Transitioning to Low Carbon Shipping Module

Sustainable Sea Transport Solutions for SIDS: Pacific Island Countries Case Studies

4. Options for Improving Energy Efficiency

http://unctadsftportal.org/sftftoolkit/transitioningtolowcarbonshippingmodule/chapter4/

Summary

In this chapter we explore the energy efficiency drive, examine the options available to shipping, and consider how these efficiency measures might affect the sea transport options for SIDS.

Key Themes: Technology – Efficiency – Alternative Fuels – Operational Examples

International shipping is undergoing an unprecedented and increasing search for energy efficiency and reducing its reliance on fossil fuels. A range of technological innovations have been tried and tested in the race to improve shipping efficiency. However, most analysts have identified a change in operational measures, such as slow-steaming, route optimization, or increased economies of scale as the key to achieving real gains in the near and medium future. Much of the innovation is happening at the large-scale and new asset end of the industry. How this might be translated for smaller and older vessels, such as those serving the needs of small islands and large developing countries, has not yet received sufficient attention or priority. The global trend towards increased technological and operational efficiency is likely to see SIDS further marginalised.

Useful Tool: IMO Train the Trainer (TTT) Course on Energy Efficient Ship Operation

4. Options for Achieving Energy Efficiency in Shipping

4.1 Context and Discussion

The shipping industry plays a critical role in the global economy moving approximately 90% of the tonnage of all traded goods. This trade has little or no alternative means of transportation in the foreseeable future. Generally, the energy efficiency of ships is high compared to other forms of transport. The industry consistently claims that shipping is a better environmental option compared to other forms of transport due to the lowest gCO_2/t.km emissions. Emissions of other pollutants, in particular SO_X, NO_X and PM (in particular back soot) are disproportionately high reflecting the poor quality of the fuel used in ships. These are now all part of the amendments to Annex VI of MARPOL, the International Convention for the Prevention of Pollution from Ships, being negotiated at the International Maritime Organisation (IMO).

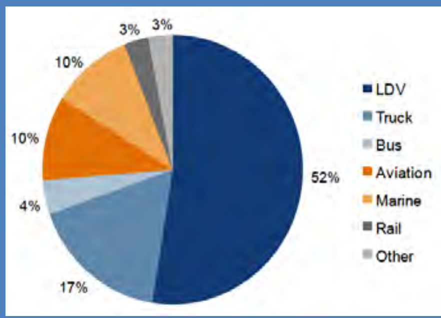
International shipping is undergoing an unprecedented and increasing search for energy efficiency and reducing its reliance on fossil fuels driven by three primary market forces: the fluctuating but escalating costs of marine fuels; international agreements to reduce greenhouse gas (GHG) emissions; and increasing awareness of the environmental and public health risk and costs from shipping emissions.

Since 2007 fuel costs have become the dominant parameter deciding where funds for new tonnage are placed, not the cost of the ship asset purchase or ship operation. This is a new paradigm in shipping history, except for a short period in the oil crisis of the 1970s/80s when fuel cost increased 15-fold in a decade. Historically the cost of fuel has not been a driver for the industry given its monopoly nature. As every operator has had to use the same fuel and because fuel has traditionally been relatively inexpensive, fluctuations in fuel price were simply passed on to the consumer. Today's trending market pull for energy efficiency is highly likely to increase given predicted long-term future cost of fossil fuel, increasing compliance costs of meeting international regulations on emissions and fuel type and content, and increasing competition within a currently overcrowded and depressed industry.

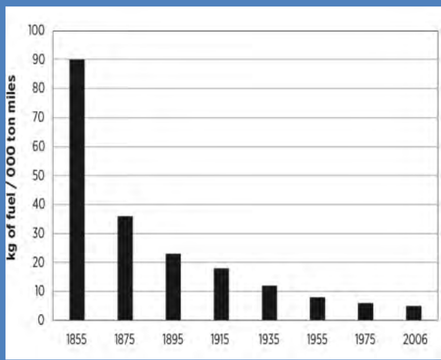
In this chapter we explore this energy efficiency drive and examine the options available to shipping. We conclude by considering the implications of current and projected efficiency measures as they might affect the sea transport options for Small Island Developing States (SIDS). As noted in other sections, much of the innovation is happening at the large-scale and new asset end of the industry. How this might be translated for smaller and often older vessels such as those serving the needs of small

The following images are selected from "Appendix D: Chapter 4."

Please refer to this appendix for full size images and sources.

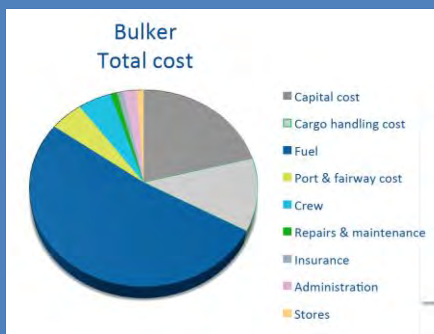


Transport energy by mode.



Individual efficiency of merchant ships has improved over time.

Today bunkers cost more than the ship.



Bulker total cost.

islands and Least Developed Countries (LDCs) has not yet received sufficient attention or priority. In the Pacific, as for other SIDS, much of the shipping asset is purchased second (even third, fourth or fifth) hand and often toward the end of its service life. So the option of achieving efficiency in the industry through new asset purchase or upgrade is not necessarily available. Many of the technological advantages coming to market today will not be available or affordable to most SIDS until they are in an "end of service life" state.

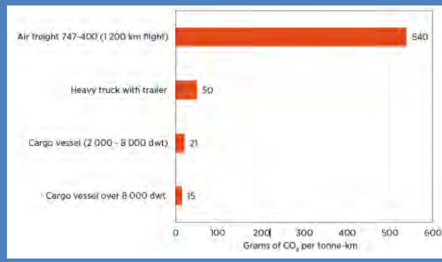
Technology advancements are only one facet of the change underway. To achieve effective improvements in energy efficiency for ships, an integrated approach is required. This must embrace naval architecture, marine and systems control engineering alongside operational practices, patterns and levels of trade. It needs to be cognisant of emerging technology and trends for using alternative fuels. Moreover, a systems approach must include all of the stakeholder requirements to achieve sustainable, flexible and resilient design solutions.

With any propulsion option it is essential that the overall emissions profile of the propulsion method and the fuel used is properly assessed, so that reductions in exhaust emissions from ships are not at the cost of increasing harmful emissions in land-based sectors that produce either the propulsion machinery or the fuel. A "whole of life cycle" energy accounting system is required to fully assess the savings from any individual technology advance. In determining appropriate technology, a careful selection must be made based on the ship's characteristics, available crew skills and the operational profile of the ship.

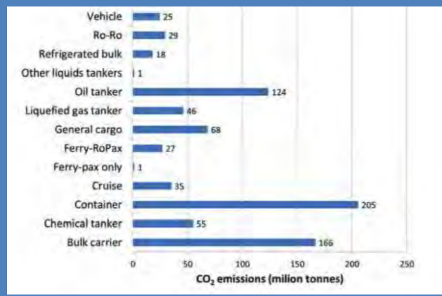
4.1.1 What is the Range of Options Available to the Global Fleet?

The International Council on Clean Transportation (ICCT) (2011) and IMO (2009) studies agreed on the range of strategies available to the industry. These include innovation in: propeller polishing, hull cleaning, speed reduction, autopilot upgrade, air lubrication, main engine retrofits, water flow optimization, hull coating, speed controlled pumps and fans, weather routing, high-efficiency lighting, propeller upgrade, waste heat reduction, alternative fuels, wind power, and solar technology. These analyses also noted that, the last three items apart, these are largely already available and most responsible operators are already, at least partially, using them. None of these measures individually achieves more than minor savings, nor do they represent any major paradigm shift.

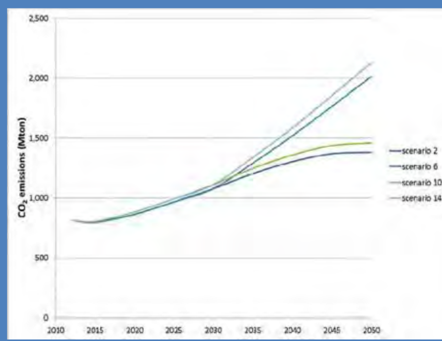
In 2013 the Royal Academy of Engineers published a comprehensive study into alternative methods of ship propulsion. Numerous naval centres of excellence are now publishing frequently in this field. These studies present a common picture. The options available to the industry are generally considered under two headings: technological change,



CO2 emissions by transport mode.



CO2 emissions by vessel type.



Impact of market or regulatory-driven improvements on CO2 emissions.

including use of alternative fuels; and operational measures. The third primary focus is the efficiencies that can be achieved in shore-side shipping operations, again in terms of both technological and operational change.

Within the industry there is debate and tension over which measures can deliver most effectively now and in the near future and therefore which initiatives to invest contested research and development (R&D) funding into. Most analysts consider that it is in operational measures that the greatest gains can be made in the near and medium future, at least double the savings that can be provided from improved technology.

4.2 Technology Options

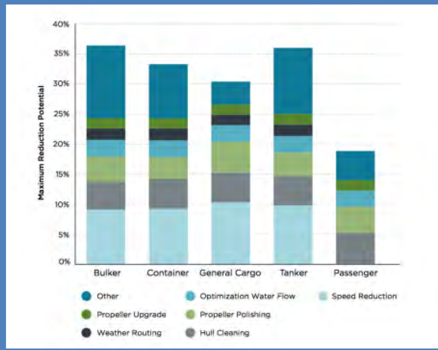
Ship owners have a number of technology options for increasing their profitability in today's market and under current regulations. It is far more cost-effective to build energy efficiency into new builds than to retrofit (install onto existing ships). However, given that existing asset is likely to be operational for at least the next two decades and the current oversupply of ships, reductions in overall shipping sector emissions requires both options to be pursued.

A wide range of technologies that can increase the fuel efficiency or otherwise lower the fuel costs of vessels are available on the market today. Most of these can be retrofitted and thus offer an alternative solution to continued investment in more efficient new builds. Retrofitting the existing fleet is crucial to creating a healthy shipping industry. Efficient new build ships may offer a step change in efficiency but they will not, on their own, ensure an economically sound and sustainable industry.

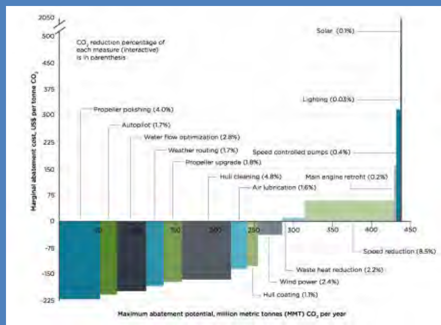
4.2.1 Increasing Efficiency from the Motors

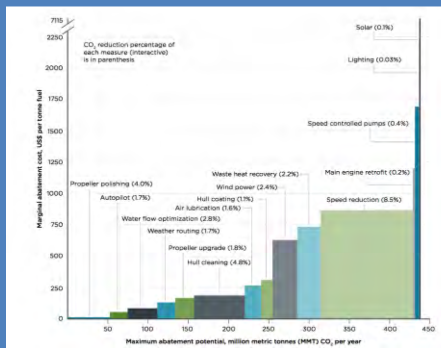
During the past 150 years shipping propulsion underwent a significant transformation from renewable energy (sail) to steam (coal) and heavy fuel oil (HFO) and marine diesel oil (MDO) – high emissions fuels which are now the dominant source of power for propulsion in the sector. Over this period the performance of merchant ships powered by diesel engines improved with thermal efficiency approaching 55% for slow speed engines. Between 1855 and 2006, the increase in efficiency was sharp; plateauing in the last 15 years of that period. While ship engines have become ever more fuel-efficient the reality is that we are nearing the limit of the efficiency we can get out of the marine internal combustion motor. Some marginal gains are being made through longer stroke motors and continual refinement of design.

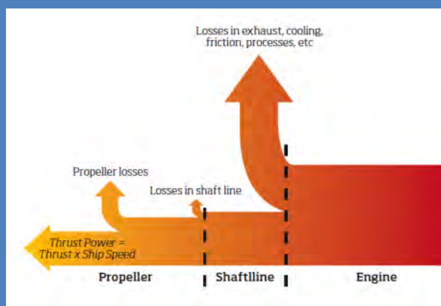
The Royal Academy study considered a conventional tanker or bulk carrier, the ship types that form 64% of the world fleet and found that, before any energy saving measures is contemplated, of the total energy input to the machinery system from burning the fuel only around 27% is actually available at the ship's propeller. This is because energy is lost to heat and friction at



Potential CO2 reduction measures.


Marginal CO2 abatement curves.


CO2 emission abatement potential and cost of fuel savings.



Losses in exhaust, cooling, friction, processes, etc.

each step in the drive chain. So, measures to either reduce such energy loss or capture and reuse such energy are being sought. In some cases, this is with a view to returning that energy to propulsion and in others to capturing that energy for use in ship ancillary systems, such as electricity generation.

4.2.2 Alternative Fuels

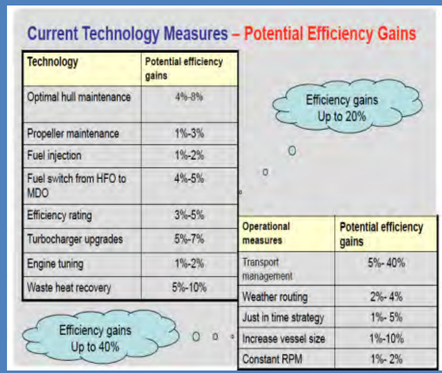
The total dominance of HFO and MDO is now being challenged by the potential for new fuels, some which claim to be more benign to the environment. The primary contenders are: liquefied natural gas (LNG), methanol, hydrogen, nuclear and biofuels (which we considered in chapter 3).

4.2.2.1 LNG and Methanol

LNG can be used in reciprocating engine propulsion systems and is a known technology with classification society rules for the fuel systems already in existence. Service experience with dual fuel and converted diesel engines, although limited at the present time, has proved satisfactory and currently LNG is cheaper than conventional fuels. LNG, while not free of harmful emissions, has benefits in terms of CO_2, NO_X, SO_X emissions, assuming that methane slip is avoided during the storage, fuelling and combustion processes. For existing ships, reciprocating engines with exhaust gas attenuation technologies are the main options. Transition at scale will require an adequate bunkering infrastructure to be developed, particularly for deep-sea voyages. This is emerging in the developed world, especially in the Special Emissions Control Areas (SECAs) in the EU and U.S. However, lack of bunkering will be a restriction for secondary routes and likely to prove uneconomic for many areas.

Production of LNG is increasing globally and ship designs, both for use of it as a propulsive fuel and specialised vessels for transporting it, are increasing. Today there are approximately 60 LNG-fuelled ships operating globally and this number is expected to double due to ships currently on order. That is not counting the almost 400 LNG carriers, many of which are dual fuel.

Many industry commentators are heralding LNG as the preferred alternative fuel for shipping. The Atkinson Center for a Sustainable Future (ACSF) is *“optimistic about the prospects for increased use of natural gas as a marine fuel”* but warns LNG conversion will not be an obvious choice for all vessels. Despite favourable LNG prices relative to marine distillate and residual fuel, annual fuel cost savings after converting to LNG may not be large enough to provide a reasonable payback for the cost of converting many vessels. DNV-GL say LNG is now a proven and available solution, although noting that conventional oil-based fuels will remain the main fuel option for most existing vessels in the near future. They note only two technical challenges with LNG, which engine makers are in the process of resolving: methane slip; and developing non-cylindrical tanks suitable for fitting in hulls with less available space.



Technology	Potential efficiency gains
Optimal hull maintenance	4%-8%
Propeller maintenance	1%-3%
Fuel injection	1%-2%
Fuel switch from HFO to MDO	4%-5%
Efficiency rating	3%-5%
Turbocharger upgrades	5%-7%
Engine tuning	1%-2%
Waste heat recovery	5%-10%

Operational measures	Potential efficiency gains
Transport management	5%- 40%
Weather routing	2%- 4%
Just in time strategy	1%- 5%
Increase vessel size	1%-10%
Constant RPM	1%- 2%

Current technology measures – potential efficiency gains.

The main fuel options.

Alternative fuels (2).

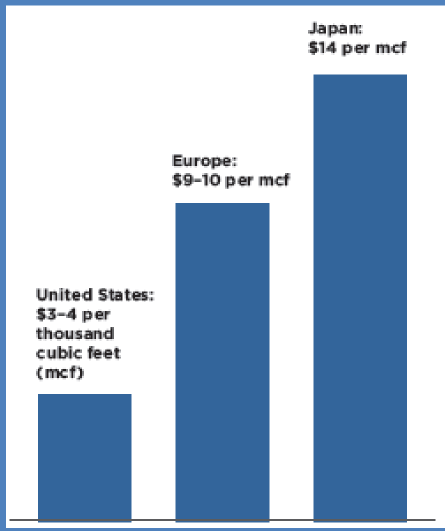
The major competitor to LNG as a near future alternative shipping fuel is methanol, most commonly produced from natural gas but it can also be produced from a wide range of biomass. Compared with LNG, methanol is in early stage of development as an alternative fuel for ships. It has advantages over LNG: being considered environmentally friendly with nil SO_X and low NO_X and PM by-product; storable in existing fuel tanks (unlike LNG which needs special tanks), and can be safely transported to port by road tanker (unlike LNG which needs separate refuelling infrastructure). Methanol however requires twice as much volume to generate the same amount of energy as MDO, raising questions over cost competitiveness, especially if this involves loss of cargo storage space. The two principal barriers are: the development of the required engine technology; and agreeing new rules for low flashpoint maritime fuel. Methanol has a lower flashpoint than conventional fuel, so additional safety measures are required.

However, other analysis does not support this optimism for either LNG or methanol. Recent work by Lloyd's Register and UCL's Energy Institute suggests that LNG is unlikely to see major uptake before 2030, particularly given transport and storage difficulties; and project that LNG will have only a 5-10% share in 20 years time. That same report also finds that methanol is unlikely to appear in the marine fuel mix in any considerable quantities by 2030.

From a low carbon perspective, the effectiveness of either fuel will depend on how well the risk of "methane slip" can be managed. This is a cause for concern because of the properties of methane, when considered as a GHG, are 21 times more potent than CO_2. Methane slip comes from two sources: operational emissions from the venting of methane to the atmosphere during re-fuelling or storage; or engine emissions of un-burnt or incomplete combustion of methane passing through the engine system. The ability of the industry to realistically control either source is also disputed with opinion ranging from almost no danger to it being difficult to control, especially with equipment and machinery deteriorating over time. The inherent danger is that even small leakages will have a high effect. A lot will depend on the efficiency of the systems implemented, crew training standards and monitoring of operations, the quality of equipment onboard and at refuelling points, and the level of investment in equipment maintenance over time.

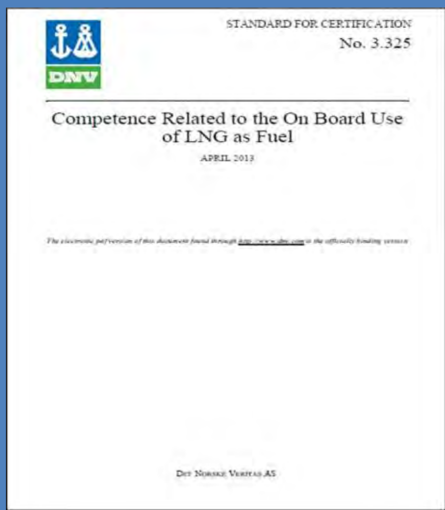
4.2.2.2 Hydrogen

LNG and methanol can only be transition fuels to true decarbonisation with hydrogen as the ultimate objective. Hydrogen was much vaunted in the mid-2000s as the fuel for the future in shipping and is still hoped to provide a long-term solution. Although the theory is relatively simple and has been known for decades, major barriers exist to practical implementation which, if they can be overcome, would be revolutionary across both global transport and energy production



LNG estimated regional price differences.

LNG container.


STANDARD FOR CERTIFICATION
No. 3.325

DNV

Competence Related to the On Board Use of LNG as Fuel

APRIL 2013

Det Norske Veritas AS

DNV : "Competence Related to the On Board Use of LNG as Fuel."

sectors. Shipping fuel cell technology development has seen significant advances and attracted significant interest, especially from the offshore supply vessel, passenger and cruise ship markets.

In 2008, the Zemships (Zero Emissions Ships) project developed the *Alsterwasser,* a 100-pax fuel cell powered passenger vessel for inland waterways and a number of other small ferries and river boats have followed suit. In 2012 as part of the FellowShip project, a 330 kW fuel cell was successfully tested on board the offshore supply vessel *Viking Lady* operating for more than 7000 hours. This was the first fuel cell unit to operate on a merchant ship, with the electric efficiency estimated to be 44.5% (when internal consumption was taken into account), and no NO_X, SO_X and PM emissions detectable. When heat recovery was enabled, the overall fuel efficiency was increased to 55% with room for improvement.

Fuel cells offer potential for ship propulsion with good experience gained in auxiliary and low-power propulsion machinery. While hydrogen is the easiest fuel to use in fuel cells, this would require a worldwide infrastructure to be developed for supply to ships and reliable, low-pressure storage of hydrogen remains a challenge to development. The other alternative is for it to be manufactured onboard using readily available seawater as the raw source. However, an energy source is then required to drive the electrolysis process. Despite increasing investment in research the move from theory to practical application proves elusive and there seems little certainty of any near or medium future deployment at scale. The high-tech nature of the technology means it is unlikely to have real benefits for most SIDS in the near to medium future without major technology and cost barriers being overcome.

4.2.2.3 Nuclear

The last major option is nuclear. Nuclear ship propulsion has the advantage during operation of producing no CO_2, NO_X, SO_X, volatile organic or PM emissions. A significant body of experience exists in the design and safe operation of shipboard nuclear propulsion plants. The conventional methods of design, planning, building and operation of merchant ships would require a complete overhaul since the process would be driven by a safety case and systems engineering approach. Issues would also need to be addressed in terms of international regulation, public perception and acceptability, financing the initial capital cost, training and retention of crews, setting up and maintenance of a global infrastructure support system, insurance and nuclear emergency response plans for ports.

Nuclear options are unlikely to be politically acceptable for Pacific Island Countries (PICs) who have long advocated for a nuclear-free Pacific, especially in light of their history of being used as guinea pigs for nuclear weapon testing by France, UK and U.S.

and the threats to the Pacific Ocean health and ecology from nuclear power plant disasters such as Fukushima. The cost and complexity of nuclear power as fuel means it is not a practical option of use in shipping for SIDS or LDCs.

4.2.2.4 Non-Engine and Fuel Energy Efficiency Technology Options

Moving from engines and fuel, what other options are available for increasing efficiency of ships? A current multi-country, multi-partner EU initiative is claiming alternative propulsion systems and new hull designs could improve the efficiency of ships and barges by at least 15%. Propeller technology has been an area of much scrutiny in the past decade with major advances being made both in propeller design, and in coatings and finishes to decrease cavitation.

Next there is the energy lost through friction from the resistance of the ship's hull to the water it is travelling in. Options for addressing this include the configuration of the hull itself, the finishing and coatings applied to the hull, the rudder or steering system. Innovative hull designs are one of the means used to create greater energy efficiency ratings in modern container ships. Experiments into pumping air under the hull to provide a low friction layer between the hull and the water also show promise of small savings although research and trials are still in an early phase.

Finally, there are the ancillary energy systems a ship uses where savings can potentially be made: everything from electricity generation, lighting, pumps, winches, refrigeration and air conditioning, safety equipment. Many technology innovators are targeting this field. While advances are being made, the savings to the overall energy budget of vessels is not high.

4.3 Operational Energy Efficiency Options

The second major way for achieving energy efficiency is through vessel operational measures. The simplest of these is slow steaming. But there are gains to be made in every aspect of ship management. Route optimisation, planning the trip to make best use of weather, maximising savings from improved maintenance schedules and procedures, greater crew training all have their part to play. At the large-scale end of the industry the biggest efficiency gains are through increasing economies of scale with larger ships and ports. This of course doesn't assist the situation for small countries and is likely to have a negative effect increasing the disparity between primary and secondary routes and ports.

4.3.1 Slow Steaming

Slow steaming is the practice of reducing engine speed on passage to create savings in fuel consumption. Global fleet activity during the period 2007–2012 demonstrated widespread adoption of slow steaming. The average reduction in at-sea speed relative to design speed was 12% and the average reduction in daily fuel consumption was 27%. Many ship type and size categories exceeded this average. Reductions in daily fuel consumption in some oil tanker size categories was approximately 50% and some container ship size categories reduced energy use by more than 70%. Generally, smaller ships operated without significant change over the period, also evidenced by more consistent fuel consumption and voyage speeds.

Slow steaming is the major contributor to the reported reduction in fleet carbon emissions between 2007 and 2012. However, there is a widespread expectation in the industry that as the economy and markets pick up and excess capacity is brought back into service, speeds will increase again to meet growing demand especially if fuel prices remain depressed. When shipping lines began promoting slow steaming they highlighted its environmental benefits. Slow speeds reduce fuel consumption and therefore emissions, helping shippers reduce their carbon footprint and reinforce their green image.

A reduction in speed and the associated reduction in fuel consumption do not relate to an equivalent percentage increase in efficiency, because a greater number of ships (or more days at sea) are required to do the same amount of transport work. Also longer transit times increase pipeline inventory costs, which needs to be factored in when calculating the full economic benefit to the operator. A 10% reduction in fleet average speed results in a 19% reduction of CO_2 emissions even after accounting for the emissions of additional ships needed to deliver the same amount of transport work and the emissions associated with building the necessary additional ships. For sustained energy efficiency improvements and environmental benefit to be achieved slow steaming would need to be regulated across the fleet rather than the current situation driven by market forces. To date the IMO has declined to consider this.

4.3.2 De-rating Engine Performance and Depowering Engine Size

If trends to slower ship speeds were to become the industry norm, then vessels would not need the size of engines they are currently equipped with that allow them to travel at high speeds. This would lead to new ships being built with smaller motors. For the existing fleet this can be achieved by either de-rating engines to lower horsepower or refitting vessels with smaller engines, each option requiring consequential propeller changes. This concept has led to stiff debate on what the minimum power requirement for ships are to provide for vessel handling in bad weather and restricted passages and channels. There is currently little industry interest in de-rating or depowering as it means losing the option of faster passage times when fuel prices are low and profit from faster delivery is high. Until a firm ambitious industry sector target for emissions reductions is set along with regulated speed restrictions this is unlikely to change.

4.3.3 Weather Routing and Voyage Optimisation

The impact of weather on the fuel consumption of a ship is route and voyage specific. Improved access to historical weather data and sophisticated computer modelling allows for route planning using both long range forecasting and historical hind-casting to predict the most efficient routing to allow for weather and sea conditions en route.

Voyage optimisation allows for "just in time" arrivals of vessels at ports thereby allowing best use of speed (and therefore fuel consumption) throughout the voyage and minimises waiting time in port or anchorages (and therefore fuel used powering ancillary engines).

4.3.4 Maintenance Schedules and Procedures

The difference between a ship's technical efficiency (what its design specifications say it can achieve) and operational efficiency (what it achieves in practice) vary greatly across the fleet. This is in part due to differing fixed characteristics of the vessels – age, size, etc – and in part due to differing operational parameters. One of the most crucial of these is the effort put into vessel maintenance and overhaul. The difference between a clean and a foul hull can significantly affect fuel consumption and vessel speed, as will the condition of the propeller surface. Well-maintained and regularly-serviced engines and related equipment (exhausts, water circulation pumps) – both for propulsion and ancillary energy use - also has a bearing on their efficiency.

4.3.5 Trim and Ballasting

The way a vessel sits in the water has a marked influence on energy efficiency and fuel consumption. It is largely determined by the loading of the vessel and her correct ballasting. Modern ships now use highly sophisticated on-board computer modelling that allow the supercargo maximum efficiency in loading distribution. The ability to maximise this aspect of ship efficiency relies heavily on access to such technology but, as importantly, the training and capacity of the operational crew and their dedication to achieving maximised results. It also assumes that the vessel is well maintained.

4.3.6 Autopilot Upgrade/Adjustment

Rudder induced drag has a big influence on course-keeping ability and vessel resistance. Advanced autopilot systems can optimize rudder position and consider wind, currents, and ship yawing on a given route and minimize vessel resistance. Such systems can optimize routing and fuel use. Upgrading autopilots to include the latest available advances in the technology will have benefit, but much also comes down to the regularity with which the system is adjusted, crew capacity and dedication to maximizing its use.

4.3.7 Supersize Me – the Rise of the Super Ship, Super Port and Super Consortium

Larger and newer ships are inherently far more efficient fuel users than small, old ones. The greatest operational savings come from intelligent use of larger assets by exploiting economies of scale. When the Maersk Triple E Ships were launched in 2011 they were the largest container ships ever – suddenly 18,000 TEU had become the new industry standard over the 13,000 TEU vessels. Three years later we have ships nudging 20,000 TEU and with the redevelopment of the major canals even bigger ships are conceivable. The global economic downturn has resulted in a current glut of shipping. So we are also seeing a trend to scrapping newer ships in order to acquire ever larger vessels so that operators remain competitive with their rivals.

Along with the increase in ship size we are also seeing the emergence of the super-port, giant transit nodes where international and interregional trade is focussed. Mainland China ports account for 70% of the top 10 ports in the world, with Shanghai handling 33.62 million TEUs of cargo in 2013, up from 31.74 million TEUs in 2011.

The past three years has also seen the rise of the super shipping consortia such as the P3 Network, an operating consortium of the three largest international container carriers: Maersk Line, Mediterranean Shipping Co. and CMA CGM. These carriers aim to gain operational efficiencies by more consistently filling their ships on the combined volumes, and being able to use the newest generation of megaships, to enable lower cost per container moved.

Combined, the P3 network controls about 15% of global container capacity. The competing G6 network announced intentions to bulk up its sailings in response to P3, while a new consortium was formed among a group of Asian carriers (Cosco, K Line, Yang Ming, Hanjin, and later Evergreen) called CKYHE. Such alliances and consortia will continue to grow in importance and dominance in the global industry.

“Supersize me.” (3)

4.4 Port and Shore-Side Energy Efficiencies

The third area for achieving energy efficiency is in shore-side operations. Ships do not operate independently in the maritime transportation system; efficiency must extend beyond the ships themselves to shore-based entities. Ports, like ships, have evolved over time, becoming increasingly specialised and sophisticated. As ships have increased in size and sophistication, so has the infrastructure to service them. Again, technological and operational measures are available. There are two primary targets: increasing efficiency at ports in terms of throughput so as to minimise the time ships spend in waiting for berthage; and servicing and reducing the energy efficiency of the ports’ land-based operations.

Improved port efficiency results in decreased fuel through reduced vessels' turnaround time in port. The fuel consumed by ships at berth is mostly used to produce electricity on board for passengers and crew e.g. for air conditioning, cooking and lighting, and also for machines to load/unload cargo. This means that ferries, cruise ships and tankers use relatively more fuel at berth compared with other ship types. Efficient port facilities aid in keeping the operational efficiency of ships at the highest level (e.g. hull cleaning and propeller polishing facilities, specialized fuel and power supply services).

A significant proportion of port running costs and environmental impacts are associated with energy consumption. The energy used by internal and external lighting, cargo handling equipment, radar, workboats, patrol boats and road vehicles, for example, can all contribute to the port's carbon footprint and have a direct or indirect effects on costs. Ports are a potentially highly polluted environment with high marine fuel and diesel emissions from both the docked cargo ships and port-based machinery. Pollution in ports often affects nearby communities. Globally, there are multiple efforts to improve the environment in ports. The contribution of ships and port activities to local and regional air quality has become a major issue for several large ports due to non-compliance with air quality standards.

Port energy management is the systematic study of areas in which a port can better utilize its energy consumption, whilst also considering the potential inclusion of distributed renewable power generators. Port energy management has not historically been recognized as a priority despite sustained growth in ports. Today given the economic challenges faced by the industry and heightened awareness of environmental issues and a greater demand for sustainable logistics, the topic of energy efficiency has come to the fore. This challenge is increasingly being taken up by port authorities. Regulation of ports, especially in the developed world, has become more stringent. Where it may reasonably be argued that the integration of port and shipping environmental management brings mutual advantage to the sector, industry and society as a whole, the question of who carries the cost of 'green shipping' is still a subject of debate.

Many green technologies that are developed for other applications, but with potential to be applied to ports, are being explored. A range of initiatives are current into improving energy efficiency of port machinery, including electrification to cut down on localized emissions. On-going research efforts include using redox batteries for cargo handling equipment in port terminals, designing of lightweight and efficient power inverter systems for marine applications and research on reducing fuel consumption using flywheel battery technology for rubber-tyred gantry cranes in contained terminals.

Port and Shore-Side Energy Efficiencies (3).

4.5 Shipping Energy Efficiency for SIDS

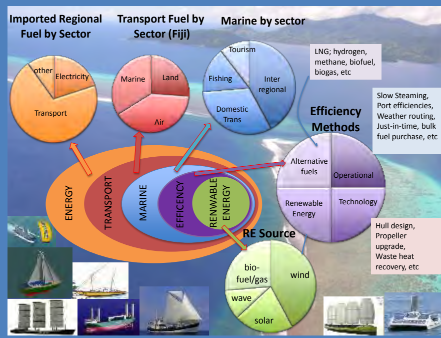
Many of the technology advances are unlikely to have immediate or affordable applications in SIDS scenarios except at the large-scale and economically viable level. For Pacific states there is a marked disparity between shipping that services their international needs, which is generally described as adequate and is usually based outside the region, and domestic fleets, which are generally described as poor.

The unique aspects of Pacific shipping (extremely long transportation routes, narrow and minute economies, high inward/outward loading imbalances) make many Pacific shipping routes marginal. Especially at the domestic level shipping suffers from old and poorly maintained vessels, poor levels of crew and regulatory staff training and capacity, poor or non-existent servicing and maintenance facilities, and poor quality shore-side and port infrastructure. Combined with financing barriers many locations are trapped in a vicious cycle of old ships replaced with old ships or countries waiting for donated vessels from bilateral donors which are not necessarily appropriate to country scenarios and do not necessarily come with sufficient resources to crew, operate and maintain vessels in the long term. These factors limit the range of options available for achieving energy efficiency for shipping in SIDS.

Technology advances that require substantive front-end financial investment or increased costs and training are unlikely to attract investment for local commercial operators. Many technologies require advanced levels of technical competency that are often simply unavailable to SIDS. Most of these options are unlikely to be accessible to our communities.

In terms of operational changes, most operators already employ slow steaming as a cost reduction measure as a matter of course. Other options are difficult to access and employ. Port-side efficiencies can be targeted but in the main this will only be available to major ports and transhipment centres linked to international routes. Most of the port infrastructure throughout the Pacific dates back more than half a century and is often in a poor state of repair.

It is highly likely that as the international industry transforms to meet a new operating environment where efficiency gains and low carbon transition is rewarded and failure to adapt incurs increasing penalties, the disparity between the shipping efficiency of large-scale shipping and that servicing SIDS will increase. Solutions appropriate to SIDS require investment into research and development; transferral of lessons learnt and advances happening in the broader industry are unlikely to result in real gains of any magnitude unless tailored to localised operating conditions. However, few SIDS have the internal capacity or resources necessary to undertake such research and trials unaided.



Shipping Energy Efficiency for SIDS.

Disclaimer

This module has been prepared for UNCTAD by Peter Nuttall and Alison Newell of the Pacific Centre for Environment and Sustainable Development, the University of the South Pacific. While every effort is made to ensure the accuracy and completeness of the module, UNCTAD assumes no responsibility for eventual errors or omissions. The content and views expressed are those of the authors and do not purport to represent any organisation.

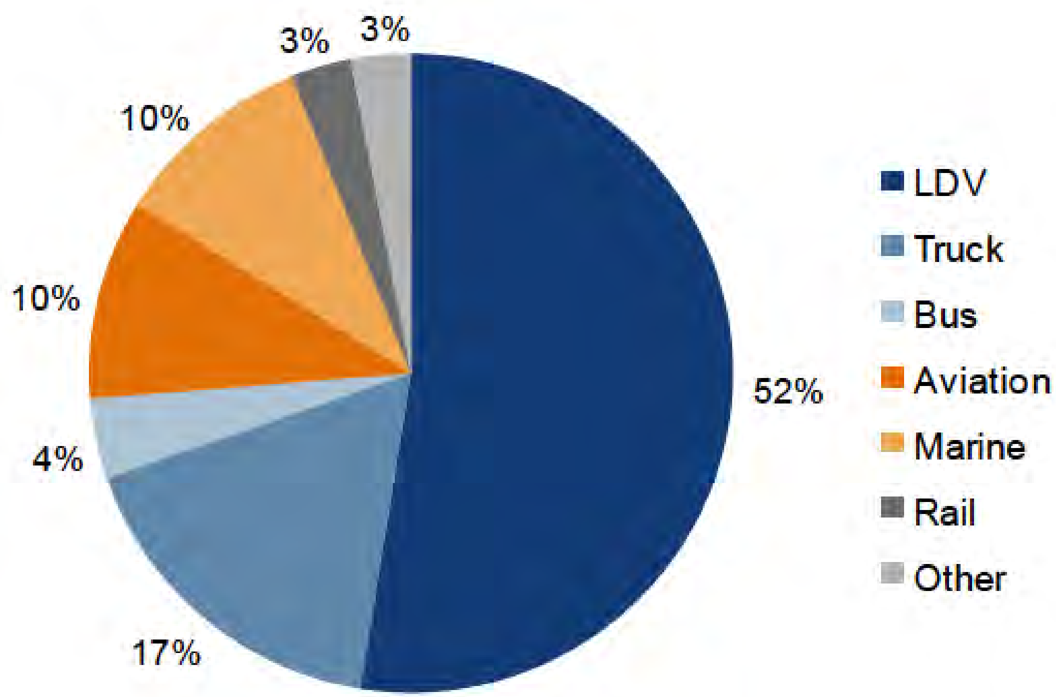
Chapter 4

Options for Achieving Energy Efficiency in Shipping

Context

- Shipping moves 90% of the tonnage of all traded goods. Global shipping tonnage loaded annually increased from 2.6 billion to 9.5 billion tonnes between 1970 and 2013.
- This trade has little or no alternative means of transportation in the foreseeable future.
- The demand for shipping is predicted to grow further, owing to the changing configuration of global production, the increasing importance of global supply chains and the expected growth in many economies.
- Generally the energy efficiency of ships is high compared to other forms of transport. The industry consistently claims that shipping is a better environmental option compared to other forms of transport due to the lowest $gC0_2/t.km$ emissions.
- Today's trending market pull for energy efficiency is highly likely to increase given:
  - predicted long-term future cost of fossil fuel
  - increasing compliance costs of meeting international regulations on emissions and fuel type and content
  - increasing competition within a currently overcrowded and depressed industry

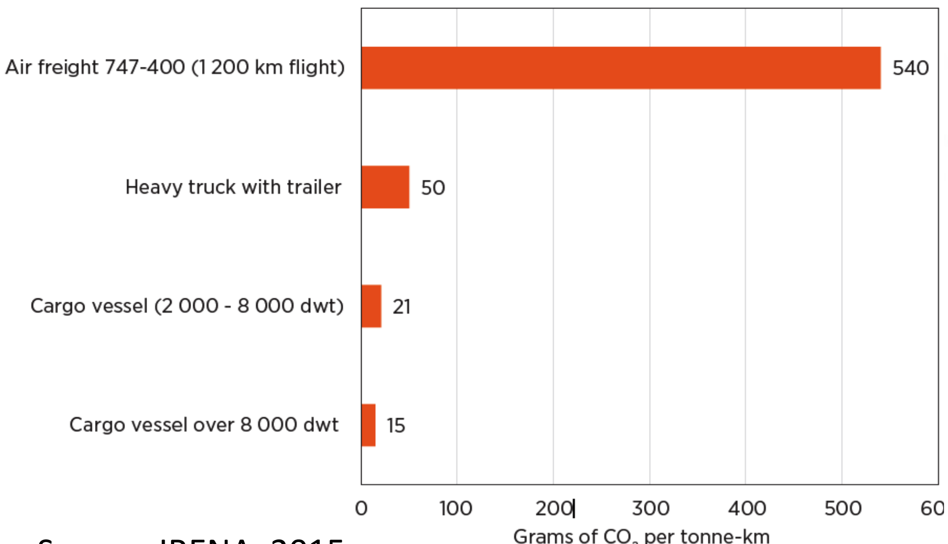
Transport Energy by Mode
(total ~2,200 Mtoe)



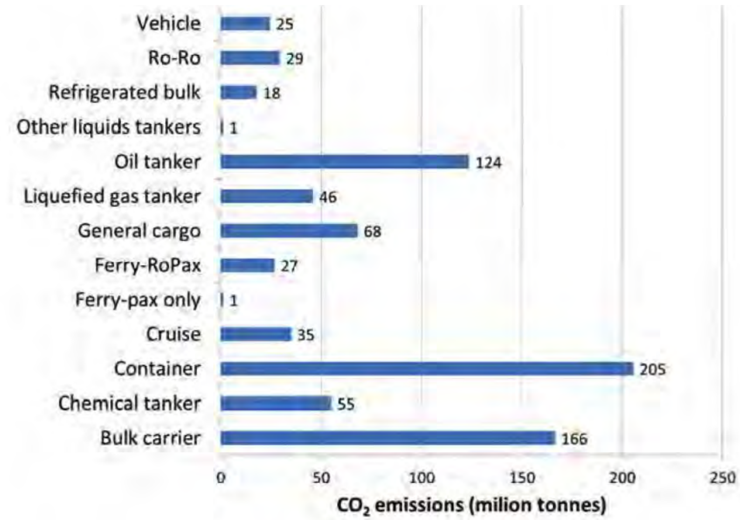
Shipping uses ~10% of all global transport energy.

Source: WEF, 2011

Comparison of CO_2 Emissions between Modes of Transport and Vessel Types

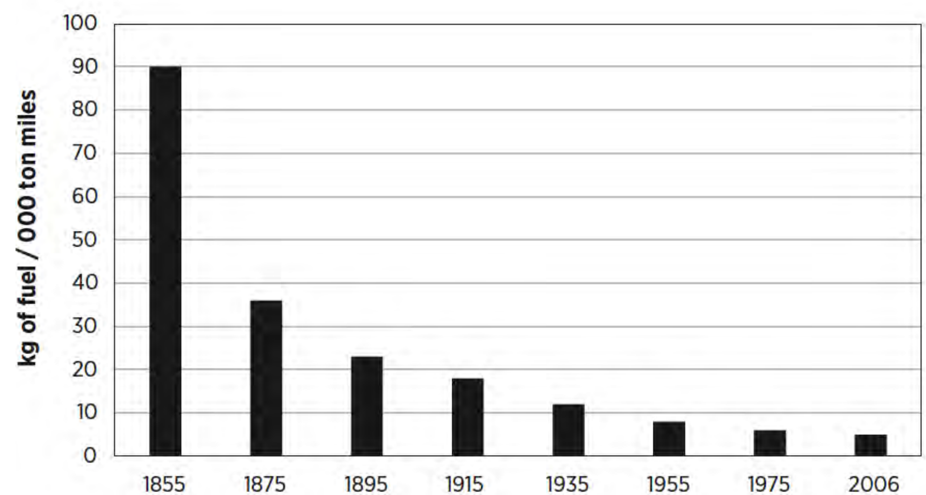


Source: IRENA, 2015



Source: Smith et al, 2014

Efficiency of individual merchant ships has increased dramatically between 1855-2006

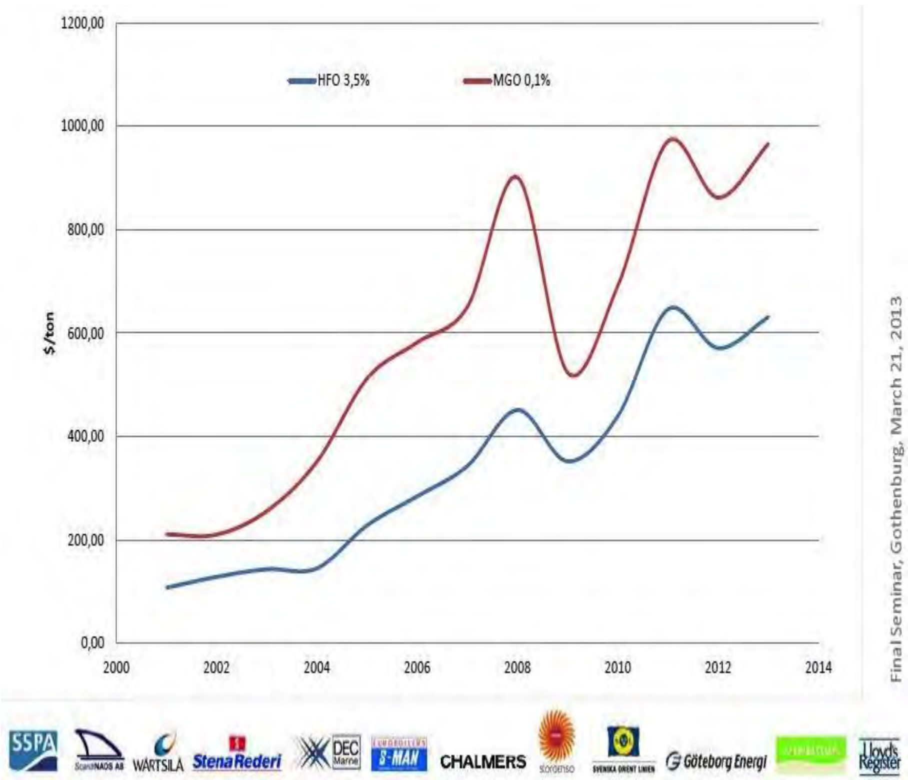


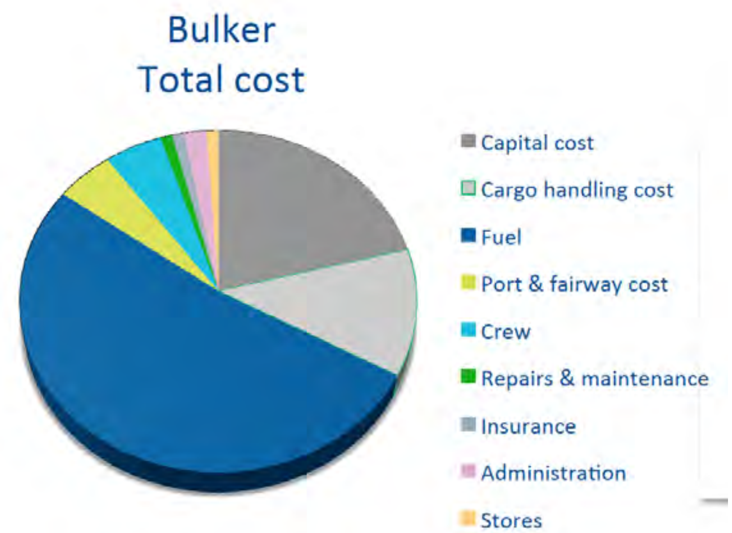
Source: Adapted from Stopford, 2010

International Shipping is Undergoing an Unprecedented and Increasing Search for Energy Efficiency

3 primary forces are driving this:

1. The fluctuating but overall escalating costs of marine fuels

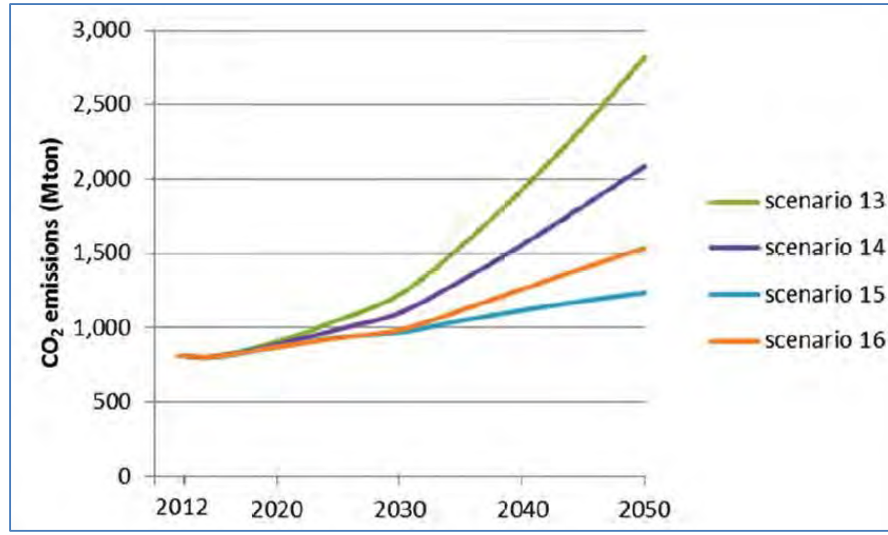


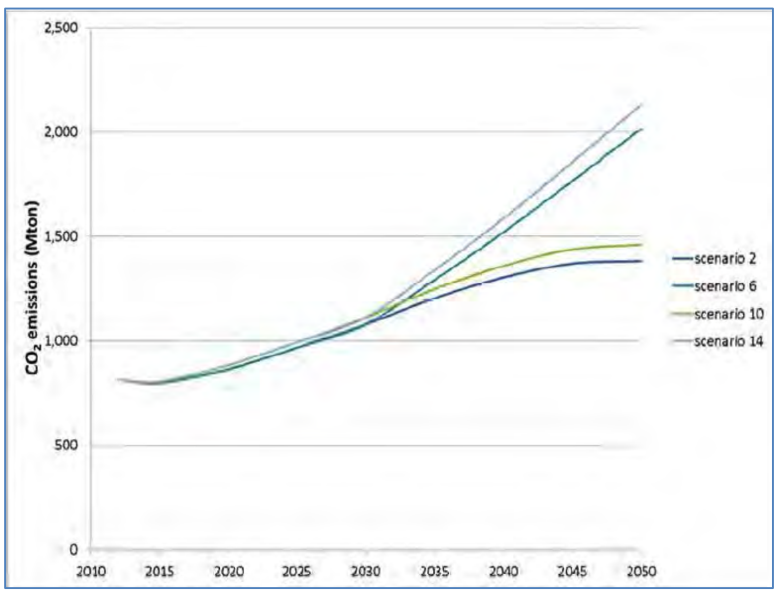


Source: Rolls Royce, 2014

2. Climate change and GHG emissions

Maritime CO_2 emissions are projected to increase between 50% and 250% by 2050.

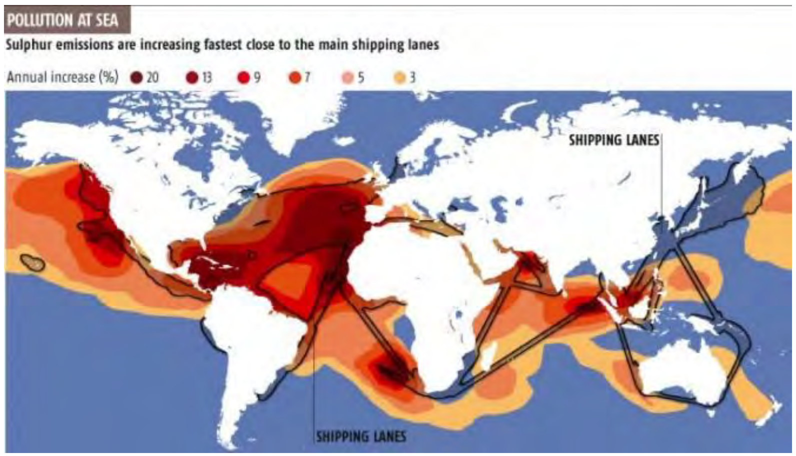




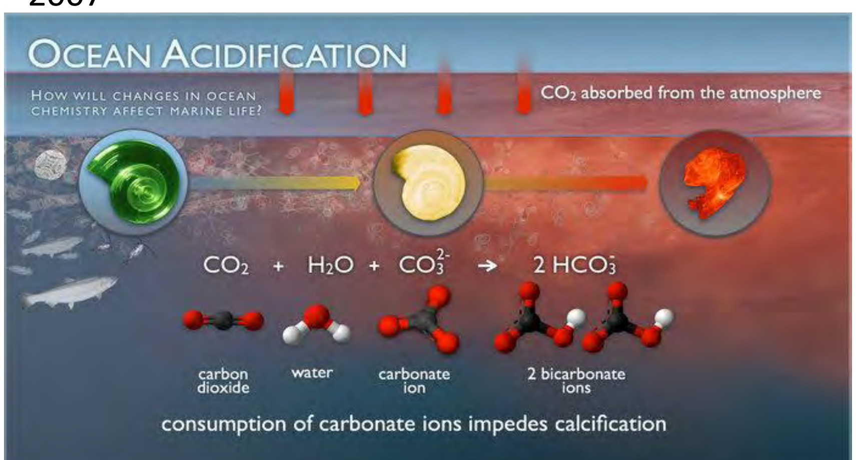
The left hand figure shows the impact of market-driven or regulatory-driven improvements in efficiency contrasted with scenarios that have a larger share of LNG in the fuel mix. These four emission projections are based on the same transport demand projections. The two lower projections assume an efficiency improvement of 60% instead of 40% over 2012 fleet average levels in 2050. The first and third projections have a 25% share of LNG in the fuel mix in 2050 instead of 8%. Under these assumptions improvements in efficiency have larger impact on emissions trajectories than changes in fuel mix.

Source: Smith, 2014

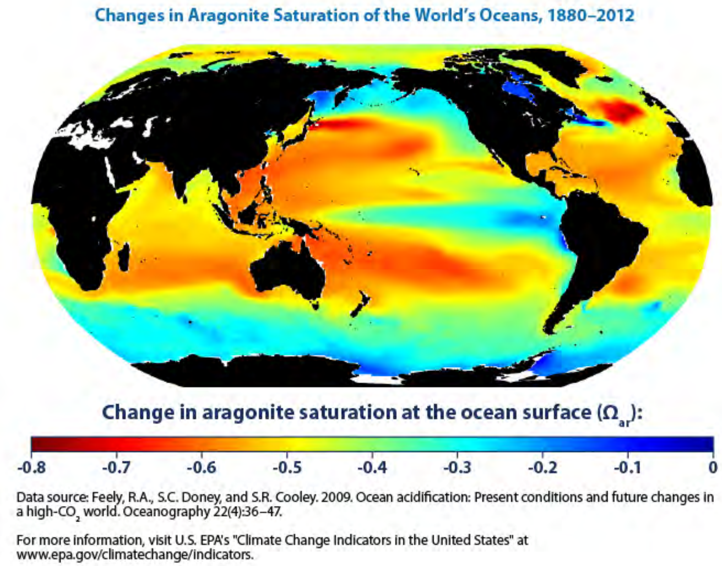
3. Environmental and public health risk and costs from shipping emissions.

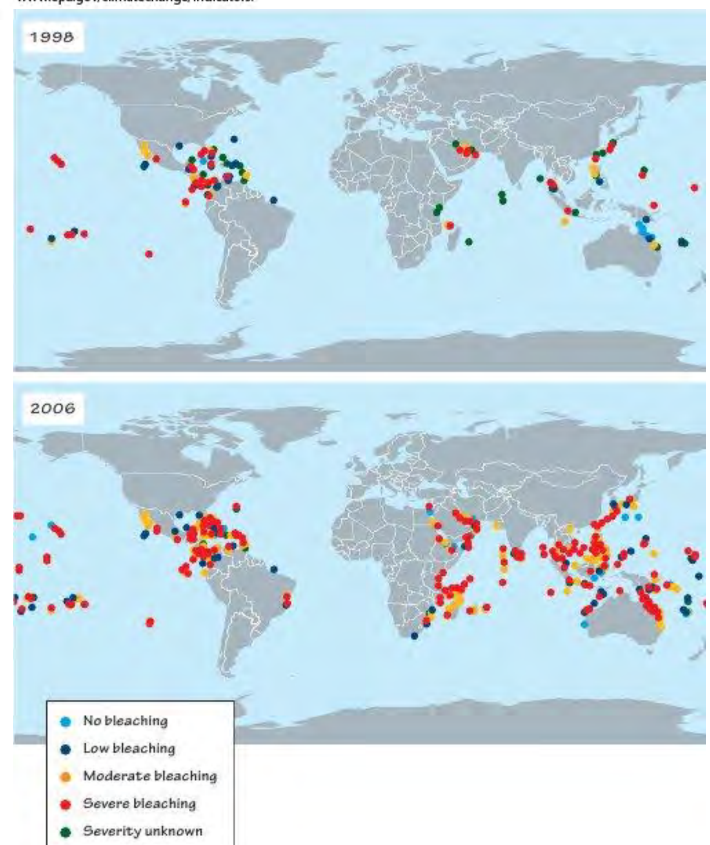


Source: Corbett, et al 2007



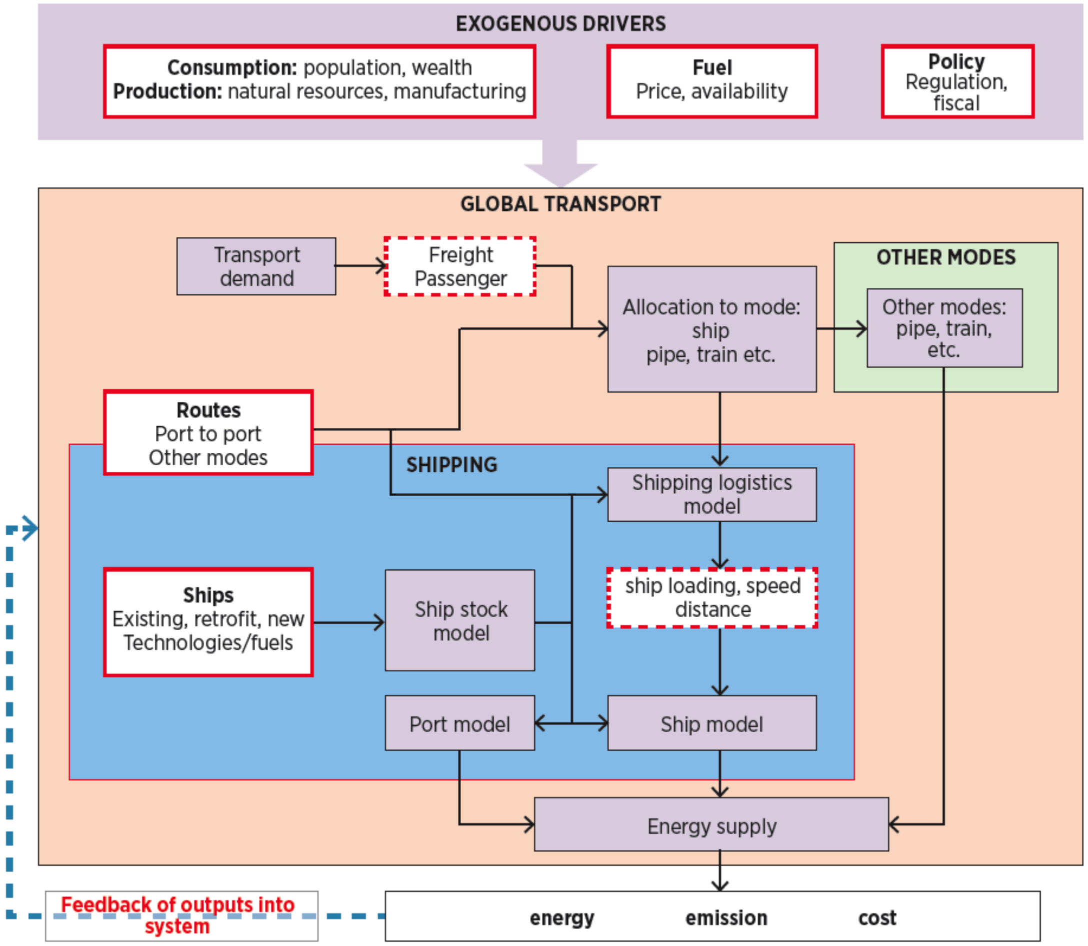
Source: http://www.pmel.noaa.gov/co2/story/Ocean+Acidification





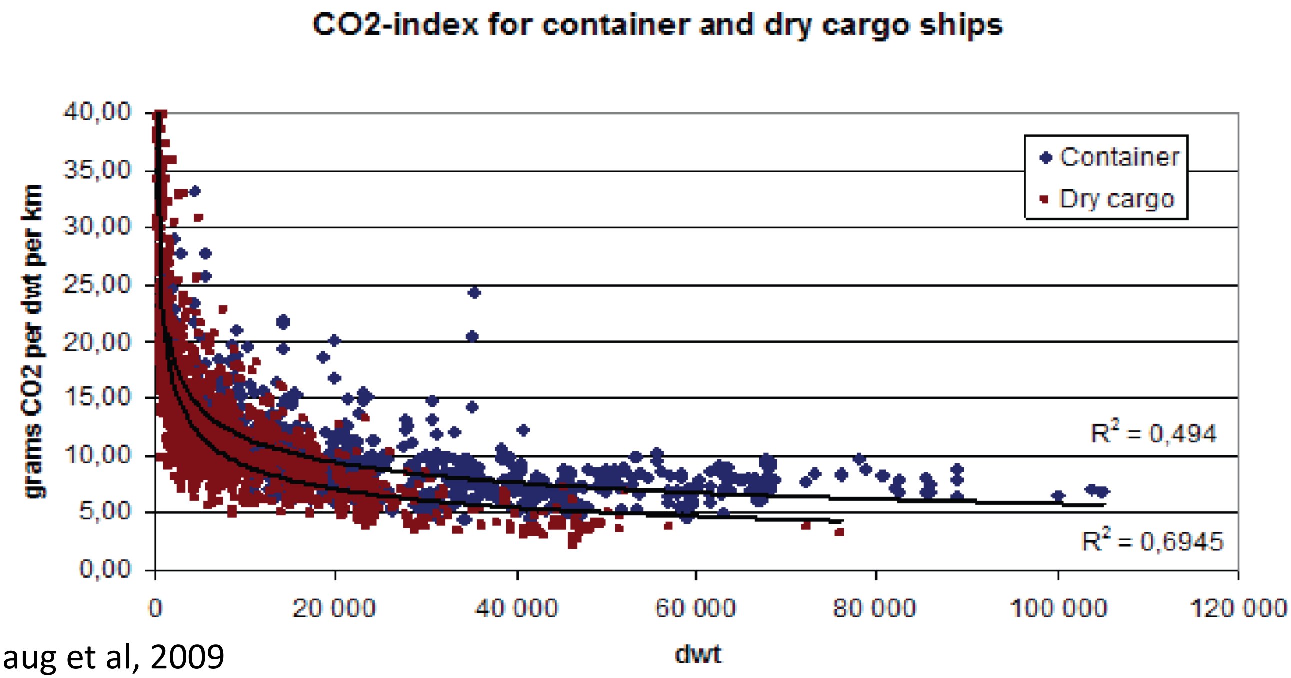
Source: www.globalissues.org/article/173/coral-reefs

Exogenous drivers for the global transport sector provide opportunities for deployment of energy efficiency and renewable measures in the shipping sector.



Source: Smith et al, 2010

Small Ships Move Least Cargo but Create Highest Emissions



Source: Buhaug et al, 2009

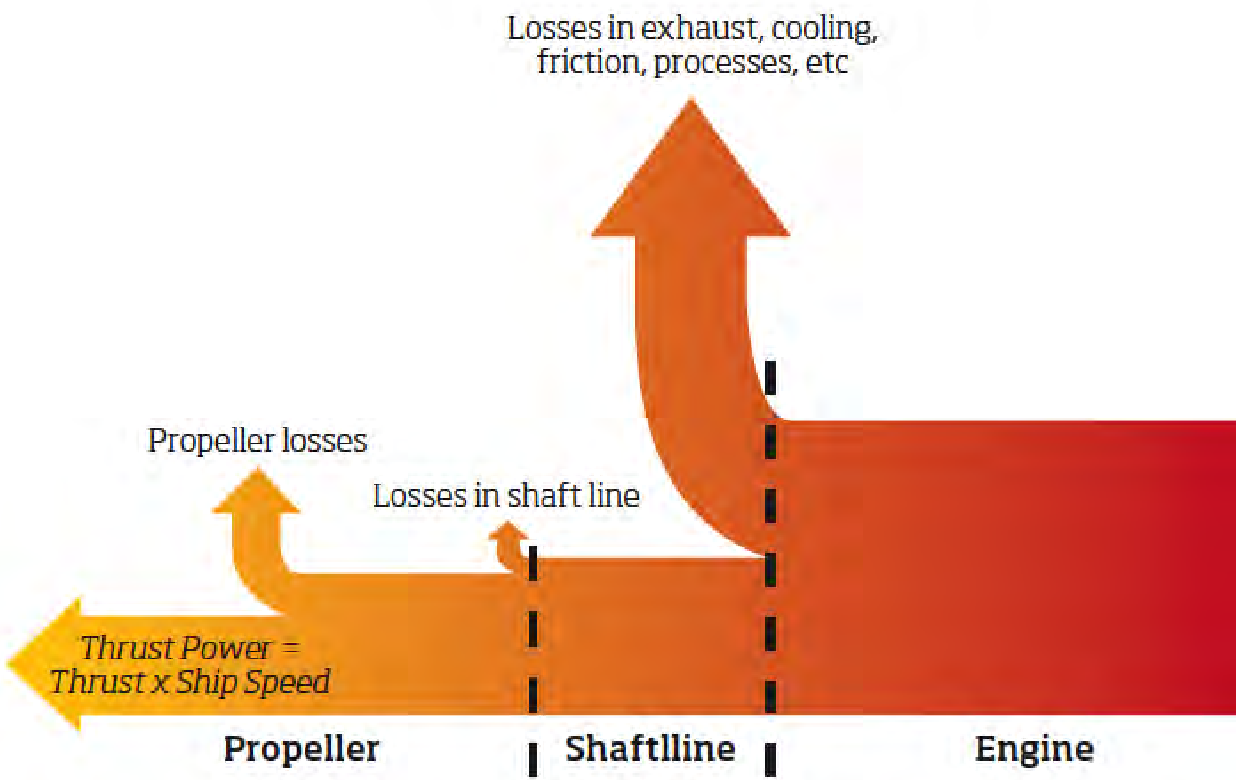
- Most energy efficiency innovation effort is targeted at large scale and new asset shipping.
- Ships under 10,000 dwt transport less than 4% of world cargo but contribute ~25% of all shipping emissions. The needs of small ships is not receiving adequate priority.
- With minimal investment, this is the sector that might provide the quickest results from RE uptake.

Options Available to the Global Fleet for Increasing Efficiency

These are separated into technology options and operational options

1. **Technology options**
   - Motors
     - Increased efficiency designs
     - Waste heat recovery
   - Fuels
     - LNG
     - Methane
     - Hydrogen
     - Nuclear
   - Hull and appendage design improvements
   - Propeller design and coatings
   - Hull coatings
   - Air cushions
   - Auto pilot upgrades
   - Ancillary systems improvements

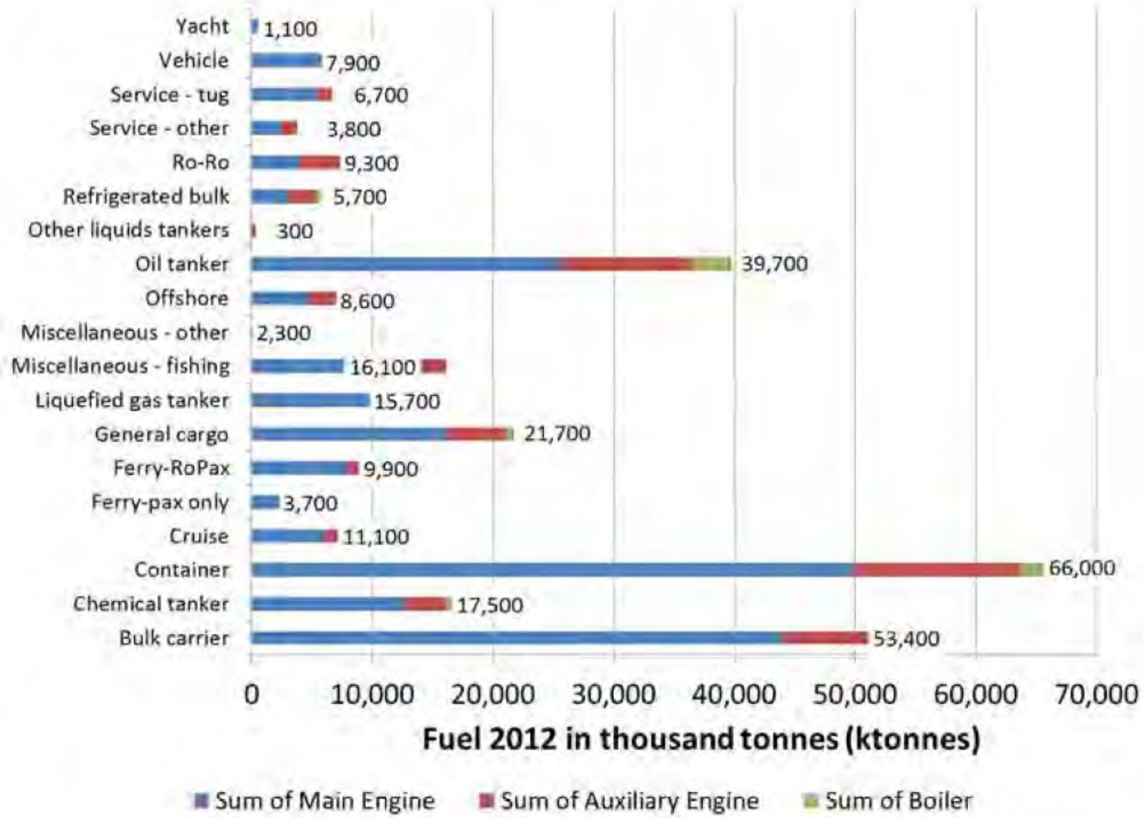
Typical Energy Utilisation in a Container Ship or Bulk Carrier



While options for increasing the efficiency of motors is limited, there are significant energy losses throughout the driven train of a ship that provide potential for efficiency increases

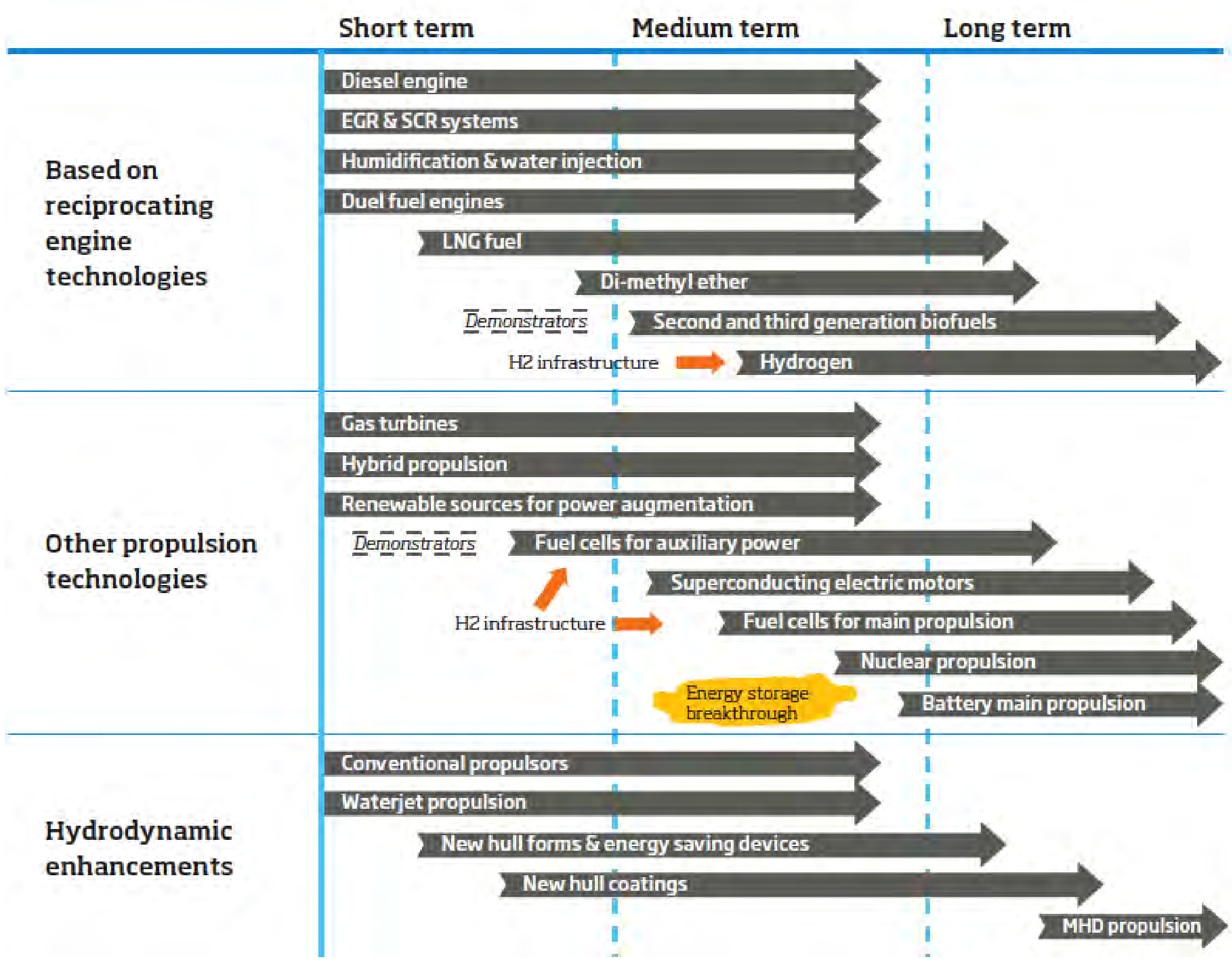
Source: Royal Academy of Engineering, 2012

Annual Fuel Consumption by Ship Type and Machinery Component (main, auxiliary and boiler)



Source: Smith et al, 2014

Potential Phasing of Different Propulsion Technologies in Time



Source: Royal Academy of Engineering, 2012

Common Fuel Efficiency Retrofits

Propeller Boss Cap Fins

Propeller boss cap fins consist of small fixed fins attached to the propeller hub. A standard propeller generates a vortex at the center of its wake. By adding fins to the propeller boss cap, some of this rotational energy can be recaptured and used for propulsion work (Fathom 2013).

- **Projected fuel savings:** 1-3% over the lifetime of the ship, though some manufacturers claim more. (HSVA; Mewis 2006; IMarEST 2010).

Mewis Duct

The Becker Mewis Duct® is a power-saving device developed for full-form slower ships and consists of two fixed elements mounted on the vessel: a duct positioned ahead of the propeller; and an integrated fin system within the duct. The duct straightens and accelerates the water flow into the propeller and also produces a net forward thrust. The fin system provides a pre-swirl to the ship propeller, which increases the propeller efficiency and also reduces the hub vortex, tip vortex and the rotational losses to improve fuel efficiency (Becker Marine Systems).

- **Projected fuel savings:** 3-8% over the lifetime of the ship (Becker Marine Systems).

Rudder Modifications

The rudder generates about 5% of the ship's overall drag. Advanced rudder designs that are coordinated with the design of the ship's propeller are able to improve water flow and reduce drag from the rudder (Fathom 2013).

- **Projected fuel savings:** 3-6% projected fuel savings over the lifetime of the ship (Hollenbach 2011).

Hull Surface Coating

Ship hulls are subject to diverse and severe hull fouling, which can negatively affect the hydrodynamics of a hull by increasing the power required to travel, and therefore the fuel consumption. Protective coatings can inhibit both organic and inorganic growth on ship hulls, as they are designed to both reduce hydrodynamic drag and prevent the build-up of marine organisms (Fathom 2013).

- **Projected fuel savings:** Up to 8% over the lifetime of the dry-dock cycle (circa five years) (Fathom 2013).

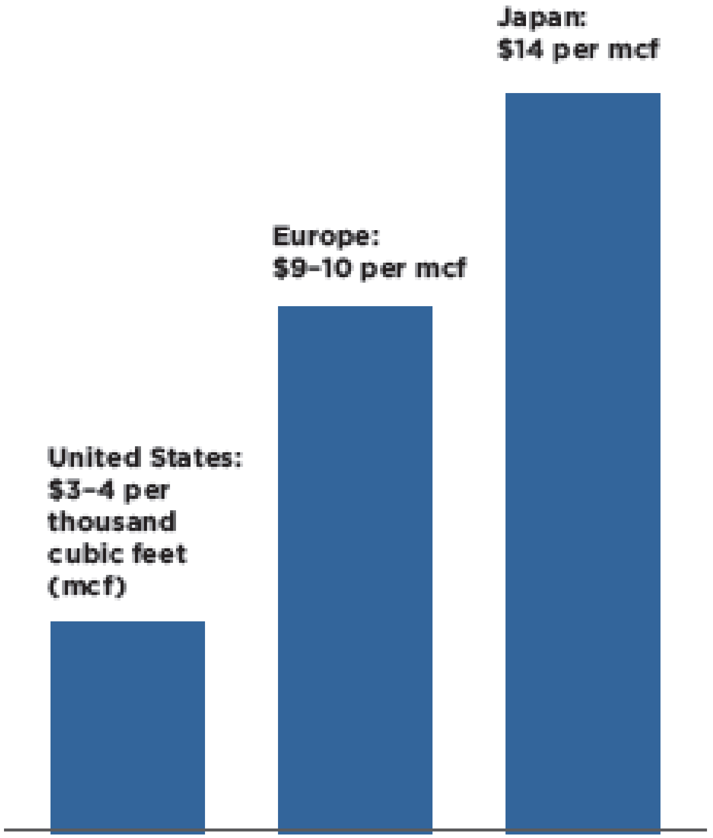
Source: Stulgis et al, 2014

Propulsive energy has changed over time from wind to coal to diesel to HFO.

In the future we will see a more diverse fuel palette available but opinion on the proportion of industry likely uptake of these is mixed.

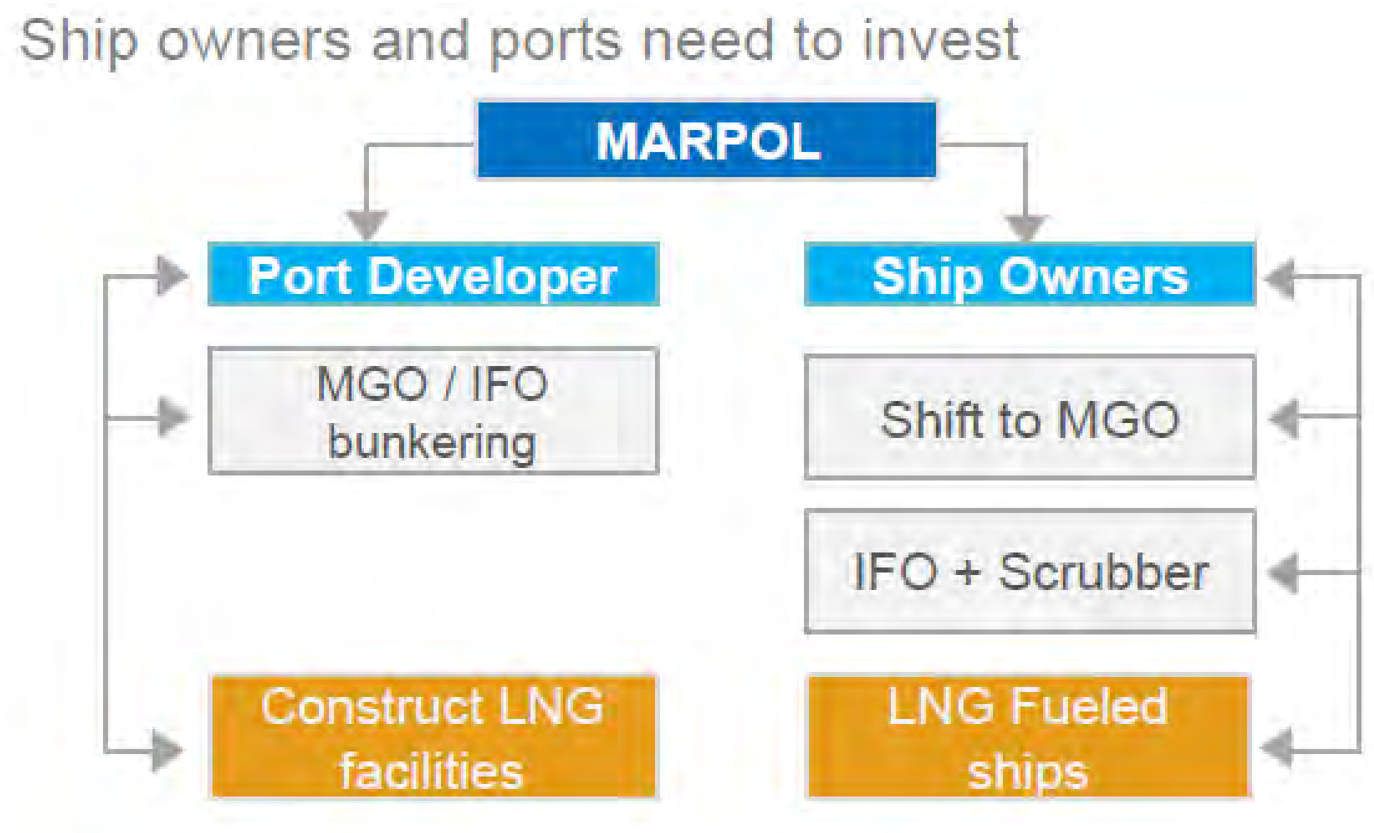
Source: Rolls Royce, 2014

LNG Estimated Regional Price Differences



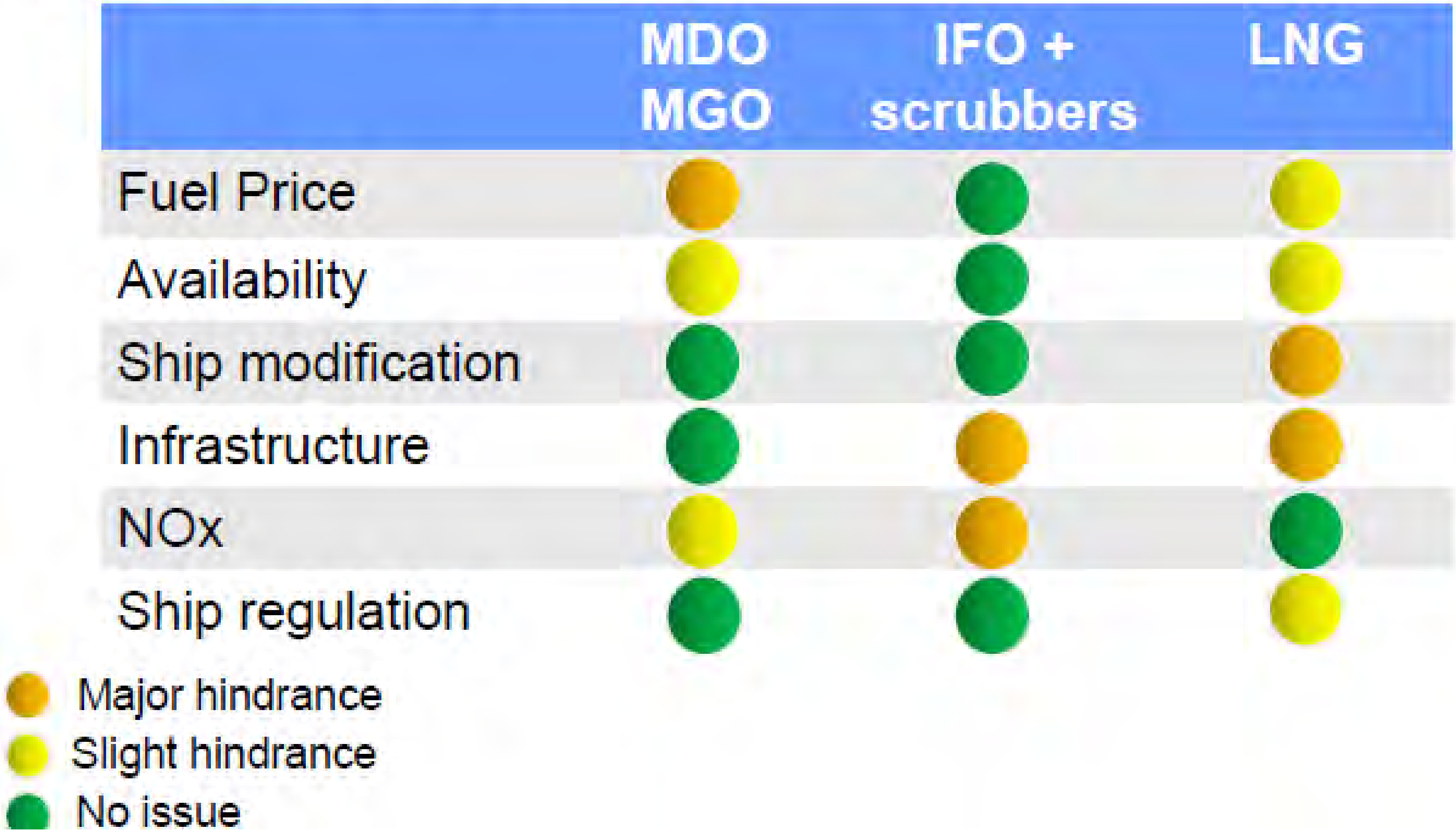
Source: Stulgis et al, 2014

Which Comes first?



Source: Adamchak & Adede, 2013

For the ship owner LNG has to be cheaper than low sulfur diesel and scrubbers

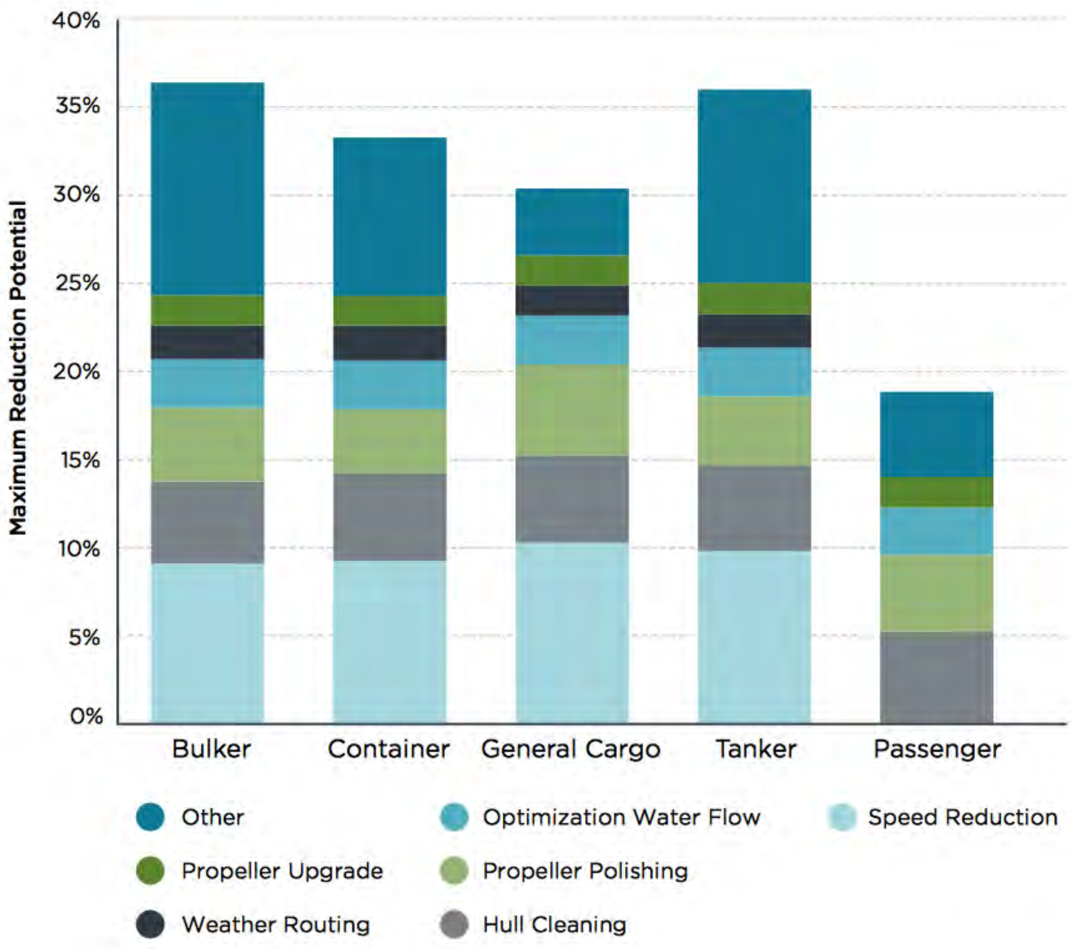


Source: Adamchak & Adede, 2013

Options Available to the Global Fleet for Increasing Efficiency

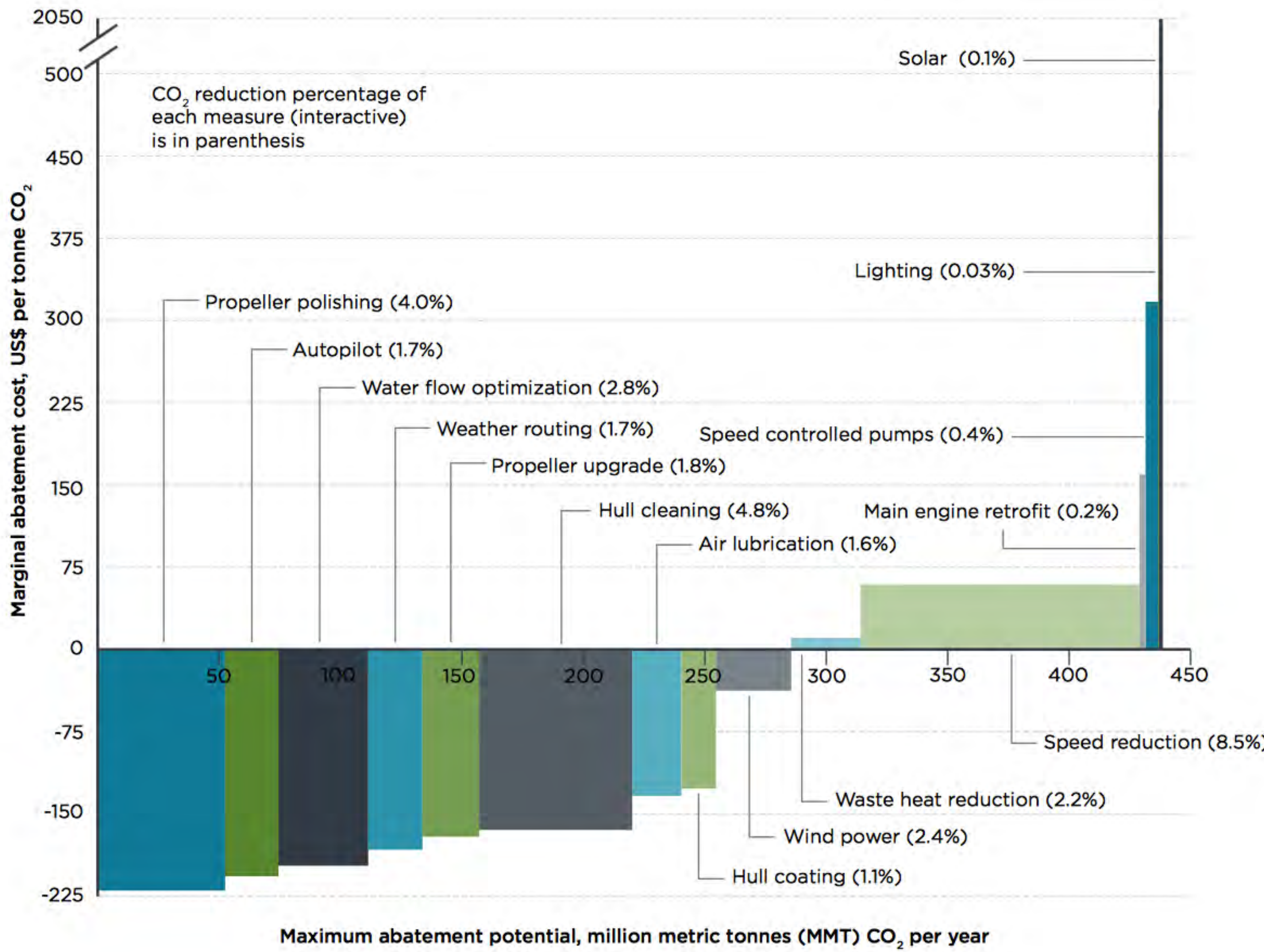
2. **Operational options**
   - Slow steaming
   - Route optimisation
   - Weather routing
   - Just in time scheduling
   - Improved maintenance schedules and procedures
   - Increased crew training all have their part to play
   - Economies of scale with larger ships and ports
   - Increased port and shore side efficiencies

Potential CO_2 Reductions of Technical and Operational Measures by Ship Type



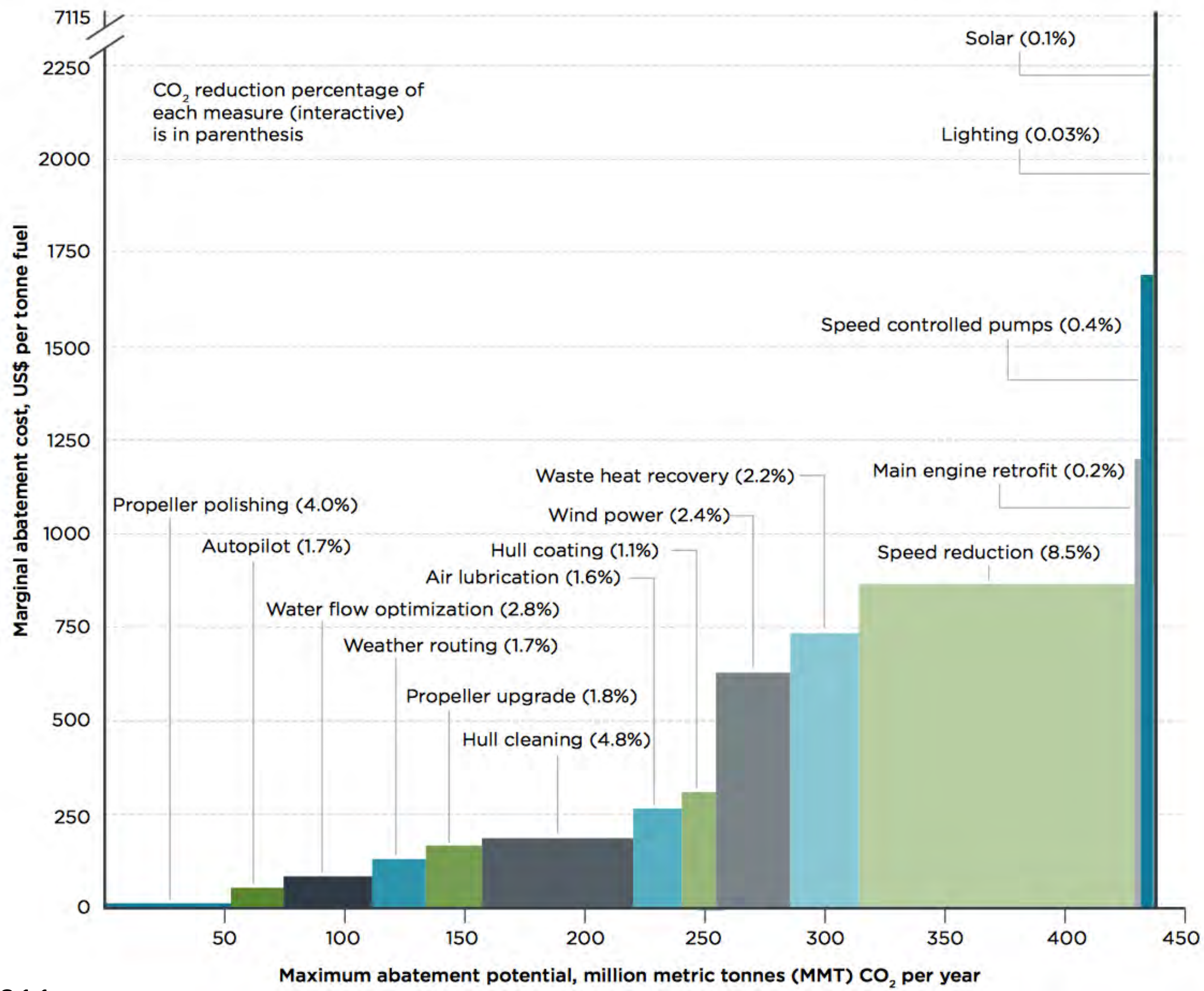
Source: ICCT, 2011

Marginal CO_2 Abatement Curves of Selected Technical and Operational Options



Source: ICCT, 2011

CO_2 Emission Abatement Potential and Cost of Fuel Savings for Selected Technical and Operational Options



Source: ICCT , 2011

Operational savings are considered to be more effective than technology changes

Current Technology Measures – Potential Efficiency Gains

Technology	Potential efficiency gains
Optimal hull maintenance	4%-8%
Propeller maintenance	1%-3%
Fuel injection	1%-2%
Fuel switch from HFO to MDO	4%-5%
Efficiency rating	3%-5%
Turbocharger upgrades	5%-7%
Engine tuning	1%-2%
Waste heat recovery	5%-10%

Efficiency gains
Up to 20%

Operational measures	Potential efficiency gains
Transport management	5%- 40%
Weather routing	2%- 4%
Just in time strategy	1%- 5%
Increase vessel size	1%-10%
Constant RPM	1%- 2%

Efficiency gains
Up to 40%

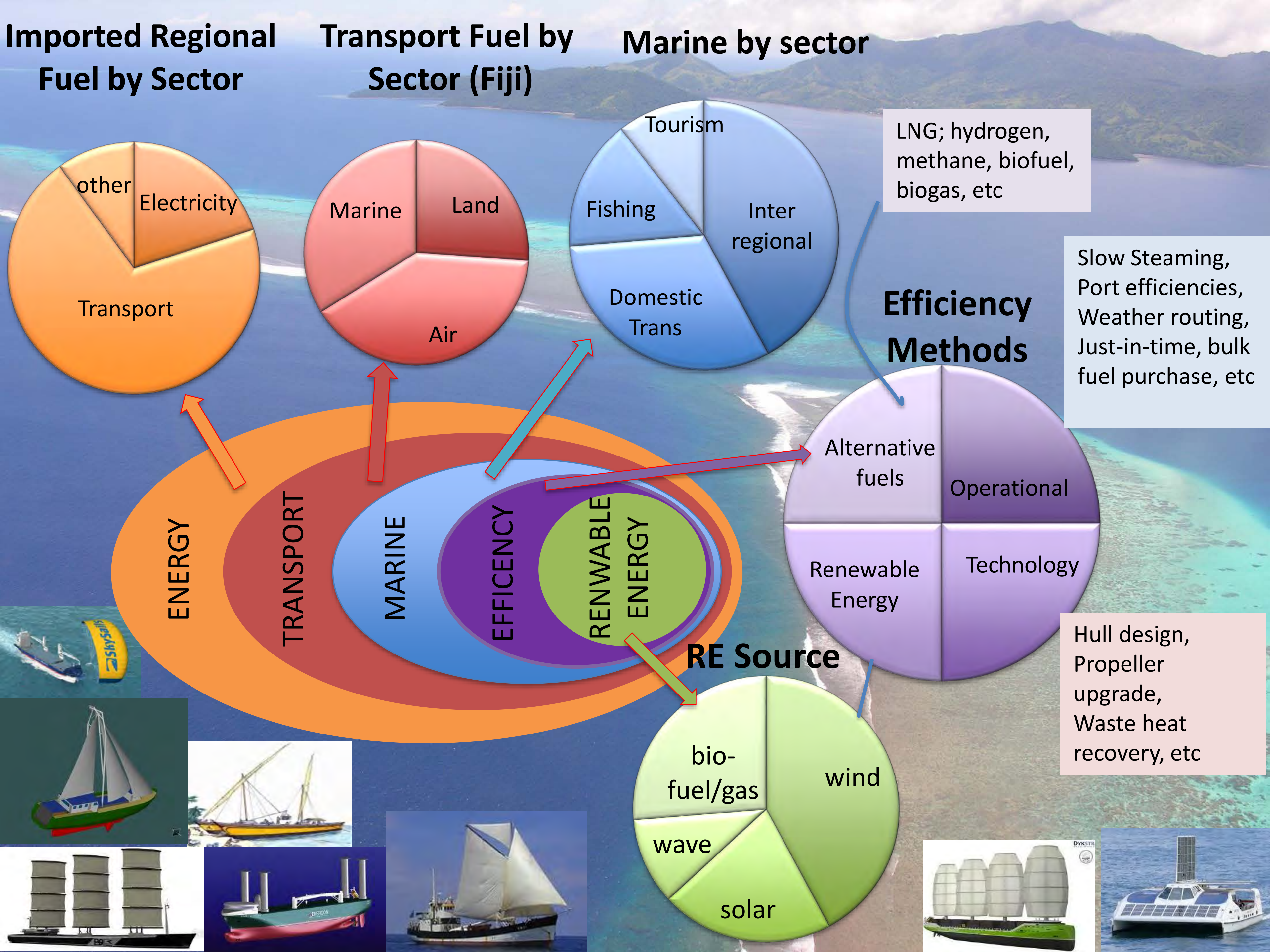
Source: Lloyds Register

Shipping Energy Efficiency for SIDS

- Many technology advances are unlikely to have immediate or affordable applications in SIDS except at the larger-scale and economically-viable level.
- The unique aspects of Pacific shipping limit the range of options available for achieving energy efficiency for shipping in SIDS.
- Technology advances that require substantive front-end financial investment or increased costs and training are unlikely to attract investment for local commercial operators.
- Many technologies require advanced levels of technical competency that are often simply unavailable to SIDS.
- In terms of operational changes, most operators already employ slow steaming as a cost reduction measure as a matter of course. Other options are difficult to access and employ.
- Port-side efficiencies can be targeted but in the main this will only be available to major ports and transhipment centres linked to international routes.

Shipping Energy Efficiency for SIDS

- It is highly likely that as the international industry transforms to meet a new operating environment where efficiency gains and low carbon transition is rewarded and failure to adapt incurs increasing penalties, the disparity between the shipping efficiency of large-scale shipping and that servicing SIDS will increase.
- Solutions for SIDS require investment into R&D; transferal of lessons learnt and advances happening in the broader industry are unlikely to result in real gains of any magnitude unless tailored to localised operating conditions. Few SIDS have the capacity or resources necessary to undertake such research and trials unaided.
- The final slide gives a diagrammatic breakdown of the options available for increasing efficiency and reducing fuel dependency for Pacific sea transport.
  - Orange pie graph shows transport use of imported fossil fuels for the region
  - Red pie graph shows transport use of fossil fuel for Fiji by sub-sector (transport = 66% of Fiji imports)
  - Blue pie graph shows estimated maritime transport fuel use by sub sector
  - Purple pie graph represents the four sets of categories for increasing fuel efficiency
  - Green pie graph represents a range of renewable energy types available



Imported Regional Fuel by Sector
other
Electricity
Transport
Transport Fuel by Sector (Fiji)
Marine
Land
Air
Marine by sector
Tourism
Fishing
Inter regional
Domestic Trans
LNG; hydrogen, methane, biofuel, biogas, etc
Slow Steaming, Port efficiencies, Weather routing, Just-in-time, bulk fuel purchase, etc
Efficiency Methods
Alternative fuels
Operational
Renewable Energy
Technology
Hull design, Propeller upgrade, Waste heat recovery, etc
ENERGY
TRANSPORT
MARINE
EFFICENCY
RENWABLE ENERGY
RE Source
bio-fuel/gas
wind
wave
solar

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