CARBON WAR ROOM

Eric Heisman & Claire Danielle Tomkins

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The Carbon War Room

The Gigaton Throwndown Initiative

Contributors

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Carbon War Room
1150 Connecticut Ave., NW, Suite 620
Washington, D.C. 20036
P / 202.717.8448
F / 202.318.4770

www.CarbonWarRoom.com

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The authors take sole responsibility for the final content of this report, unless otherwise cited.

Author contact information

Eric Heisman, eheismanl@gmail.com

Claire Danielle Tomkins, Ph.D., The Center for the Next Generation, claire.tomkins@tcng.org

CARBON WAR ROOM

GIGATON THROWDOWN

C O N T E N T S

Executive Summary

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A gigaton opportunity is one that can reduce a billion tons of global carbon dioxide (CO_2) emissions in the course of a decade.

Shipping Fleet Transformation is a Compelling Investment Opportunity for the Next Decade

The worst seems to have passed with respect to the commercial shipping decline, ongoing since 2008 as a result of the global financial crisis that saw a pronounced decrease in dry cargo volumes and excess capacity. With 80 to 90 percent of global trade seaborne, the long-term growth trend is strong.[i, ii] Globalization will continue apace and shipping will remain the dominant mode of transport for goods. Shipping fleet transformation, wherein new and existing vessels undergo technology upgrades to enhance performance and reduce fuel consumption, is a compelling investment opportunity given the payback periods (under three years in many cases) and strong fundamentals for the shipping market. Emissions regulations for ships burning bunker fuel are increasingly likely, and demand for cleaner ships already exists and is growing. The shipping industry is poised for technology adoption and investment.

Incentives for Shipping Technology Investment Have Been Strengthening

Rising fuel prices, pollution control through regulatory efforts, awareness of health costs, and competition all drive the market towards technology to increase efficiency and reduce bunker fuel consumption. Oil prices are projected to rise as additional Asian demand comes online, with bunker fuel prices generally rising more quickly than the underlying price of oil due to increased refining. Pressure from ports and communities to reduce pollution from shipping, rising health costs, and potential carbon regulation are also drivers. Until recently, shipping was below the radar as a source of significant pollution, due in part to its extraterritorial operation and positioning by the industry as an efficient transport solution relative to air, rail, and road. Shipping was one of the few industries not included under the Kyoto Protocol. In recent years, the magnitude of shipping pollution and the potential for reduction through innovation has been the subject of several major reports, including the release of the 2007 Intergovernmental Panel on Climate Change (IPCC) report and the 2009 International Maritime Organization (IMO) study *Prevention of Air Pollution from Ships: Second IMO GHG Study.*[iii] A 2007 report by Corbett et al. highlighted the impact on health, with statistics that reveal approximately 60,000 cardiopulmonary and lung cancer deaths per year due to shipping emissions globally – a number that could increase by 40 percent over the next five years due to a rise in shipping volumes.[iv] The Danish Society estimated annual health costs of over $1.1 billion associated with shipping pollution; the U.S. EPA projects $110 billion will be saved in annual health costs under 2015 ECA regulations.[v, vi]

There are Over 130 Technology Companies Focused on Performance Enhancement and Efficiency in the Shipping Space

A number of advanced technology companies are positioned to take advantage of the strengthening incentives for technology investment are. Growth in the shipping market, leading up to the financial crisis, and the drivers outlined above with respect to pollution and efficiency, has inspired a number of technology companies. A recent survey by Fathom Shipping, identifies over 130 technology providers, including a number of early stage companies with new technology offerings.[vii] Major categories of technology include ship hull, propulsion, propellers, engine, software, and alternative energy.

Shipping is a 'Gigaton Opportunity'

A gigaton opportunity is one that can reduce a billion tons (Gt) of global carbon dioxide (CO_2) emissions in the course of a decade (in keeping with climate stabilization targets). For economically viable gigaton opportunities, the market is by definition a large one. Shipping technology is such an opportunity. Shipping pollution is responsible for approximately 3 percent of global carbon dioxide (CO_2) emissions and significant SOx and NOx emissions.[viii] Through efficiency measures, it is estimated that shipping can reduce fuel consumption by between 30 and 60 percent, with the large variance due to differences in models, ages of ships and technological uncertainty. With CO_2 emissions from shipping in 2020 projected to potentially reach 1.6 Gt, a 60 percent efficiency scenario would deliver approximately 1 Gt of CO_2 savings. Current 2010 global emissions are estimated at 48 Gt and projections of business-as-usual (BAU) show emissions increasing to an estimate 56 Gt by 2020.[ix] In order to have a better than 50 percent chance that global warming will be limited to within two degrees Celsius, anthropogenic global emissions of CO_2-equivelant (CO_2e) need to decrease to an estimated 44 Gt of CO_2e annually by 2020.[x] This translates into a required minimum reduction of 12 Gt and likelu more if we want to improve the odds of not exceeding two degrees Celsius in warming. Regulation to this effect is increasingly likely.

The Market for new Shipping Technology is Estimated at Over $20B Annually

The shipping technology market is estimated to be over $20 billion annually for the next decade, under widespread adoption scenarios. This investment aligns the interests of the ship owners and investors in avoiding downside regulatory risk, and the customers with respect to fuel savings and reduced supply chain emissions. Investment in shipping technology satisfies the triple bottom line with positive return on investment (ROI), short payback periods, and a positive net impact of pollution reduction that addresses dangerous climate change and improves health and quality of life for people. The United Nations defines the triple bottom line as "people, planet, profit," or "the three pillars."

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Slow adoption of new technology is a barrier to attracting finance into the shipping technology sector.

New Build Opportunity is Significant

The airline industry has a history of improving efficiency with each new generation of planes. The new Boeing 787 Dreamliner, for example, boasts a 20 percent efficiency increase in comparison to the previous generation of commercial aircraft.[xi] Similar efficiency gains are available in the shipping industry through new design. Capital investment for retooling at the shipyards will be required to take advantage of efficiency enhancements through new design. Passing these costs through to the customer should be possible with financing structures in place, given the cost savings on the operational side. China, Korea, and Japan are the world's primary ship builders, with China poised to become number one.

Market Failures Persist but can be Addressed Once the Right Information is in the Marketplace

Significant market failures currently limit demand for efficiency technologies and inhibit capital allocation to these technologies. Significant market failures include: (1) principal-agent problem: current contracting structure, which passes the fuel bill through to the customer and thereby provides a limited incentive to the shipping company to reduce fuel consumption through technology investment, (2) asymmetric information: customers, and in some cases shippers, are unaware of technology availability and impact, (3) externalities: no health costs or other damages associated with pollution are currently charged to the industry, including CO_2e, and (4) lack of financing to test and deploy technology. These barriers can be overcome in part by providing the market, with better information regarding efficiency potential, technology readiness, and true costs. In some cases, regulation (or the threat of regulation) is a driver, e.g. with respect to pollution and health costs. In anticipation of regulation, smart capital will act as a first-mover and address the problem.

Accelerating Change is Likely to Remain a Challenge

Slow adoption of new technology is a barrier to attracting finance into the shipping technology sector. Commercial shipping is a mature industry that has experienced relatively little change over the past several decades. Interviews across more than three dozen close to the industry experts confirmed that the pace of change is slow. The catalyst must come in part from outside pressure on the industry. Strong leadership by shipping companies that recognizes both competitive advantage and the imperative to change is also important, and companies are showing leadership here.

Transparency, Finance, and Technology Adoption are Critical to Shipping Fleet Transformation

Transparency has helped drive efficiency in many sectors, including appliances and automobiles. The shipping industry still lacks transparency with respect to the efficiency and emissions profile of ships within the fleet. Recently, the Carbon War Room, in partnership with A.P. Moller-Maersk, Teekay Corporation, Alaris Companies, BMT Group, Laurin Marine, Heidmar Inc., and engine manufacturer Wartsila among others, launched the online portal ShippingEfficiency.org, which provides insight into the efficiency of the shipping industry on a per vessel basis (using an A to G rating based on ship type and size). With this information, ship charterers can optimize their choice of vessels, to minimize fuel costs. Shipping fleets are thereby incentivized through the supply chain, competition, or regulation to adopt technology. Finance must be available for technology adoption.

Finance is Needed in Several Areas

There is a role for venture capital to make early stage investments in what is a nascent technology market for new shipping technology. Growth capital will be required as transparency and potentially regulation drive adoption. A significant barrier to technology adoption is the requirement that small companies self-finance the demonstration of their technology. A government fund to support technology demonstration, such as the recent allocation in the U.S. in the fuel sector for proof of concept of initial ethanol plants, would accelerate technology adoption. Once technology is verified, third party financing can help support retrofit activity in the shipping market. In some scenarios, debt financing could be secured by increased cash flows from greater use of the ship and/or from increased revenues as a result of fuel cost savings.

Opportunity for the Global Shipping Fleet

The shipping industry serves as the backbone of global trade. Ships move more than 80 percent of the volume of global trade and are likely to remain in this dominant position. With globalization continuing apace, the demand for shipping will grow over the next decade. As the industry continues its expansion, there are significant incentives for change that have the potential to shape it in a new way.

These incentives for change align with respect to enhanced efficiency and performance of the shipping fleet to reduce consumption of bunker fuel and simultaneously cut costs, pollution, and risk. The result would be improved operation and competitiveness of the industry. The industry is well positioned for a large expansion in technology adoption, to enhance both efficiency and performance for existing and new ships.

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Shipping imposes significant costs on human health and the environment, and changes to the industry to address these costs are likely to be increasingly pressure.

This expansion creates a major global investment opportunity, with investment required to support a new wave of technology – including venture capital investment into early-stage technology firms, financing for ship owners (for upgrades of existing ships) and investment into the fleet, financing for ship builders (for new technology applications), and project finance for technology companies as they expand. We estimate the market for new technology associated with a transformation of the shipping fleet to be over $20B annually.

Incentives for Change

In many ways, the shipping industry is due for change. The industry is mature, complex, and generally conservative. The complexity and size of both the industry and its regulatory bodies isn't conducive to change, compared to newer and smaller industries, but increased pressure for change by ports, customers, and regulators cannot be avoided indefinitely.

Shipping imposes significant costs on human health and the environment, and there will likely be increasing pressure on the industry to address these costs. The cost of crude, tightly coupled with the price of fuel for ships (bunker fuel), is projected to rise, and as regions implement shipping Emission Control Areas (ECAs) that require cleaner, costlier bunker fuel, overall prices will rise. This creates an incentive for efficiency and for cost-savings in other areas. The volatility of fuel prices is also projected to increase, providing an additional incentive for alternatives. As a critical component of almost all global supply chains, shipping has enabled global economic growth. It now presents a compelling case for investment to address its current issues.

The industry has avoided confronting its emissions profile and impact until quite recently. In the late 1990s, during negotiations of the Kyoto Protocol, shipping managed to avert attention from its own carbon footprint by arguing that shipping served as an efficient transport solution. Shipping is indeed less carbon-intensive than other transport. However, while this may be the case, shipping alone is responsible for over 3 percent of CO_2 emissions, and total emissions from the sector are increasing.[xii]

The 2007 IPCC report, delineating national and international shipping emissions, raised the profile of shipping emissions and signaled the inevitable inclusion of shipping in an international regulatory framework for carbon dioxide-equivalent (CO_2e) emissions.

The case for regulation is mounting, as not only the impact of CO_2 emissions but also the impact of harmful greenhouse gases (GHG) such as Nitrogen Oxide (NOx) and Sulfur Oxide (Sox), and particulate matter from shipping become better understood. A 2007 study released by Corbett *et al.* from the University of Delaware estimated that the emissions of particulate matter from shipping are responsible for over 60,000 deaths a year near heavily trafficked port regions.[xiii] Additional investigation is underway with regard to the impact of black carbon emitted from ships on the melting of the ice pack in the Arctic and the Himalayas. When black carbon settles on ice, it absorbs heat (due to its black color) and can cause or accelerate melting.[xiv]

The development of new technology and the increasing awareness of existing eco-efficiency solutions gives the industry and investors an opportunity to manage the downside risk of regulation and take a leadership stance, while realizing the economic gains of enhanced efficiency (and reduced fuel consumption) and performance.

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Technology Arrival

There are significant efficiency and performance enhancements available for ships. Current estimates of the potential impact of new technology on reducing fuel consumption and emissions range considerably but are consistent in their suggestion that there are major savings available. According to Gillian Reynolds of Lloyd's Register, in presentation to the EU House of Commons, "The potential for technical measures to reduce has been estimated at up to 30 percent in new ships, and up to 20 percent in existing ships or ships constructed using present technology."[xv] The IMO substantiates this, reporting that the potential range of efficiency gains is 25-75 percent, with the large variation reflecting the heterogeneity of the shipping fleet and the remaining technological uncertainty.[xvi] Det Norske Veritas (DNV), a shipping industry rating agency, offers a more conservative estimate of the potential for cost-effective savings available for the fleet today at 15 percent, but acknowledges it could increase to 30 percent by 2030.[xvii] Furthermore, they assess the potential at 60 percent by 2030 if all available measures were utilized, without respect to cost effectiveness. In the Carbon War Room analysis, the efficiency gains from cost-effective technology (with a payback period of under three years) applied to containerships were estimated at over 60 percent.

Technology Categories

There are over 60 technologies and over 130 technology providers in the shipping space.[xviii] A number of veteran technology providers, including companies such as Wartsila, Mitsubishi and Caterpillar, are increasingly offering eco-efficiency products. The start up space is also active, with a number of new companies founded in the last five years. Categories of efficiency technology relevant to existing ships include the following:

Ship Hull • coatings, optimization, and maintenance
Propulsion • alternative propulsion systems, e.g. wind-powered
Propellers • new propellers, maintenance, and optimization
Engine • recovery system, gas-fuelled engines, and engine upgrades
Software • weather routing software

Examples of these technologies and their estimated efficiency potential are presented in Table 1 below. Ranges in efficiency estimates reflect in part the difficulty to obtain good estimates due to operational variances, as well as remaining technology uncertainty.

Technology	Estimated Efficiency	Source
Ship Hull		
Anti-fouling coating	0.5% - 9%	Wartsila, IMO, Green Ship of the Future, Hempel
Foul release coating	1% - 9%	Wartsila, IMO, Hempel
Nanotech coating	9% - 15%	IMO, NYK, Corbett
Propulsion*		
Solid-wing sail	4% - 21%	Wartsila, NYK
Slettner rotor	20% -30%	Wartsila, GreenWave
Towing kite	3% - 35%	Wartsila, IMO, Skysails
**All three propulsion technologies are wind-powered*		
Propellers*		
Pre-swirl devices		
Propeller cap turbine	2% - 5%	IMO, Green Ship of the Future, Ship Propulsion Solutions
Costa propulsion bulb	2% - 4%	Ship Propulsion Solutions
Rudder thrust fin	1.6% - 6%	IMO, Green Ship of the Future, Ship Propulsion Solutions
Post-swirl devices		
Simplified compensated nobble	0.1% - 10%	Wartsila, IMO, Green Ship of the Future, Ship Propulsion Solutions
Hydrodynamic partition plate	2% - 4%	Ship Propulsion Solutions
Fore-propeller hydrodynamic fin sector	4% - 10%	IMO, Ship Propulsion Solutions
Thrust shaft bracket	4% - 7%	Ship Propulsion Solutions
**Different configurations of both pre- and post-swirl devices can be used to attain greater efficiency gains than any single device*		
Engine		
Cooling water pumps	0.2% - 2%	Wartsila, IMO, Green Ship of the Future, Desmi
Plate heat exchanger optimization	8% - 12%	APV
Waste heat recovery system	7% - 15%	Wartsila, Green Ship of the Future, ABB, Siemens
Software		
Weather Routing	0.1% - 10%	Wartsila, IMO, Green Ship of the Future, Applied Weather
Energy Management		
Alternative Energy		
LNG Fuel*	4% - 30%	Wartsila, Green Ship of the Future
Solar panels**	2% - 4%	Wartsila, IMO, NYK
**Used to power auxiliary engines and as a blended fuel*		
***Used to meet electrical power needs onboard*		
Other		
Air Cavity System	0.9% - 15%	Wartsila, IMO, NYK, Green Ship of the Future, DK Group
Cold Ironing (Shore Power)**	2% - 4%	Siemens, CleanAir Marine Power, Cavotech
**Used to meet power needs of ship while in port; ports using shore power include L.A., Long Beach, Antwerp, and Gotherburg*		

Table 1 Examples of technologies by category. There are a range of technologies that provide significant estimated efficiency enhancement.

Ship Hull • *Coatings, Optimization, Maintenance, and Design*

What Works

The surface roughness of the ship increases over time due to cracking and coating damage, rust, and biological fouling. This layer grows in thickness along the sides of the hull, increasing the viscous (frictional) resistance. Monitoring hull coatings to ensure uniform thickness and smoothness is essential. Using divers or automated systems to brush the entire hull, or to just focus on critical parts, in order to remove organic buildup and inconsistencies can significantly reduce resistance. Typically every three-to-five years, foul-release and anti-fouling coatings are reapplied to achieve correct uniform thickness and smoothness on the hull. The more frequently that these can be applied the better. Increasing docking frequency to brush the hull can offer efficiency gains, as well. Artificial air-lubrication technologies including polymers, air bubbles and air cavities have been suggested to reduce resistance more than 5 percent. Recently there has been discussion of high potential efficiency hull coatings based on nanotechnology. Preliminary data suggests this technology can yield approximately 15 percent reductions in viscous frictional resistance, which would be significant. Finally, ships with small Length/Beam ratios (L/B ratios) can be retrofit with after-body flow-control systems such as guide vanes in front of the propeller and wake-equalizing ducts, which increase propulsive performance. Hull practices can be applied to the range of ships and are most effective for tankers and bulk carriers. Ship operators can adopt best management practices to check hull performance including performance monitoring through data reported from the ship, and speed trials.

Challenges

Ports have introduced restrictions for the practice of hull-brushing, due to the threat of invasive species. The performance of most coatings is reduced over time and the product must be reapplied. Foul-release coatings are high cost, and require dry-docking to apply. There are a limited number of dry-docks which could limit overall availability for the procedure. Additional research is needed into air-lubrication technologies and nanotechnology coatings.

Propulsion • *Alternative Propulsion Systems*

What Works

Alternatives to the screw propeller, which integrate the propeller and rudder units, have adopted creative descriptions such as "duck feet," "whale tail," "fish tail," and "goose feet." These systems are based on a more complex motion and have the potential to increase efficiency.

Challenges

Complicated engineering associated with these systems can result in higher costs to build, install and maintain. Additional research is needed to reduce engineering costs in order to justify efficiency gains.

Propellers • *New Propellers, Maintenance, and Optimization*

What Works

Efficiency gains can be obtained by reducing the revolutions per minute (RPM) and increasing propeller diameter such as with fixed-pitch (helical), controllable-pitch (CP), and vertical axis (azipods) propellers options. Fitting new large diameter propellers on existing ships with smaller diameters can offer an estimated 5-10 percent efficiency gain. In addition to new propellers and propeller upgrades, devices are available which recover rotational energy in propeller flow and pre-rotation of inflow into the propeller such as coaxial contra-rotating propellers, free rotating vane wheels, ducted propellers, pre- and post-swirl devices, and integrated propeller and rudder units. Relying in part on testing data (as many of the devices are still in the testing phase), the range of efficiency gains for each is typically between 1-10 percent. However, some technologies have demonstrated gains of between 15-20 percent. Propeller maintenance, including polishing and pitch optimization, can decrease fuel consumption by as much as 3 percent. Scenarios tested include cargo ships, bulk carriers, tankers, and container ships.

Challenges

A number of devices are still in the testing phase. Maintenance is often overlooked or underperformed, reducing the effectiveness of the technology. Upgrades are appropriate for a limited number of ships, and it may be difficult to identify the potential to upgrade a propeller. Additionally it may be difficult to document performance following an upgrade. As a result, ship owners may not be motivated to pursue this option. Clearance requirements between the propeller and hull, as well as propeller submersion requirements, can restrict certain increases in propeller diameter. Additionally, propellers operating at low RPM's may require additional reduction gear in order to connect to the main engine.

Engine • *Recovery Systems, Gas-fuelled Engines, and Engine Upgrades*

What Works

Engine recovery systems for low- and medium-speed engines such as Organic Rankine Cycle systems and thermo-efficiency systems can increase engine power approximately 10 percent by reducing heat loss. Payback has been estimated at five years for many of these options. Gas-fuelled engines, particularly natural gas, have been demonstrated to increase shaft efficiency around 6 percent. These engines have higher exhaust temperatures and therefore higher recovery potential. Engine upgrades can reduce fuel consumption by increasing power output. Upgrades include turbochargers, parts to increase compression ratios, and parts to minimize the loss of combustion efficiency.

Challenges

Engine work requires a significant amount of engineering work to design and install upgrades, and is therefore expensive. Additional research is needed on engine performance enhancement to reduce fuel consumption.

Software • *Weather Routing*

What Works

Cost efficient software which charts the most appropriate course for a vessel is currently available and can reduce fuel consumption by an estimated 5-10 percent. Weather routing is a cost effective way to significantly reduce fuel consumption.

Challenges

Ship Captains may choose to follow their own course and disregard the route provided, potentially lowering if not erasing the efficiency gains.

Other

What Works

Other energy efficient system upgrades include speed-control pumps and fans, and substituting steam with electricity for cargo pump power. However, to date the evidence suggests that these upgrades have limited impact on the overall efficiency of the ship.

Alternative Energy • *Solar, Biofuels, Wind, LNG, Nuclear*

The feasibility of alternative energy for ships depends greatly on not only availability and price but also practical suitability for use on board the ship, as well as regulations. Alternative energy today is restricted to powering electrical needs on board or providing auxiliary power. Options are discussed below.

Solar cells

Solar cells could be interesting from a long-term perspective when efficiency levels reach 45 - 60 percent for heating purposes, as a partial source of power or combined with/integrated into sails.[xix]

Challenges

Currently, solar cells only sufficiently cover a fraction of auxiliary power.

Biofuels

There is an increasing demand for biofuels in the transport sector, which may increase their desirability for shipping. Biofuels can be blended with diesel or heavy fuel oil.

Challenges

Biofuels are significantly more expensive than fossil fuels, and there may be issues including stability, acidity, lack of water-shedding, plugging of fuel filters, and wax formation.

Wind- or sail-assisted power technologies

Wind, or sail assisted power technologies include traditional sails, solid-wing sails, kites, and flettner-type rotors. Recent studies demonstrate that these technologies could supply additional supplementary power. Best scenarios exist in North Atlantic and North Pacific regions. Studies conducted at the Technical University of Berlin have demonstrated that under normal circumstances the typical savings using wind power may be 5 percent at 15 knots and up to 20 percent at 10 knots. This study also showed that with optimal weather routing in the North Atlantic and given the best ship with best sail type, savings can reach 15 percent at 15 knots and 44 percent at 10 knots.

Challenges

There is currently only limited full-scale experience and additional research is needed.

Liquefied natural gas (LNG)

LNG is a proven solution, which has demonstrated CO_2 reductions of 15 percent.[xx] Currently direct-drive LNG propulsion four-stroke medium-speed engines are already on the market and at least 10 ships are currently in operation. LNG is also lower cost than distillate fuels and about the same as residual fuel oil. It is an especially promising option solution for regionally operated tankers.

Challenges Challenges include storage space issues that can result in some loss of cargo space due to the relatively greater volume of LNG compared to traditional fuel, and limited availability at bunkering ports. LNG dramatically lowers NOx and Sox emissions but does cause an increased level of methane (CH_4) emissions.

Nuclear

Marine reactors have been developed and used with success, e.g. to power naval submarines.

Challenges

It is generally considered too high-cost – not just from an equipment perspective but also due to added labor costs. Operating nuclear power onboard requires highly-trained nuclear engineers. Ramping up a nuclear solution would also take time, due in part to the limited availability of engineers and need for training.

Additional energy savings are available through operational adjustments, with examples provided in Table 2 below.

Operation	Estimated Efficiency	Source
Virtual Arrival	1% - 21.5%	IMO, Maersk, BP Brostrom Anchors
Speed Reduction ("Slow Steaming")	10% - 33%	Wartsila, IMO, NYK
Removal of Turbo Charger*	1% - 2%	Man Diesel
Energy Management**	2.25% - 10%	Wartsila, IMO
Hull Cleaning***	1% - 15%	Wartsila, IMO, Dive Fair Helen, Commercial Dive Services
D-rating or engine tuning	0.1% - 5%	Wartsila, IMO, Torn, Ship Propulsion Solutions

** During slow steaming. ** Of onboard electrical . *** Brushing, hydroblasting – spot blast or full blast*

Table 2 Examples of operational strategies to enhance efficiency. Generally requiring low or no upfront investment, there are a range of operations that provide significant estimated efficiency enhancement.

Payback Periods

In a review of over 30 new technologies, Carbon War Room estimated that 75 percent had average paybacks of less than three years. Technologies with some of the shortest payback periods, of under 1 year, include weather optimization software and advanced paint (ship coating) offered by International Paint, Henpool, and others, that reduces friction and offers an estimated 9 percent fuel savings. Despite the availability of these technologies, some of which have been independently verified with respect to efficiency claims, uptake has been gradual to date.

Other low hanging fruit with respect to technology upgrades include plate-heat exchanger optimization and certain configurations of pre- and post-swirl devices. Operational enhancements that payback within a year, on average, include propeller and hull maintenance, the removal of the turbo changer during slow steaming, and energy management.

Shipping Fleet Transformation

Transformation of the shipping fleet refers to the upgrade of all existing ships in the fleet (for which an upgrade is a sound investment) and the enhanced design of all new builds to reduce fuel consumption, reduce pollution, and improve performance. An ambitious but achievable goal would be to transform the shipping fleet over the course of the next decade. Such a transformation presents a major investment opportunity.

Upgrade Potential of Existing Ships

Technology upgrades to existing ships stand to significantly enhance efficiency and performance, while addressing the downside risk of regulation. Upgraded ships have enhanced competitiveness, as they boast lower fuel bills and are in accord with current initiatives to green the supply chain.

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In close analogy to the buildings sector – where increased awareness regarding the problem and opportunity with respect to energy consumption and emissions by buildings has stimulated growth in green building technology companies and practices – awareness regarding the opportunity in the shipping industry has helped stimulate technology expansion.

It is natural to perform upgrades to existing ships while ships are in dry dock. Ships are typically required to go into dry dock twice every five years, for inspection of the hull, maintenance, and repairs. The intervals between dry docking are gradually becoming longer, due to technological improvements. A ship typically stays in dry dock for a week. This provides an opportunity for technology upgrades. Upgrades while a ship is in dry dock can take as little as a several hours, in the case of coatings applied to the outside of ships or software installation, to as long as a few weeks for installation of new devices, e.g. new propellers or sails.

Availability of dry docks is not a bottleneck for technology upgrades to the existing fleet. There are over 4,235 ports worldwide; these ports have extensive dry dock infrastructure. The existing dry dock capacity could easily handle turn-over of the entire fleet over a 5-year period (or less) if technology upgrades became mainstream. In addition, new dry docking facilities are planned for China, Qatar, and India.

New Build Potential

For new ships, there is considerable flexibility with design components that are otherwise unalterable for existing ships. This includes new aerodynamic and hydrodynamic design components and new hull design.

In close analogy to the buildings sector – where increased awareness regarding the problem and opportunity with respect to energy consumption and emissions by buildings has stimulated growth in green building technology companies and practices – awareness regarding the opportunity in the shipping industry has helped stimulate technology expansion.

The re-design and enhancement of new builds requires the cooperation of the existing shipyards. Most shipbuilding takes place in Japan, Korea, and China. In these countries shipbuilding is a prominent national industry, and any change to the shipyards would involve the government. Significant investment will be required for retooling to build newly designed ships. Japan has signaled leaders aggressively leading the way with respect to efficient ship design, while Korean shipyards are also committing to new efficiency goals in design.

Ship Design • *Aerodynamic and Hydrodynamic Ship Design*

Through design improvements, propulsion and hull optimization can reduce drag from propeller loss and hull friction in most tankers and bulk carriers, and many general cargo vessels. For large ships, systematic streamlining of the superstructure could potentially reduce power consumption by 2-5 percent, and potentially an additional 1-2 percent by keeping topsides uncluttered and streamlined by repositioning cranes, applying spoilers over funnel and deck-houses, and designing more streamlined deck-houses.

There are challenges for new ship design, including requirements concerning the amount and type of payload and dimensions of terminals and ports could potentially limit the resistance optimization achieved on large ships through such measures. Also, widespread adoption of design improvements may be limited due to existing designs owned by specific yards.

Gigaton Opportunity

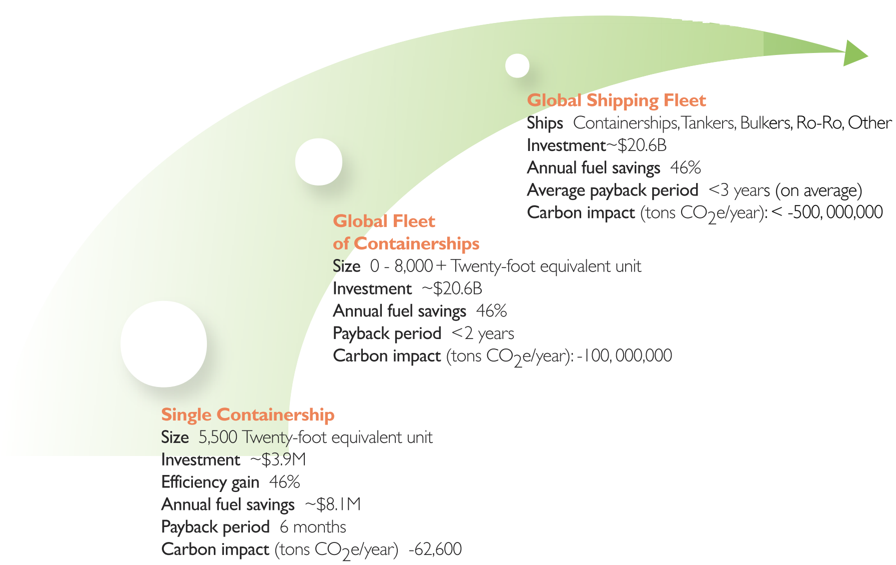
A gigaton opportunity is one that can scale up, within a decade or less, to reduce annual emissions of carbon-dioxide equivalent (CO_2e) by at least one billion tons, or one gigaton. As emissions reductions principally come from decreases in fossil fuel consumption, they have the net effect of reducing additional pollution (NOx, SOx, particulate matter, carbon monoxide (CO), among other pollutants), thereby addressing human and environmental health issues. In addition, gigaton opportunities generally reduce resource intensity, thereby enhancing planetary sustainability. **When the economics work, gigaton opportunities are compelling investment opportunities that offer significant scale potential in the global market.** Gigaton opportunities tend to naturally aligned with health and environmental regulation, thereby protecting against downside regulatory risk. Transformation of the shipping industry is a gigaton opportunity.

The shipping industry (excluding domestic shipping) consumes between 225 and 340, with an average estimate of 276, million tonnes (Mt) of fuel annually, based on 2007 numbers, and is responsible for approximately 3.3 percent of global CO_2 emissions (based on 2007 estimates) and significant SOx and NOx emissions.[xxi] International shipping is responsible for the bulk of these emissions – 82 percent based on 2007 numbers – and continues to expand more rapidly than domestic shipping. The CO_2e emissions from shipping in 2020 are projected to be close to 1.3 Gt. Reducing bunker fuel consumption in shipping would have significant impacts on pollution.

The world shipping fleet is comprised of roughly 100,000 vessels.[xxii] A group of these vessels – containerships, tankers, and bulk carriers – comprise 22 percent of the total fleet but account for the majority of fuel consumption and for approximately 63 percent of total CO_2 emissions.[xxiii] Containerships alone account for roughly a quarter of all ship emissions, while comprising only 5-6 percent of the current fleet. The remaining vessels – roll-on/roll off (ro-ro), cruise, ferry, cargo, and fishing vessels – account for the rest. The containerships, tankers, and bulkers are rightly the focal point of initial efforts to enhance efficiency and performance, while reducing emissions.

Possible CO_2 Savings and Investment Potential for Global Shipping Fleet Efficiency

Figure 1 Significant Efficiency Potential Translates Into Billions of Dollars in Fuel Savings for Containerships, and the Global Fleet. Containerships represent the most attractive market for efficiency investment, due to high fuel usage leading to rapid payback periods. For the high efficiency scenario explored below, the estimated fuel savings are over $8M per ship and the payback period is under six months.



Gigaton Analysis • *An Example*

The analysis considers the scale up of technology across containerships to achieve projected fuel savings of 60 percent over a 10-year period (in the high case), and associated emissions reductions of 40 Mt of CO_2e per year by 2020.

Containerships, tankers, and bulkers account for roughly 25 percent of all vessels, and approximately 61 percent of total shipping emissions. Bulkers have limited economics, based on our model, at current price points for relevant technologies, but will be important as technology prices fall. Containerships are particularly promising as early-adopters, given their fuel consumption. Below are results for containerships. Containerships and tankers represent the greatest leverage point in the industry, with the greatest share of emissions and fuel consumption per ship and hence the strongest initial payback profile.

For the analysis, current technologies were bundled into three scenarios based on cost, efficiency potential, risk, market acceptance, and complexity of application. Three bundles were defined for both new build and retrofit tankers and container ships. Relevant technologies vary for different ship type and new builds; each bundle is therefore unique. The three scenarios represent a 'low investment' case focused on easy-to-apply technologies and a short payback period, a 'mid investment' case, and a 'high investment' case in which more technology risk is assumed with additional potential savings and longer paybacks (still less than three years).

The analysis presents a challenge to dissect the shipping industry to determine appropriate bundles of technologies to apply to vessels for efficiency and performance upgrades. The technology bundles used here were developed in close consultation with industry experts and review by and expert naval architect. They represent one of many plausible scenarios and are intended for demonstration purposes only.

As discussed, there is a wide array of newly available technologies, many still in the pilot phase, presenting many possibilities. The industry is also in an early phase of technology adoption, with a notable lack of agreement on performance metrics and data on most technologies.

Fleet Breakdown by Vessel Category

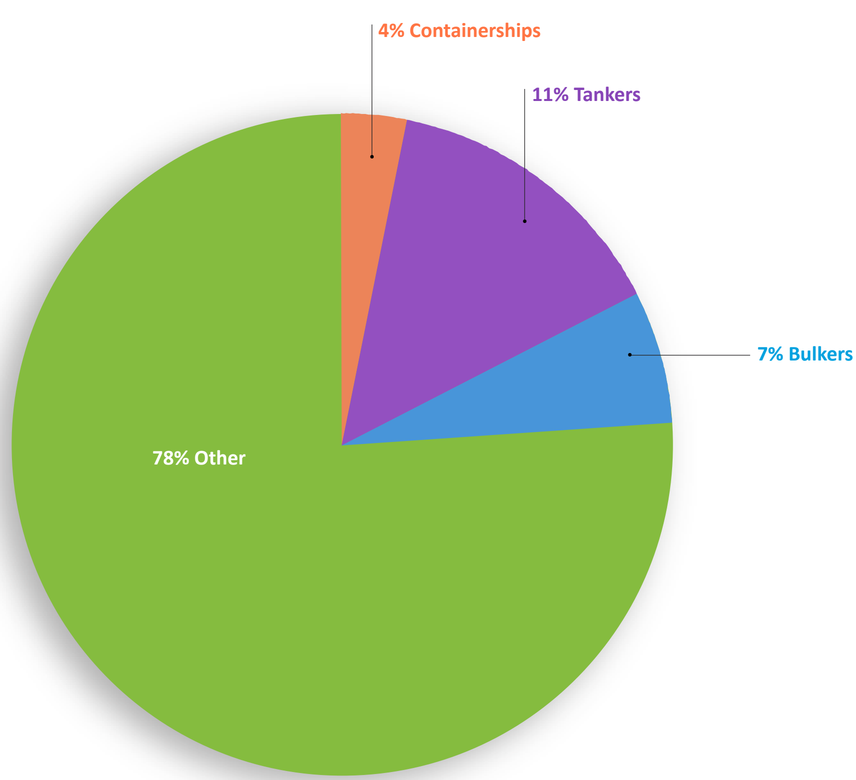


Figure 2 Containerships represent just over 4 percent of the fleet but account for over 20 percent of the fuel consumption. The economics of fuel efficiency technologies are strongest for containerships, followed by tankers. As costs come down over time (and with growing applications), these technologies will look increasingly attractive for other vessel categories.

As discussed, there is a wide array of newly available technologies, many still in the pilot phase, presenting many possibilities. The industry is also in an early phase, with a notable lack of agreed upon performance metrics and data on most technologies.

The model assumes that upgrade activity for existing ships begins to accelerate in 2012 and continues through the decade. In 2014, the first wave of shipyards have retooled for application of new efficiency technology and design, adoption accelerates initially and then continues through the end of the decade. This is a highly ambitious – but achievable – scenario were all new ships are built with new technology from 2016 onwards. The results are illustrated in Figures 1 and Figure 2 below.

Assumptions regarding fuel consumption by containerships and tankers were based on IMO data from 2009. According to IMO's 2009 report *The Prevention of Air Pollution from Ships*, the average containership consumes 42,100 tonnes of fuel per year. [xxiv] According to Lloyds Register, the average tanker consumes 27,000 tonnes of fuel per year, while the average bulk carrier consumes 9,000 tonnes of fuel per year. [xxv] There are currently 12,930 tankers, 7,392 bulk carriers, and 4,138 container ships.[xxvi]

Figure 1 below shows the potential CO_2 savings from upgrading new and existing ships over the next decade. The model assumes that efficiency savings of over 60 percent can be realized on a per-vessel basis under the 'optimistic' efficiency case (based on the technologies outlined in Table 3), resulting in estimated savings of over 230 Mt of CO_2 in 2020.

Notably scrubbers were not included in the technology bundles. They have only indirect market value (for customers interested in greening the supply chain). However, scrubbers do represent an additional investment area and are important for meeting air quality standards. Under Marpol Annex VI guidelines, sulfur release from fuel will be restricted from 4.5-3.5 percent by January 1, 2012, with a goal of 0.5 percent by 2020.

Possible CO_2 Savings from Containerships by 2020

Figure 3 Efficiency savings of over 60% are potentially available through technology upgrades to new and existing ships, resulting in over 230 megatons of estimated CO_2 reductions by 2020. This analysis assumes that the number of ships upgraded per year is constant at 500 units starting in 2012 and is for illustrative purposes only and not intended as a market projection.

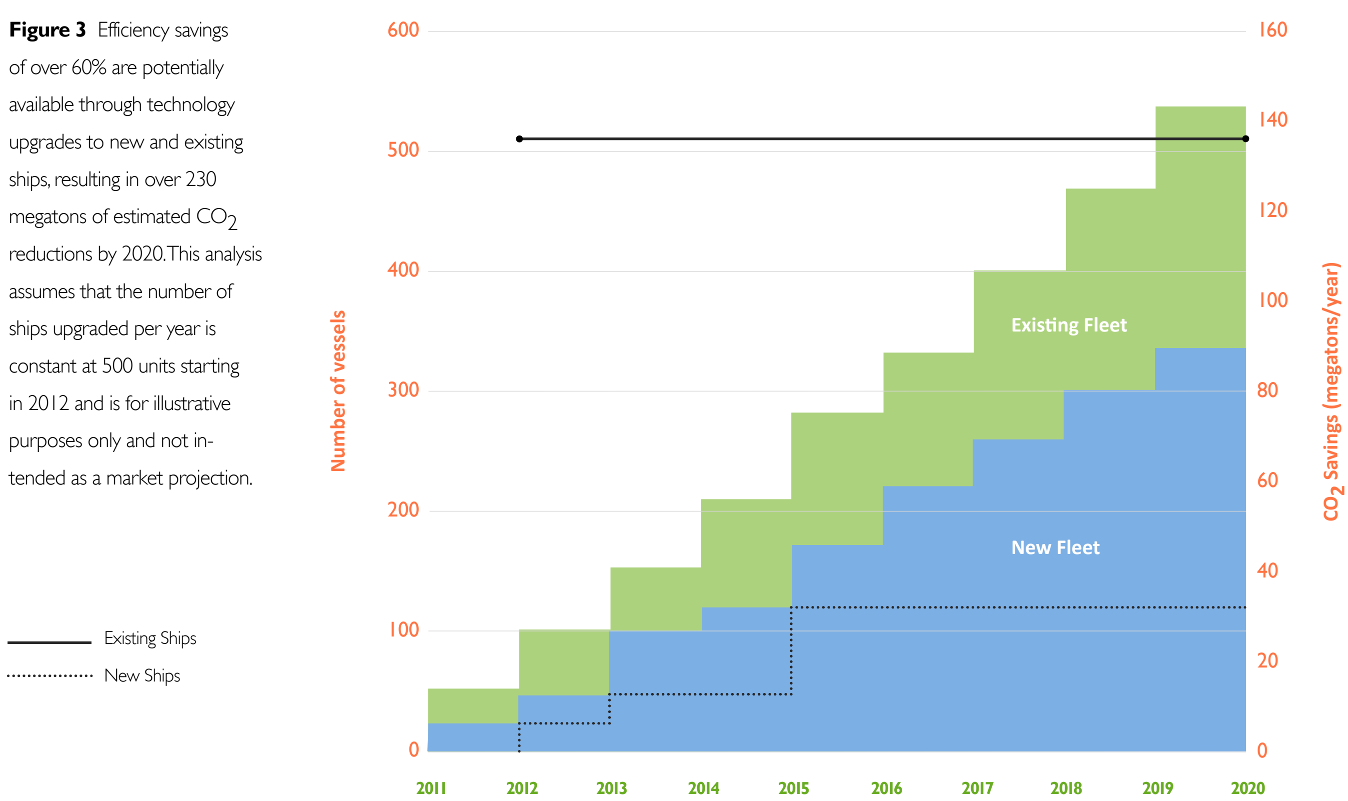


Figure 4 There is significant variance with respect to the potential efficiency gains from different individual technologies and bundles of these technologies. Validating achievable efficiency targets is an important step in this nascent market.

Range of CO_2 Savings by 2020 from Containerships Upgraded with Technology Bundles

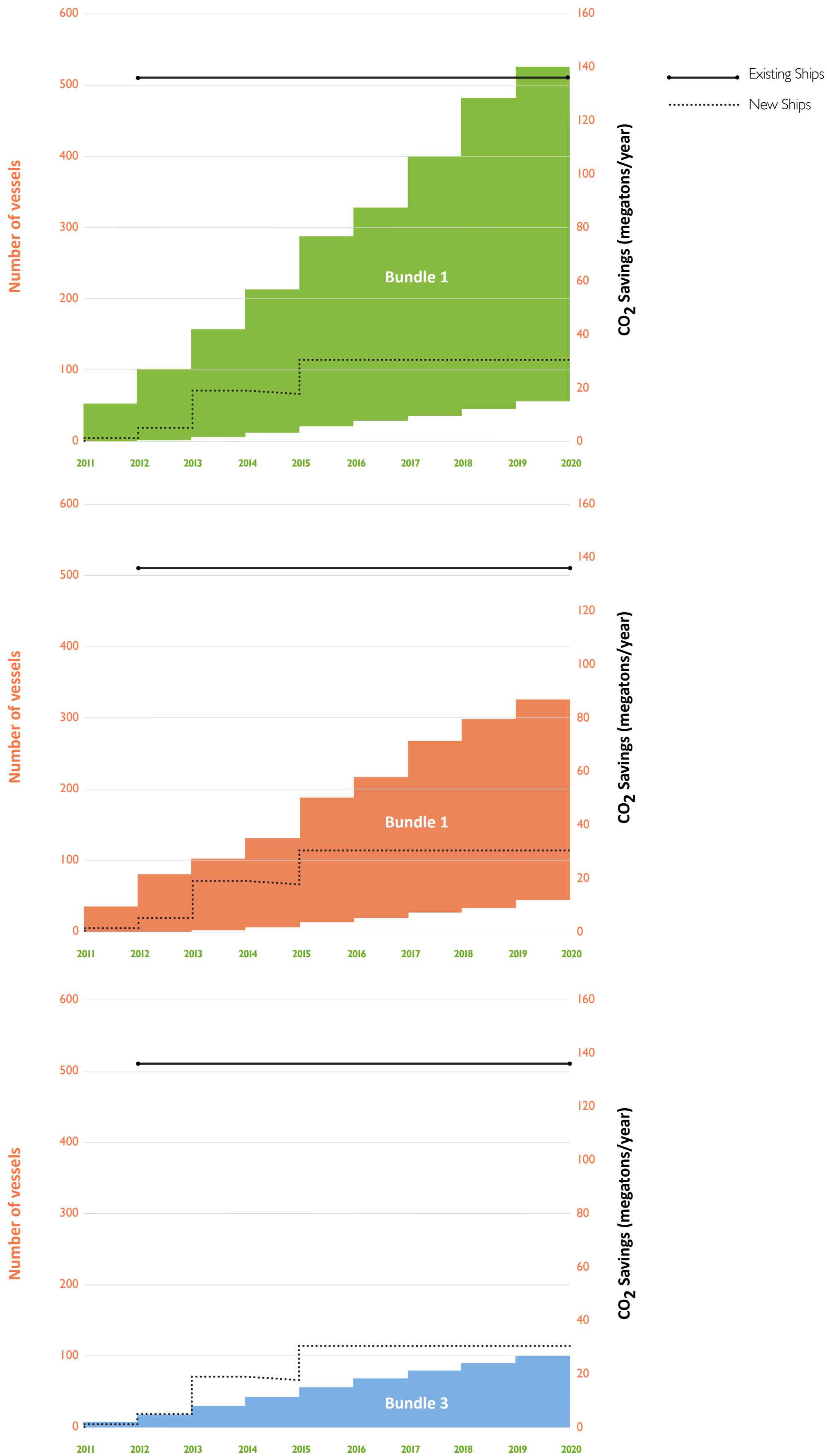


Table 3 below depicts summary statistics for the technologies included in the analysis.

Technology	Estimated Cost	Estimated Efficiency	Maturity
Container Ship • *New Build*			
Bundle 1		Low 1% Avg 7% High 13%	
Weather routing software	$21,450/yr (avg. $1,900/mo)	0.1% – 10%	Market Ready Deployments: 3000+
Model testing to optimize bow	$60,000	2 %– 10%	Market Ready
Bundle 2		Low 13% Avg 23% High 32%	
Optimal propulsion	$271,500	1 – 10%	Range from Pilot to Mature
(application of pre/post swirl devices,			Deployments: 0 to100s
Boss Cap Fin, other)			
Waste heat recovery	$1,250,000	8 – 10%	Market Ready
Foul-release coating	$490,000	.5 – 2%	Range from Market Ready to Mature
Optimized plate heat exchanger	$150,000	8 – 12%	Range from Pilot to Market Ready
Bundle 3		Low 20% Avg 40% High 60%	
Towing kite	$1,700,000	10 – 35%	Pilot Deployments: <10
Container Ship • *Retrofit*			
Bundle 1		Low 0% Avg 5% High 9%	
Weather routing software	$21,450/yr (avg $1,900/mo)	.1 – 10%	Market Ready Deployments: 3000+
Increase frequency of propeller polishing	$41,250	.5 – 3%	Mature
Bundle 2		Low 7% Avg 16% High 25%	
Optimal propulsion	$271,500	1 – 10%	Range from Pilot to Mature
(apply pre/post swirl devices,			Deployments: 0 to 100s
Boss Cap Fin, etc.)			
Waste heat recovery	$1,250,000	8 – 10%	Market Ready
Foul-release coating	$490,000	.5 – 2%	Range from Market Ready to Mature
Optimized cooling pumps & fans	$96,500	1 – 2%	Range from Pilot to Market Ready
Bundle 3		Low 14% Avg 30% High 46%	
Towing kite	$1,700,000	10 – 35%	Pilot Deployments: <10

Table 3 Technology bundles evaluated for the analysis of containerships. Cost estimates are based on a 5500 TEU Container Ship.

Global Gigatons

Current 2010 emissions are estimated at 48 Gt and projections of business-as-usual (BAU) show emissions increasing to an estimated 56 Gt by 2020.[xxvii] In order to have a better than 50 percent chance that global warming will be limited to within two degrees Celsius, global anthropogenic emissions of CO2e need to decrease to an estimated 44 Gt of CO_2e annually by 2020.[xxviii] This translates into a required minimum reduction of 12 Gt, and more if we want to improve the odds of not exceeding two degrees Celsius in global warming.

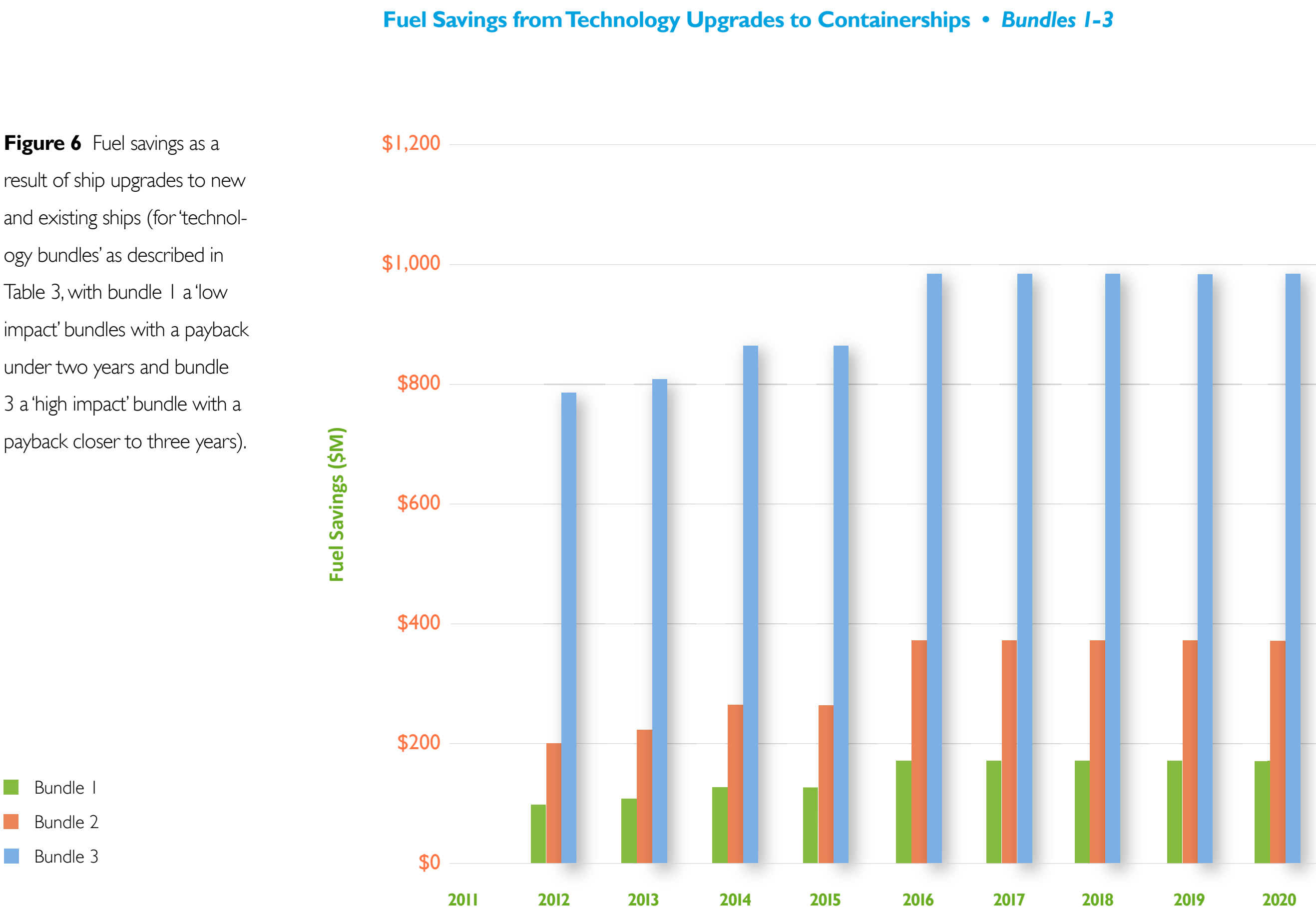
Investment Opportunity

Figure 4 illustrates the investment requirement for the 'high efficiency' case (also referred to as 'bundle 3'), with a turn-over of the entire shipping fleet over the next decade. Total estimated annual investment is close to $2.46 billion. With adoption scaled up across the rest of the shipping sector, we estimate that the market for new technology could be close to ten-times that amount, or over $20 billion. The containership market for new technology is roughly 10 percent of the total market. Notably, the market for technology is likely to expand given the incentives discussed, and while 'bundle 3' represents a possible scenario, it is intended as an example not a prediction. As additional technologies come online and fuel savings are demonstrated, we expect the market to expand. The $20 billion figure is conservative, even though the adoption scenario is aggressive.

Figure 5 illustrates the fuel savings from technology adoption, on an annual basis. Payback periods for all technology bundles are under three years.

Figure 5 Required annual investment for technology upgrades. Assumptions are that 500 existing ships are upgraded per year, starting in 2012. This assumption is for illustrative purposes only.

Figure 6 Fuel savings as a result of ship upgrades to new and existing ships (for 'technology bundles' as described in Table 3, with bundle 1 a 'low impact' bundles with a payback under two years and bundle 3 a 'high impact' bundle with a payback closer to three years).



The cost savings on fuel are compelling. As discussed, payback periods are in most cases under three years in length.

Economics of Optimal Technology Bundles

While many technologies cost more for containerships due to size, the higher fuel consumption by these ships translates to a faster payback. In many cases, this is substantial enough that container ships have the shortest payback time for a given technology investment. Thus, the conclusion is that focusing investment on container ships and tankers offers the most substantial efficiency gain for the lowest cost.

Another observation is that in many cases, different technologies can be applied to vessels under new build and retrofit scenarios. However, the investment cost and payback for most optimal technology bundles do not appear to vary substantially. Therefore, our investment recommendations focus on technologies, which can be applied to new build and retrofit container ships and tankers. We assume that the efficiency gain will remain constant and the cost-to-value of savings ratio will therefore remain constant as well, since value of savings is based on fuel saved from applying technologies at a particular efficiency level.

Cost-effectiveness is critical. Some in the shipping industry have raised concerns that increased costs due to emissions regulation will lead to freight being transported by road instead of sea – although this concern is only relevant in short sea shipping.

Market Failures

Market failures in the shipping industry currently limit demand for efficiency technologies and inhibit capital allocation. These market failures can be classified as follows: (1) principal-agent problem, (2) externalities, (3) lack of information, or imperfect information, and (4) lack of financing. These barriers can be overcome in large part by providing the market with better information regarding the efficiency potential and associated cost savings of new technology and operations, technology readiness, and payback periods. In some cases, regulation (or the threat of regulation) is the obvious driver, e.g. with respect to pollution and health costs incurred by current operations within the shipping industry. Smart capital will act in anticipation of these measures to address the problem.

Market Failure #1 • *Principal-agent problem*

The principal-agent problem – a well-documented market failure formalized in the political science and economics literature – arises when there is a conflict of interest between a principal (usually an owner or employer) and an agent (usually a tenant or an employee). The conflict often arises due to lack of information (imperfect or asymmetric information) and, to some degree, lack of control. In shipping, the conflict of interest is between the ship owners and the charterers, or customers, with regard to efficiency practices. Charterers, who typically pay the fuel bills associated with shipping goods, would prefer to pay a lower fuel bill. The ship owner is indifferent. Lowering the fuel bill is possible through investment in efficiency technologies and efficient operations. However, ship owners have not been motivated to invest heavily in new efficiency technologies that reduce fuel consumption due to the fact that they typically pass all fuel costs through to their customers, the charterers, as part of the shipping contract.

As the charterers lack information with respect to what is possible with regard to efficiency and fuel savings, they cannot apply pressure on the ship owners. In addition, there is a general lack of transparency with regard to which ships are more fuel-efficient than others and are therefore lower-cost and preferable.

This is a familiar incentive problem, also seen in the commercial real estate sector where building owners' are not incentivized to invest in energy efficiency upgrades that would ultimately save their tenants money on utility bills.

Correcting the Principal-Agent Problem

There are several approaches to addressing the current principal-agent problem in shipping. One approach would be a change in contract structure, such that some portion (if not all) of fuel costs are covered by the shipping companies. This would have the effect of aligning incentives for fuel conservation. However, such a change would be dependent on the ability of shipping companies ability to manage fuel price risk, and both parties agreeing to a shift in a long-standing contract structure.

Another approach comes from the commercial real estate sector, which also suffers from a principal-agent problem. The approach is to revise the value proposition. For example, commercial buildings derive significant value from the occupancy rate. A building's occupancy rate is improved by offering tenants a more attractive deal, e.g. a lower monthly utility bill than that available at an equivalent building. By driving the occupancy rate, an investment in energy efficiency can therefore drive building valuations – and this is ultimately what the owner cares about. Similarly, a ship with a lower overall fuel bill relative to another equivalent ship is more attractive to customers wishing to charter a ship and can drive the utilization rate. For a ship owner, an investment in efficiency can payback through higher utilization rates of the ship. For the adoption of efficiency technologies throughout the shipping industry, this approach requires a first-mover (or two) to drive investment through competition. It also requires some measure of transparency such that charterers can identify the most efficient ships.

Pressure to increase efficiency can come directly from the customers of the shipping companies, who currently pay the fuel bill and also care in many cases about "greening the supply chain." Large, influential companies such as Wal-Mart, Gap, Adidas, Home Depot are among the shipping industry's principal customers, and many of the cost increases and fluctuations due to fuel prices end up getting passed to them as customers. With detailed information on the available cost reductions, and environmental benefits, through efficiency technologies, many of these companies are likely to become activists for investment in these areas. As carbon accounting becomes more stringent, and these companies include the shipping portion of their supply chain within their own GHG emissions inventories, which is so often over-looked, the pressure for greater efficiency will only increase. Satisfying client demands for cost savings and carbon savings stands to become a competitive issue for shipping companies, particularly as awareness by influential shippers of the latent emissions savings that could be realized profitably increases.

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Satisfying client demands for cost savings and carbon savings stands to become a competitive issue for shipping companies, particularly as awareness by influential shippers of the latent emissions savings that could be relinquished profitably within shipping increases.

Overall, correcting the underlying information problem – which requires (a) transparency in the marketplace with regard to current performance and relative efficiency of ships and (b) awareness of available options (technology, operations) to enhance efficiency, and thereby generate cost savings through the value-chain – is an important first step. The Carbon War Room recently launched ShippingEfficiency.org with support from a number of innovative leaders in the shipping industry, including A.P. Moller-Maersk, Teekay Corporation, Alaris Companies, BMT Group, Laurin Marine, Heidmar Inc., and engine manufacturer Wartsila, among others, to help address the first issue.

Notably, additional tools to support transparency and measurement of available cost savings and carbon savings are needed. These include a standard for translating potential shipping efficiency gains into widely-recognized transportation cost savings for charterers, a more detailed carbon accounting for the shipping industry, in order to tie operational and technological efficiency enhancements for ships to customer goals with respect to greening their supply chains, and emissions data combined with monitoring for companies to use in assessment with their GHG profile.

Market Failure #2 • *Externalities*

None of the human health and environmental costs associated with shipping are currently charged to the industry or its customers. As discussed, the study by Corbett *et al.* estimated that particulate matter emitted by the shipping industry is responsible for an estimated 60,000 cardiopulmonary and lung cancer deaths a year. Corbett's study reported that under the current regulatory circumstances, "Annual mortalities could increase by 40 percent by 2012." [xxix] The environmental harm includes the contribution to global warming and dangerous climate change poised by carbon emissions from the shipping industry, as well as SOx and NOx emissions and black carbon.

Correcting Externalities

The classic approach to treating externalities is to impose a regulatory framework – in this case, either a strictly-enforced cap on pollution by the industry or a tax, such that the true cost is taken into account. For the shipping industry, regulation would need to address both the health and environmental costs, with the latter even more difficult to estimate in monetary terms.

International regulation has been slow to come to the shipping industry, and carbon emissions regulations are generally only found regionally. Regulatory bodies including the IMO and the U.S. Environmental Protection Agency (EPA) have taken some action and are considering additional regulation. It is only a matter of time until standards are tightened given growing awareness of the environmental and human health harm.

International Regulation

The IMO is the regulatory body governing the shipping industry. Individual countries, states, and ports can establish their own policies to curb emissions from domestic and coastwise shipping. However, in order to significantly impact emissions, policies from the IMO will be necessary. Significant opportunity certainly exists through a wide spread of policy models.

The IMO has implemented MARPOL Annex IV which regulates emissions from particulate matter and from NOx and SOx emissions. Currently, the IMO is considering additional regulatory measures that address additional pollutants and include design measures for new build ships. Enforcement for regulation must occur at ports and Port State Control outlines the specifications for how countries must check incoming ships including what the ships need to abide by. These measures may be followed by ports in industrialized countries, but there is skepticism with regard to the measures employed by developing countries. This poses a significant challenge to the efficacy of potential regulations with respect to achieving the desired global impact.

According to Jasper Faber, Coordinator of Aviation and Shipping at CE-Delft and contributor to the 2009 IMO report *Prevention of Air Pollution from Ships*, policy instruments for curbing shipping emissions can be market-based, command-and-control, and/or voluntary and should address the following areas: GHG emissions, operational efficiency, design efficiency, fuel lifecycle carbon emissions, and other.[xxx]

A preference is likely to be given to market-based regulatory tools moving forward. The IMO found cost-effective options with the highest environmental effectiveness are market-based instruments, which directly target maritime GHG emissions, includes emissions trading, emissions levy and fuel levy.[xxxi] In contrast to this finding, command-and-control standards aimed at ship design are less effective in terms of both cost and emissions reduction, and voluntary measures are not very effective for reducing emissions, yet are very cost-effective. The IMO found that a cost-effective command-and-control measure, a mandatory limit on the Energy Efficiency Design Index for new ships, can provide incentive to improve design efficiency. However, this option does not incentivize improvements in operations and only covers new ships, thus limiting the environmental effect. Faber and others have emphasized that the identification, examination, and mitigation of undesired impacts under all scenarios are of significant concern, especially considering the industry's international governance and framework.

Action by Ports

Ports have significant power to influence shipping practices and associated emissions and efficiency, particularly when acting collectively. Acting alone can be viewed as a competitive disadvantage, since tougher regulations at one port may influence shippers to simply use a nearby port with less stringent regulations. Emissions from ships are typically a big issue for ports, given the concentrated human health and environmental impacts. An example of active ports, the Port of Los Angeles and the Port of Rotterdam are involved with developing solutions to address the emissions problems.

Some ports are currently examining smart-scheduling programs to help reduce the number of ships that speed to ports and then have to wait in line for a slot to be serviced, burning fuel and generating pollution while waiting. The new procedures have been dubbed 'Virtual Arrival' and entail bringing ports, shipping companies, transportation companies, and charterers together to create a new method for arriving ships, where ships can contact ports in advance and create a schedule for arrival. By doing so shippers could plan their journeys more efficiently, enabling ship operators to travel at substantially lower speeds to reach ports, thereby reducing fuel consumption and associated emissions. The efficiency gain through speed reduction and efficient scheduling is substantial.

The extremely inefficient practice of 'full steaming' to ports, only to have to wait extended periods for docking, became the industry standard during the economic boom period prior to the 2008 financial crisis. Following the economic downturn and the rise in fuel prices, shipping companies have become more aware of the excessive waste associated with this behavior. The Virtual Arrival concept would reinforce this awareness.

Notably, this inefficient practice is often encouraged contractually, in some cases. Some charterers have contracts in place with shipping companies that include provisions instructing the shipping companies to travel at the fastest speed to reach ports. These contracts would need to be amended, and there is concern that changing this single contractual provision would create issues throughout the entire contract, necessitating revisions and possible renegotiation of the contract. These revisions would occur necessarily if there is a regulatory shift.

Developments in the following areas would support regulatory action by the ports: (1) ability for better ship routing and utilization scheduling, likely through expert software, (2) port participation and a coordination channel available for scheduling at ports, such that ships that have made arrangements to arrive at a certain time would receive preferential treatment if the ships can document that they travelled at lower speeds to reach the port, and (3) new efficiency-focused contracts between charterers and shipping companies which account for port scheduling and other efficiency considerations. Current discussion within the IMO is focused on evaluating these policy options.

Regulatory Challenges

In terms of implementing regulation, the globalized regulatory framework presents a formidable challenge, as there are so many varying interests at the discussion table.

Typically the nations are divided, with industrialized regions, including Europe and North America, favoring a proactive approach built around technical measures and market-based instruments. However, China and Saudi Arabia head a small group of objectors who argue for "common but differentiated responsibilities" between developed and developing nations. In the case of the Saudi's, compensation for the potential impact regulation would have on its oil sales is at issue.[xxxii, xxxiii]

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There is significant lack of information on actual emissions from the shipping industry, both as a whole and at the level of individual vessels.

The dialogue at IMO engagements also tends to focus on the specific needs of countries, rather than focusing on global emissions regulation. In the past, proposals for emissions reductions have ended up on the backburner. There are also information holes that still need to be addressed, in order to ensure that the proposed policy would in fact have the desired impact. For a conservative industry, the unintended consequences of policy action are a major concern.

Market Failure #3 • *Lack of Information*

Also referred to as 'imperfect information,' lack of information impedes markets from functioning. Below are three informational barriers to market function, not including the lack of information available on current ship efficiency and on available efficiency technology and operations that was discussed in the principal-agent section above.

1 There is significant lack of information on actual emissions from the shipping industry, both as a whole and at the level of individual vessels. This lack of information has several consequences, including the inability of countries to establish emissions trading schemes and to include shipping emissions in such schemes, and the inability of charterers to accurately reflect the lifecycle emissions of shipped goods. Failing to account for these lifecycle supply chain emissions in sustainability evaluations leaves a big piece of the emissions pie unaccounted for – and is a major problem. Shipping isn't currently included in the sustainability targets and objectives of major global charterers. This is one of the reasons shipping has managed to avoid significant oversight and regulation to date. There are currently available estimates of total shipping emissions, but it is widely known that these estimates, including the source breakdowns, have a high standard of error.

A lot has been accomplished on this front over the past three years. For the IMO's 2009 report *Prevention of Air Pollution from Ships: Second IMO GHG Study 2009*, leaders across the industry joined together to address the issue of GHG emissions from ships. The publication of this report was a critical initial step for the industry in establishing perspective on the current emissions scenario, the critical problems, and potential solutions.

The IMO's comprehensive 2009 report accomplished the following:

- Established a baseline regarding the current state and potential future scenarios of emissions from shipping
- Identified the key innovative policy, technology, and operational options that exist
- Described potential future emissions scenarios, and
- Highlighted the effectiveness of MARPOL Annex IV, the primary regulatory measure addressing emissions from ships.

Missing from the report is an assessment of how to effectively address the existing barriers to change to fully realize the technological gains available to the industry.

2 Carbon accounting and sustainability information throughout the shipping value chain is needed. Information on the carbon and resource intensity for products and processes utilized by different segments of the industry is not readily available. Information of this kind would help with decision-making throughout the value chain.

3 Reliable data on available technologies, performance and testing of these technologies, and payback periods is lacking. The need for this information is closely tied to the discussion of the principal-agent problem – in general, both parties (ship owners and customers) require information on the options for enhancing shipping efficiency and reducing emissions cost-effectively.

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To address the lack of information, additional research and testing of products is needed, as are centralized repositories for information on emissions, carbon footprints in the value chain, and technologies.

There are examples of individual companies hiring independent technologists to assess their products and/or verify efficiency claims. This is helpful, but may impose an undue burden on small companies and also does not result in an aggregated and centralized place for information, which is also lacking. Existing data is scattered, difficult to find, and not based on any uniform testing protocol.

There are a number of challenges to verifying technology performance. Application scenarios vary significantly based on ship type and size. This is problematic in the sense that the cost of some technologies vary significantly based on these scenarios and some do not. For example, some propulsion technologies may cost almost twice as much if a ship has two propellers, but it is impossible to segment ship categories to reflect this fact. A battery of tests is required, including tank tests and sea trials. It can also be difficult to isolate efficiency gains from technologies given other variables, such as varying environmental conditions (ocean current, wind, storms) during sea trial results. Notably, also, tank trials often show significant variability from sea trial results.

Largely, the industry lacks a centralized source for information and available information is fragmented, disjointed, and decentralized. A centralized and reliable data set on available technologies is also needed to verify the real potential and cost to the industry of meeting emissions targets.

Correcting the Lack of Information

To address the lack of information, additional research and testing of products is needed, as are centralized repositories for information on emissions, carbon footprints in the value chain, and technologies. Correcting lack of information in a market is in principal a distribution issue – ensuring that information exists and is widely available and disseminated. Reliable and widely accessible information is critical for entities developing and implementing effective action plans.

Market Failure #4 • *Lack of Financing*

Third-party financing requirements exist throughout the shipping value chain and are currently being only partially met, or not met at all. Financing is required by early-stage technology companies to develop, test, and implement technologies, by shipping companies for technology upgrades on existing ships and new builds, and by shipyards for retooling. Current financing models encumber scale up and, in some cases, are unsustainable.

The global financial crisis has made matters worse not better, making it more difficult to secure financing, with significantly less capital available for investment in the shipping industry. Ship owners are even less willing to invest additional funds for technology enhancements, given that they have to post additional capital to finance new build ships. This has inhibited investment in innovative technologies and forced historically risk-averse decision makers to further avoid risk. Banks in general have been providing half as much financing for new ships since the economic crisis, and the bar for investment in new technologies has been raised, requiring additional data to support such an investment. This new level of diligence is not in itself bad but may be placing unreasonable financial demands on early-stage companies with promising technology.

The current model of self-finance used by technology companies does not scale and is a major encumbrance for early-stage companies in particular, who have limited balance sheets. Technology companies must bear the cost of the initial installation ('trial') for an existing ship owner. If successful, the technology may be adopted across other vessels. Innovative technology companies with new technology are pressured to offer an initial installation at no cost in order to close a deal. In the case that a technology fails to produce specified results, perhaps due to some operational defect rather than a problem with the technology, the technology company risks failure. This model is not sustainable and many technology companies have gone out of business as a result. This is a highly unsustainable model for large-scale, rapid integration of technologies onto ships. This financing model is driven by ship owners that are risk-averse with respect to any new technology.

Finance has also been slow as a result of over-committed investors in the new build space. Investors who placed orders before the bust are now in a precarious situation since the value of new build ships has declined nearly one-third for many ship types. Investors have committed to buy ships, which are now worth way above market value and face short-term lower demand for shipping. Investors who have committed funds already are facing the decision of whether to cancel orders and lose the money they've already paid in the process.

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Shipyards must make significant investment to research and evaluate efficiency technologies, redesign manufacturing processes, and ultimately retool to support new technology installation.

Shipyards must make significant investment to research and evaluate efficiency technologies, redesign manufacturing processes, and ultimately retool to support new technology installation. It is most cost effective for shipyards to use existing infrastructure to build new ships. However, today some shipyards are evaluating efficiency technologies in an attempt to preempt ship design regulation, requirements and potential demand. They will require third-party financing to do so, some of which may come from the government.

Correcting the Lack of Financing

In general, new financing models are needed, as is more reliable data and testing procedures for technology, which was discussed above. With respect to technology deployment, there is a general need for a fund that can support technology testing.

Adoption of new technology is both risky and expensive for shipyards and for shipping companies. Before the risk of a technology is managed and understood, significant costs and time must be spent obtaining data compiled under test scenarios, and the private sector may prove unwilling to take this risk, as it has so far. In the absence private capital, a national or international public fund should be established.

Once verified, technologies will be able to attract private capital. Ship owners and builders are extremely risk-averse when it comes to ship applications that could cause a ship to require maintenance and down time. Still, it is difficult to test technologies to the extent that all application scenarios are represented.

With respect to new builds, it is clear governments have a role to play in catalyzing capital formation. The ministries in Korea, Japan, and China are hugely influential, the latter in particular. These governments can signal support (both regulatory and financial) for retooling in the shipyards to produce efficient and high-performing ships.

Other financing barriers are likely sufficiently addressed through information. The outlook for the global shipping industry is strong, and the economics of a number of technology products are well demonstrated, which requires extensive sea trials on test ships and the production of certain results. In addition, results typically vary significantly based on atmosphere and water conditions, increasing the difficulty in determining a consistent and reliable efficiency rate.

Different Roles of Finance

Venture capital is needed to finance early-stage technology companies. Project finance is needed to scale up technology companies. In addition, third-party financing (banks, investment banks, and private equity) is needed to finance ship upgrades for both existing and new ships. There is also a role for government finance with respect to research, development and deployment (RD&D) to support of technology development in the industry.

A finance model that negates the issue of prohibitive 'up front' costs to ship owners and operators and encourages outside investment, lured by attractive ROI on fuel cost savings, could trigger market pro-activity and increasing clean technology installation. Many observers suggest that 2015, when the North American ECA will see vessels burning very low sulfur bunker fuel, might be the year when the marine clean technology market flourishes.

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The shipping industry is both mature and complex. The growth of the industry has introduced many diverse players and has established webs of disjointed interaction up and down the shipping supply chain.

Industry Leadership

This is a moment of opportunity for leadership by the shipping industry. Industry leaders have demonstrated their support of innovation. Moreover, leaders across all industry segments have committed their organizations to environmental sustainability goals. An opportunity exists for early-movers and those that want to play a critical role in driving transformation of an industry, which serves as the backbone of the global economy. As a result of slow change to date, there is plenty of low-hanging fruit for harvest by investors and innovators. Paybacks can be extremely fast since fuel accounts for approximately one-third to one-half of the cost of shipping operations.

The shipping industry is both mature and complex. The growth of the industry has introduced many diverse players and has established webs of disjointed interaction up and down the shipping supply chain. The industry has been around for centuries and has many interacting and dynamic segments. As with other mature and dense industries, change happens slowly within the shipping sector. In part, the slow nature of change can be explained by the international and decentralized nature of the sector. The result is a need to identify and promote market opportunities that can drive new technologies and methodologies into the industry.

There are considerable leverage points in the shipping industry, with a number of actors.

Background on the Shipping Industry

The sea trade market experienced the greatest boom in modern history between 2003 and 2008. From 2005 to 2007, contracting increased from 93 282 million deadweight tons (dwt). In August 2008, new ship prices peaked. Then in October 2008, contracting peaked at 53 percent of the fleet, or 619 million dwt, and the shipbuilding bubble burst. Contracting for new ships drastically dropped from $160 billion in 2008 to $26 billion in 2009. The industry is still recovering from the global recession, and over-subscription in terms of new builds is still an issue in the short-term. However, the long-term outlook is positive and among other things the global recession has accelerated the demolition of outdated (and generally inefficient) ships.

Impact of Global Financial Crisis

The shipping market is highly correlated with the global economy and experienced a pronounced drop in accordance with the global financial crisis, beginning in late 2008. The impact of the financial crisis on shipping was aptly summarized by Martin Stopford of Clarkson's in an Advance Press Conference SMM 2010, as follows:

- Average vessel earnings, which peaked at $32,126 per day, fell 65 percent to $11,330 per day, as measured by the Clarksea Index, and all major shipping markets had a tough year.
- The container market fell 9 percent in 2008 and was the worst hit.
- The total volume of cargo fell 4.8 percent to 7.75 billion tonnes, and oil trade was down 4 percent.
- The only segment that grew was major bulk trade, which grew 1 percent, mainly due to Chinese imports of iron ore and steam coal.

Before the global financial crisis hit, orders for new ships were at an all time high and so were prices. Shipyards and ship owners had executed contracts for exorbitantly high prices. Once the bubble burst, ship owners were still contractually obligated to come up with the remaining 80 percent of the cost of ships, or they could cancel the contract and lose the 20 percent they had put in.

Options for ship builders included the following, as outlined by Martin Stopford of Clarkson's:

- Continue building, if they could get financing to support it. This would create a surplus and be bad for market recovery. Questions remain regarding who would incur the loss caused by falling ship prices.
- Spread the orderbook over 6 years, renegotiate contracts, freeze expansion plans and keep output at 2008 levels. This would be better for capacity, but financing will still remain an issue.
- Cancel orders by making a 40-50 percent nominal capacity cut, freeze expansion, and restructure. Under this scenario, shipbuilders could diversify into the less competitive offshore market and experience early recovery benefits.

Container Shipping Industry Value Chain and Segment Definition

	Shipment origination routing and capacity procurement	Provide containers	Provide and operate vessels	Load and unload shipments	Inland delivery
Key activities	• Customers Sales • Shipment routing • Capacity procurement • Customer service • Billing • Tracking	• Ownership of containers • Storage and maintenance • Repositioning	• Ownership of vessel • Operation of vessel	• Terminal control (ownership or lease) • Terminal operation Container handling	• Control of trucks • Ownership of railroads • Container handling
Competitor types	• Container carriers • Forwarders / NVOCCs	• Container carriers • Container leasing companies	• Container carriers • Outsourced / third party • Dry leases • Wet leases	• Container carriers • Captive terminal operators • Third-party terminal operators	• Railroads • TL truckers • Drayage truckers • Container carriers (limited)
Total revenue	$32 billion	$8 billion	$102 billion	$35 billion	$28 billion
Historical Growth (Revenue '97-'07 CAGR)	10%	11%	7%	11%	7%
Estimated ROCE [b]	50%	9%	3%	25%	34%

Notes a Defined as inland portion of itinerary purchased by customer (e.g., port gate to door); does not include transload market.
b ROCE = return on capital employed calculated at EBIT (earnings before intered and taxes) divided by net working capital plus book value of plant and equipment.

Source MergeGlobal analysis and estimates.

Figure 7 Supply Chain for Containerships. Source: MergeGlobal 2010.

There were many cases where new ship orders were cancelled, mostly by smaller shipping companies. This put pressure on ship builders since they lost revenue that was in their pipeline. Now orders for new ships are down which is also pressuring ship builders.

Contracting for new ships fell a staggering 75 percent in 2009, and only 46 million dwt of new ships were ordered. The orderbook had fallen to 38 percent of the fleet, or 489 million dwt, in May 2010, and new build prices had fallen 25%. Shipbuilding output slumped 30 percent, 1 million compensated gross tons (CGT's), between fourth quarter 2008 through fourth quarter 2009. In the fourth quarter of 2009, shipyards reduced production 13 percent to 10.5 million CGT. However, deliveries of new ships still increased in 2009 by 29 percent to 116.7 million dwt. There was 61.3 million dwt of capacity ordered and not delivered in 2009. Today there is a surplus of shipping capacity.

Still, there are signs of recovery. In May 2010, the average vessel earnings economic indicator had recovered to a still weak $18,397 per day, according to the Clarksea Index. The market is in a transitional period, recovering from the dip.

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Financing New Ships

During the shipbuilding process, investors must typically make five payments (each of 20 percent) attached to milestones during the shipbuilding process. Payments are made upon signing of contract, delivery of the ship, and three specified milestones during the typical 18-20 months it takes to build a ship. Before the global financial crisis, third-party financing would typically contribute 80 percent of the cost of a ship, with the rest of the capital supplied by the ship owners. Now those banks that have stayed in the market are typically investing only 40-60 percent. In addition, fewer investors are putting their bets on shipping and many large investors have ceased investment in shipping altogether. Demand is down significantly for most segments. Investors are also contributing much less towards shipbuilding as well. A number of investors have exited the market in recognition of the over-supply of new ships currently in the pipeline.

Activity by Country

The top regions investing in the shipbuilding market in 2008 were Europe, with 50 percent, Asia, with 25 percent, and the Middle East, with 8 percent. In 2009, Europe accounted for 46 percent of the orderbook value and Asia Pacific accounted for 34 percent. Table 4 below shows the investment breakdown by country.

Greece • **$18.3**	South Korea • **$6.3**	Japan • **$6.7**
Germany • **$17.6**	Norway • **$5.2**	Hong Kong • **$2.5**
China • **$11.4**	Italy • **$4.6**	Singapore • **$2.3**
Denmark • **$7.5**	US • **$5.1**	

Table 4 Investment in Shipping by Country ($B)

Trends

The outlook for the world shipping industry is positive, with the worst of the recession passed.

World Fleet Growth

The world fleet is expected to grow by more than 7 percent in 2010 and by over 8.7 percent in 2011. The merchant fleet is projected to reach 1,443 million dwt by 2011, which is 42 percent higher than five years ago. Sea trade markets depend on strong recovery in the world economy and it is important to note that historically, recessions have significantly changed the business climate in these markets.

Demolition

Demolition has a strongly geographic orientation. Historically, India, Pakistan, and Bangladesh beaches have been used for demolition, but recently Jiangmen Yinhu and Jiang Xiagang in China have become more appealing to companies including Maersk. This trend has arisen as a result of increased standards for docking ship yards and more environmentally responsible practices. [xxxiv]

China Ascending in the Ship Building Market

The top three shipbuilding nations are South Korea, Japan and China. Shipyards had initiated expansion plans during the boom to support the growing needs of the market. South Korea remains the top shipbuilding nation with 35 percent of CGT deliveries. In 2009, China jumped into second place with 27 percent of deliveries and overtook Japan, which holds a 21 percent market share. China is positioned to possibly become the leading shipbuilding nation, with a small margin over Korea.

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About The Carbon War Room

The Carbon War Room aims to harness the power of entrepreneurs by unlocking market-based solutions to gigaton (billion ton) scale reductions in carbon and creating climate jobs, GDP growth, and ultimately the newest crop of entrepreneurial wealth.

The War Room aims to bring together successful entrepreneurs in collaboration with the most respected institutions, scientists, and business leaders to identify and remove market barriers in each sector; help channel capital to the entrepreneurs; and promote climate wealth creation and prosperity for all.

We target the movement of institutional capital into a working marketplace and the elimination of market inefficiencies (in the form of insufficient information and high transaction costs). Policy and technology are necessary conditions to the solution, however they are not sufficient, and not the bottleneck to progress.

Climate Wealth is the Carbon War Room's platform for change. Our vision is to see markets functioning properly and clean technology successfully scaling to promote climate wealth, prosperity, jobs and growth.

As the role of a 'Climate Wealth' catalyst – Carbon War Room focuses on areas where a sector-by-sector approach to climate change can be applied to generate gigaton-level carbon savings. We seek to complement existing efforts and organizations, leveraging our convening power, our market driven solutions-oriented focus, and our powerful global network to develop and implement gigaton-level solutions.

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Carbon War Room
1150 Connecticut Ave., NW, Suite 620
Washington, D.C. 20036
P / 202.717.8448
F / 202.318.4770

www.CarbonWarRoom.com
www.twitter.com/cwarroom