sources which were deployed to identify baseline dry bulk movements in 2010.

Based on drivers of future shipping movements such as Arctic ice melt, an upgraded Suez canal, piracy, resourcing and changed mode splits identified in trade press articles and academic opinions, an instrument was devised to test for consensus regarding future market trends. A Delphi panel comprised of 51 experts with long term industrial commitments was recruited and their agreement with various quantitative statements was canvassed. Mean estimates were fed back in a second round of questioning along with an opportunity to revise initial opinions. Coal is the second largest global dry bulk trade, and the major one for the UK. Reserves are estimated to last for 122 years, is easy to store with low obsolescence, but high inventory costs (WCI 2005). The development of technologies for 'clean' power stations has improved the potential performance of coal as a fuel from a climate change perspective, but it remains some way from the level of emissions required if we are to meet Kyoto Agreement levels for reduction in CO_2 emissions by 2050. Growth in the use of biofuels, renewable and even nuclear energy, and dematerialisation of western economies will temper significant growth in maritime tonne kilometres.

Issues which do not on the surface appear to have much impact upon the decarbonisation of global shipping, such as tackling piracy, could also achieve significant reductions, through the reduction of distance hauled. Detailed modelling of shipping emissions and the effectiveness of potential regulatory and operating procedures to mitigate them are predicated by realistic estimates of the future demand for shipping. Estimates revealed expert perceptions that bunker price changes impact DB spot freight rates substantially. The considered mean short run spot freight rate elasticity for coking coal in relation to bunker fuel prices was 0.95 with long run estimates of 0.92. Similarly the estimated short run spot freight rate elasticities for steam coal in relation to bunker fuel prices rise was 0.534.

Policy issues consequent on predictions of substantial growth in DB tonnes lifted to 2050 partially offset by expectations of shorter hauls include fleet expansion and scope for design upgrades via EEDI to ensure a stock of low carbon DB carriers. Drivers such as growth in biofuel use and localised production, and dematerialisation of the UK economy will temper growth in maritime tkm in developed economies and consequent carbon emissions, and measures to tackle piracy proffer significant reductions. If global DBSM demand slows, carbon emissions also grow less rapidly, but global demand will increase, even for coal, to satiate raw materials demand in rapidly developing economies. Despite increasing dematerialisation of more economies, research into reducing energy intensities and raising the technical efficiency of production to minimise raw materials input is urgent. Although freight rates are estimated to respond elastically to bunker price changes, this analysis ignores cost pass-through considerations where substantial rises in delivered unit prices may drive a search for alternative fuels to thermal coal, or non-metal material substitutes to steel for car making. Further, in this analysis, EEDI regulations alone were expected to reduce total global tkm slightly, although coal hauls will shorten slightly due to localised and multi-sourcing. New Arctic passages caused by ice-melt will shorten N.E. Asia-W. Europe hauls, and even if increased piracy lengthens hauls in the Indian Ocean, this impacts a reducing proportion of hauls. International agreements to manage Arctic developments sustainably and tackle piracy could reduce shipping's carbon emissions. For UK hauls, slight reductions in haul length due to rising bunker costs, offset by increased re-routing to avoid ECAs and piracy imply a dwindling source of quick win-win carbon reduction operational strategies. Major changes would stem from growth in biofuel demand, increasing self-sufficiency in biofuels, intolerance of fossil fuels, carbon capture and dematerialisation of the UK economy.

5. A Sustainable Shipping Industry

In a very low carbon future scenario, where realisation of global climate change has engendered a socio-political shift to abatement and mitigation at all costs; market forces will ensure the maximum practical abatement of GHG emissions globally, including shipping. Effectively CO2 abatement will have become monetised and a part of the everyday business decisions of organisations and governments worldwide. Further to this, recognition of other drivers such as resource demand, human health impacts and population pressure, exacerbated by climate change impacts (sea level, global warming, food scarcity, exponential population growth), will mean greater public and political perception of wider environmental impacts.

Sustainable approaches are becoming the norm throughout industry, and shipping can be no exception. The concept of a sustainable industry or economy is an interesting one; oil is the major energy source powering the global economy and supplying 95% of the total energy fuelling world transport. Maritime transport relies heavily on oil for propulsion, and is not yet in a position to adopt effective energy substitutes, however, fossil fuel reserves are finite. The implications of rising and volatile oil prices for transport costs and trade will be very important, especially for developing countries (Landamore, 2011). If the shipping industry is to effectively and sustainably reduce its environmental impact, a model for assessing that impact against a cost base will be required. *Low Carbon Shipping – A Systems Approach* aims to develop a holistic systems model for world shipping capable of identifying pathways for the reduction of (primarily) carbon emissions from global shipping, through the design, powering, operation, routing, regulation and financing of the global shipping industry. Development of the economic imperative available via holistic measurement of the 'triple bottom line' of economic, environmental and social impact can signpost the way in which global shipping can contribute to a lower carbon future for all. The sustainability agenda has been applied to many areas of economic activity for a decade or so but it is only relatively recently that the scope for applying sustainability models has been applied to shipping. Landamore & Campbell (2010) approached the issue of sustainability using a 'full-cost' lens to analyse the scope for sustainability assessment of shipping operations using an existing model (the 'SAM' – Sustainability Assessment Model; Davies, 2009) that has been conceptually employed in other contexts, including petrochemicals and construction.

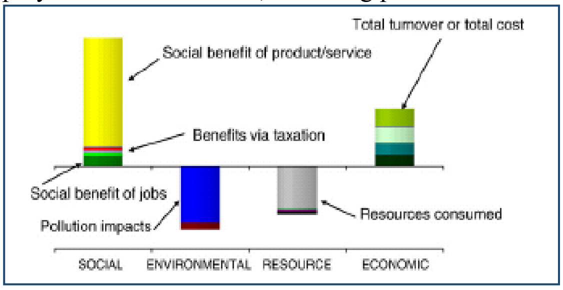

Figure 4: The SAM signature. Source: Bebbington et al, 2006:229

Companies are being encouraged, and will increasingly be forced, to take 'cradle-to-grave' responsibility for their products, which of course includes shipping. These pressures have seen an increasing move towards 'life cycle thinking'. Following the work of the likes of Bows & Gilbert (2012) and Corbett et al (2007) we can assume that a business as usual approach will not work, and that a future scenario for energy use and emissions must follow one of the other routes, designed to deliver meaningful reductions in global emissions, and at a rate sufficient to prevent global warming above 2% by 2050. In this context, a sustainable shipping industry must be one that can adapt to operate within the new global paradigm, and balance its economic, environmental and social responsibilities to ensure survival. The impact this will have on future demand for shipping will be presented in a future publication by the authors. It is important to remember that this approach is not prescriptive: we do not yet know what a 'full cost' price would look like, but we do acknowledge that economies must move towards generating an *increasingly full cost*. Achieving even a reasonably sustainable position will require 'the most profound, fundamental and visionary change' (Bebbington et al, 2001).

Low Carbon Shipping – A Systems Approach focused primarily on emissions during operation, and the work undertaken in WP4 underlined the near market validity of this approach. However, supply drivers, and responses, associated with a very low carbon future scenario, such as non-fossil fuel powered ships, reduced use of steel and reduced speed, as well as accelerated scrapping of inefficient ships, however, will likely demand a more holistic approach to emissions assessment (Landamore, 2013) as the impact from other phases and inputs become significant, for example, Landamore (2013) calculated that for every 10% reduction in speed (near 2011 service speed), the impact share of the ship's whole life emissions from all phases other than operation increased by 2-3%, extremely slow ships will see increases greater than this still. When looking beyond the immediate future, it is important that an assessment of overall impact is included, to identify the true cost to society, industry and the environment.

6. Conclusion

We expect a likely spatial momentum of future CO_2 emissions arising from bulk movements involving the UK which reflects geographically inert configurations of deep-water ports but volatile domestic production and use of oil, coal, steel and other materials. As more sustainable products such as biomass are imported ahead of local production for energy consumption, cargoes may change radically, but tonnages handled will only reduce as energy or transport intensities reduce significantly. Forty-year projections are necessarily speculative and market volatility implies unknown but potentially substantial variations in the magnitude of both movements and emissions. Other movements are spread nationwide, engaging many small ports and often small ships with high CO_2 emissions per unit handled. Because of this complexity, maritime flow forecasts are interlinked with macro-economic decisions, developments in marine technology, logistical and supply chain sourcing, mode choice and routing decisions, micro and macroeconomic developments, regulatory changes and operational strategies which all affect the reduction of shipping's CO_2 emissions. Because long term maritime flow forecasts for one sector are inevitably interdependent on complex operating and regulatory decisions taken across and beyond the shipping sector, complex scenario dependent testing of various combinations of technologies and operational strategies is needed to guide future work.

Implicit within, and underwriting, the European Commission's call for FCA are two assumptions: that current prices do not reflect the 'ecological truth', that is they do not reflect the true cost to society or the planet of the product, process or service; and secondly that if the market price of a product, for example, were to reflect accurately the environmental cost of that product, then market forces would encourage consumers to switch to 'more ethical' choices through financial incentives (Bebbington et al, 2001). Recognition of the social and environmental costs of key activities associated with the international shipping industry will serve to deliver a different future energy scenario, one where external costs are properly incorporated into the decision making. Assuming that, as expected, a key driver would be the reduction of emissions to address climate change, then behavioural shifts would focus around actions which massively reduce the need for energy from fossil fuels, and where use is unavoidable in the short term, monetisation of negative impacts would encourage efforts to maximise efficient use and to capture harmful emissions where they can't be avoided. It is likely that any successful attempt to significantly and quickly reduce the emissions from shipping, in line with those required by the most stringent future scenarios (Bows & Gilbert, 2012) to 2050 would result in a significantly different global fleet to that which we see today, and furthermore, the quantity of goods being shipped globally would also have to reduce, resulting in fewer journeys by fewer ships. One consequence of rising bunker fuel prices (and by extension, a likely initial reaction to the introduction of Carbon price fuel levies) is slow steaming. Whilst still delineated by ship type (primarily design speed and cargo value dependent), operators of wet and dry bulk carriers are increasingly turning to reduction in operating speed to save on operating costs (Claudepierre et al, 2012).

Chowdhury & Dinwoodie (2011) demonstrated how a simplified method of internalising environmental cost, applying a 'carbon' levy to bunker fuel prices might impact the freight rate for a major energy dry bulk flow into the UK, coal. The results show that post 2005 estimates are more elastic and significant compared to the estimates before 2005, which are statistically insignificant. Post 2005 estimates range from 0.51 to 1.38 and are significant. Elasticity is lower the longer is the distance and is higher for coking coal, Capesize vessels (big ships) and the Pacific market than steam coal, Panamax vessels (smaller than Capesize) and Atlantic market respectively. The post 2005 estimates are similar whether the 180 CSt bunker price or the 380 CSt is used as an independent variable. The estimates are compared with the import of coal from Australia to India. The Indian study found that a 10% increase in bunker price would lead to a 15.4% increase in freight rate for coal, while Chowdhury & Dinwoodie (2011) find that a 10 per cent increase in bunker price would increase freight rate by 5.1% to 13.8%. The higher this elasticity really is, the more effective raising bunker price as a market based measure to reduce emissions from shipping will prove to be. Chowdhury & Dinwoodie (2011) did not take into account the cost pass through ratio between the producers and the consumers, or the substitutability between different alternatives. However, the study establishes that post 2004 estimates (when the world trade/economy has significantly changed, with China as a major player) are elastic and significant.

Necessarily speculative forty-year projections combine with volatile markets to amplify uncertainty. Because of this complexity, future research might usefully attempt to frame maritime flow forecasts within a holistic systems framework which encourages complex scenario dependent testing of combinations of vessel technologies, operational strategies and regulatory decisions taken across and beyond the shipping sector (Dinwoodie et al, 2012). A significant paradox in the assessment of major shipping flows, particularly in the bulk trades, in a project focussing on reducing Carbon Emissions is the fact that the cargoes themselves are significant polluters. Any full cost approach cannot ignore the impact of the cargo onboard when assessing impact, much as any assessment of the ability of the global community to meet its commitments to decarbonisation by 2050 could no more ignore emissions from energy production, as it could those from transport, whether of people, finished goods, or raw products.

> "Just over three quarters of the UK's current primary energy demand is met by oil and gas. In 2020, it is estimated that 70% of primary energy consumed in the UK will still come from oil and gas" (Oil & Gas UK, 2010)

Having said this, the focus of *Low Carbon Shipping: A Systems Approach* is to consider the emissions from global shipping itself, and particularly operational emissions as well as those pertaining to flows to and from the UK. Oil and coal are major UK sea-borne imports, and as such are likely to play a significant part in the future makeup of UK-bound global shipping trade for some time, except in the case of a major paradigm shift towards governmental (i.e. policy-driven) impetus to reach a very low carbon future scenario, such as that referred to by the Tyndall Centre for Climate Change Research (Bows & Gilbert, 2012) as the minimum necessary to meet obligations under the Kyoto agreement.

This paper considers the drivers for demand in International Shipping primarily associated with the major wet and dry bulk energy products: crude oil and coal. Hence future global energy scenarios are key to predicting what future demand for shipping may look like in this context. The ship design and equipment developments which are the focus of the *Low Carbon Shipping: A Systems Approach* project were selected primarily for their potential to reduce the carbon dioxide emissions from ships during operation, and as such, most of the developments address the efficiency of the drive train, or of the ship itself moving through the water. The potential to meet emissions targets afforded by combinations of these will be key to improving emissions from shipping in a 'slow and steady' energy use reduction scenario, but alone will fail to achieve the required impact for a very low carbon future scenario. The demands associated with extreme scenarios including reactionary sudden ('shock' scenario) immediate and significant reductions in global emissions from all sources paint a significantly different picture for the future technological development of shipping, and shipping's role within the global economy. A key finding is that there is a large disconnect between the conservative perceptions of maritime specialists and the industrial implications of low emissions policies. This implies a need for extensive education and targeted dissemination of the implications of low emissions policies amongst maritime professionals, specifically in the wet bulk trades, but likely throughout maritime transport (Dinwoodie et al, 2013).

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