RESEARCH REPORT

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HIDDEN TREASURE: FINANCIAL MODELS FOR RETROFITS

THE CARBON WAR ROOM | UNIVERSITY COLLEGE LONDON ENERGY INSTITUTE

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Hidden Treasure: Financial Models for Retrofits

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Executive Summary

Innovative self-financing models have significant potential to enable the adoption of retrofit technologies, thereby reducing fuel payers' operating costs, while requiring zero capital expenditure

This paper examines financial models capable of enabling the adoption of fuel-efficiency and alternative fuel technologies that profitably reduce the fuel use and resulting greenhouse gas emissions (GHG) of the shipping industry.

The international shipping fleet is incredibly diverse in terms of the vessels used, as well as the purposes for which they are used and the conditions under which they operate. One of the only commonalities among the different shipowners and charterers is their shared experience of facing rapidly rising costs for maritime fuels. Fortunately, a wide range of retrofit technologies that can increase the fuel efficiency or otherwise lower the fuel costs of these vessels are available on the market today. Retrofitting the existing fleet is crucial to creating a healthy shipping industry. Efficient newbuild ships may offer a step change in efficiency but they will not, on their own, ensure an economically sound and sustainable industry. Newbuilds alone will not deliver the industry's full potential fuel savings, and the industry does not want a "two-tier" market containing stranded, uneconomic older vessels.

However, significant market barriers are preventing those retrofits from happening. For example, the capital-intensive nature of maritime retrofit technologies poses a significant barrier to their deployment, particularly given the capital-constrained nature of today's shipping industry. Ship financing is a concentrated industry, with the top 40 banks holding more than 90% of the world's $500 billion[1] in shipping debt. Many of these sources of financing are reducing their shipping commitments, leaving shipping companies with restricted access to capital and credit. The top 10 lenders alone have reduced their shipping loan books by $50 billion since 2008 as a result of the global financial crisis (Devabhaktuni & Kennedy 2012). Another important barrier is the way that fuel is paid for in the industry, as there is a substantial split incentive between the shipowners, who would need to pay for the retrofits themselves, and the charterers, who pay for the fuel approximately 70% of the time and would therefore enjoy the savings resulting from the majority of upgrades.

This paper finds that a variety of innovative self-financing models have significant potential to enable the adoption of these technologies, thereby reducing fuel payers' operating costs, while requiring zero capital expenditure (CapEx) from the owner or charterer[2] and, in some cases, allowing them to keep the cost and risk of retrofits off their own balance sheets. Off-balance-sheet financing[3] is likely to be attractive to both shipowners and charterers who may still be feeling the effects of the global economic contraction, as well as to highly diversified corporations that would not prioritize fuel-saving retrofits in their shipping fleet over investment opportunities more directly connected to their core lines of business.

Specifically, this paper considers one financial model that facilitates the adoption of retrofit technologies that improve a vessel's fuel efficiency, and a complimentary model that allows for the converting of vessel engines to run on Liquefied Natural Gas (LNG) or other alternative fuels.

The beneficiaries of all of these models include owners, charterers, financiers, and technology vendors. Investors in these models are compensated through the distribution of fuel cost savings, at a rate that is proportionate to the costs and risks they assume, while technology vendors are able to increase their sales, and fuel payers can, depending on the structure, enjoy a percentage of the fuel savings immediately and 100% of the fuel savings after investors are repaid. Moreover, shipowners will also benefit from increasing the fuel efficiency of their vessel through a relevant combination of the direct fuel savings, improved compliance with current regulations, and greater likelihood of gaining business in a charter market increasingly concerned with fuel expenditures.

The potential positive impact of these retrofit technologies on both cost savings and emissions reductions is substantial. In 2007, the international shipping fleet consisted of just fewer than 50,000 cargo ships and consumed an estimated 277 million metric tons of fuel, releasing 870 million metric tons of CO_2 in the process (IMO 2009). A hypothetical 46,000-deadweight ton (DWT) bulk carrier that operates at sea for 225 days of the year could, by installing a certain bundle of fuel efficiency retrofit technologies costing approximately $1,000,000, enjoy a 10% increase in its fuel efficiency. This would deliver fuel cost savings of $500,000 per year and reduce that ship's emissions by 2,148 metric tons of CO_2 per year. Alternatively (or additionally), switching to an engine that accepts LNG fuel, such as a dual-fuel system, would cost approximately $10,000,000 and provide annual fuel savings of nearly $3,000,000, while also reducing emissions so as to ensure compliance with the requirements of low-emission zones.

Though the shipping sector's diversity makes it difficult to accurately extrapolate these numbers and make industry-wide predictions on the potential of specific fuel efficiency retrofit technologies, their general applicability to a range of ship models and operational cycles strongly suggests that there is a significant and profitable emissions-reduction potential to be found in scaling their adoption. For example, were the existing global shipping fleet to improve its overall average fuel efficiency by 10%, the industry would save $16.6 billion on fuel costs per annum and reduce its GHG by up to 87 million metric tons of CO_2 per annum, while still enjoying strong annual growth.[4]

This paper is part of a broader project aimed at accelerating fuel and carbon savings in the shipping industry. If you are interested in finding out more, or in participating in the financial models covered here, please see www.carbonwarroom.com and www.shippingefficiency.org, or email Victoria Stulgis on shipping@carbonwarroom.com.

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[1] All monetary amounts given in USD unless otherwise stated

[2] "Charterers" refer to those who own the cargo transported by international vessels and will often charter an entire vessel to ship their goods.

[3] A form of financing in which large capital expenditures are kept off a company's balance sheet through various classification methods. Off-balance-sheet financing allows companies to keep their debt-to-equity (D/E) and leverage ratios low, especially if the inclusion of a large expenditure would break negative debt covenants.

[4] Calculated from 2007 IMO estimates for international shipping fuel consumption (227 million metric tons of fuel) and CO_2 emissions (870 million metric tons) and a fuel price of $600/metric ton (which is a low estimate, as MGO and MDO prices are considerably higher—IMO 2009).

Key Findings

Technology Options

- Shipowners have a number of technology options for increasing their profitability in today's market and under current regulations.

- Most of these options can be retrofitted (installed onto existing ships), and thus offer an alternative solution to continued investment in more efficient newbuilds.

- Two such options are considered in this paper:
  - **Fuel efficiency retrofits:** A variety of physical and operational modifications that increase the fuel efficiency of ships and allow them to burn less fuel while hauling the same amount of freight.
  - **Alternative fuel engine conversions:** Engine conversions allow a ship to run on a fuel that is cheaper than oil and produces lower emissions. This paper focuses on dual-fuel LNG engine conversions, though other alternative fuels are briefly considered, and could be important future options.[5]

- Both of these options save money, reduce the exposure of fuel payers to fuel price fluctuations, and allow shipowners to meet emissions regulations.

As demonstrated by surveys with nearly 150 global shipping companies, a number of market barriers are preventing promising technologies from being widely adopted

Market Barriers

- As demonstrated by surveys with nearly 150 global shipping companies (Rehmatulla & Smith 2012), a number of market barriers are preventing these promising technologies from being widely adopted.

- Some of the barriers are general to the shipping industry, while others are specific to a certain technology.

- The barriers discussed in this paper include:
  - **Lack of capital:** Though payback periods are short, shipowners struggle to finance these technologies upfront.
  - **Split incentives:** Often the shipowner, who would need to pay for a technology upgrade, does not pay for the fuel costs of their vessel, and so would not see any benefit or even payback from investing in a retrofit. Meanwhile, it is not commercially attractive for a charterer to take on financing if the payback of a technology is shorter than the duration of the charter (with contract lengths varying from several months to 10 years).
  - **Measurement and verification [specific to fuel efficiency technologies]:** Accurately calculating the fuel savings that result from a fuel efficiency retrofit requires a robust and reliable methodology and advanced monitoring equipment, both of which are nascent to the industry.
  - **Lack of infrastructure [specific to alternative fuels]:** There is a need for new fueling infrastructure and the guaranteed supply of alternative fuels, such as LNG, if shipowners are going to be able to depend on such fuels for their operations.

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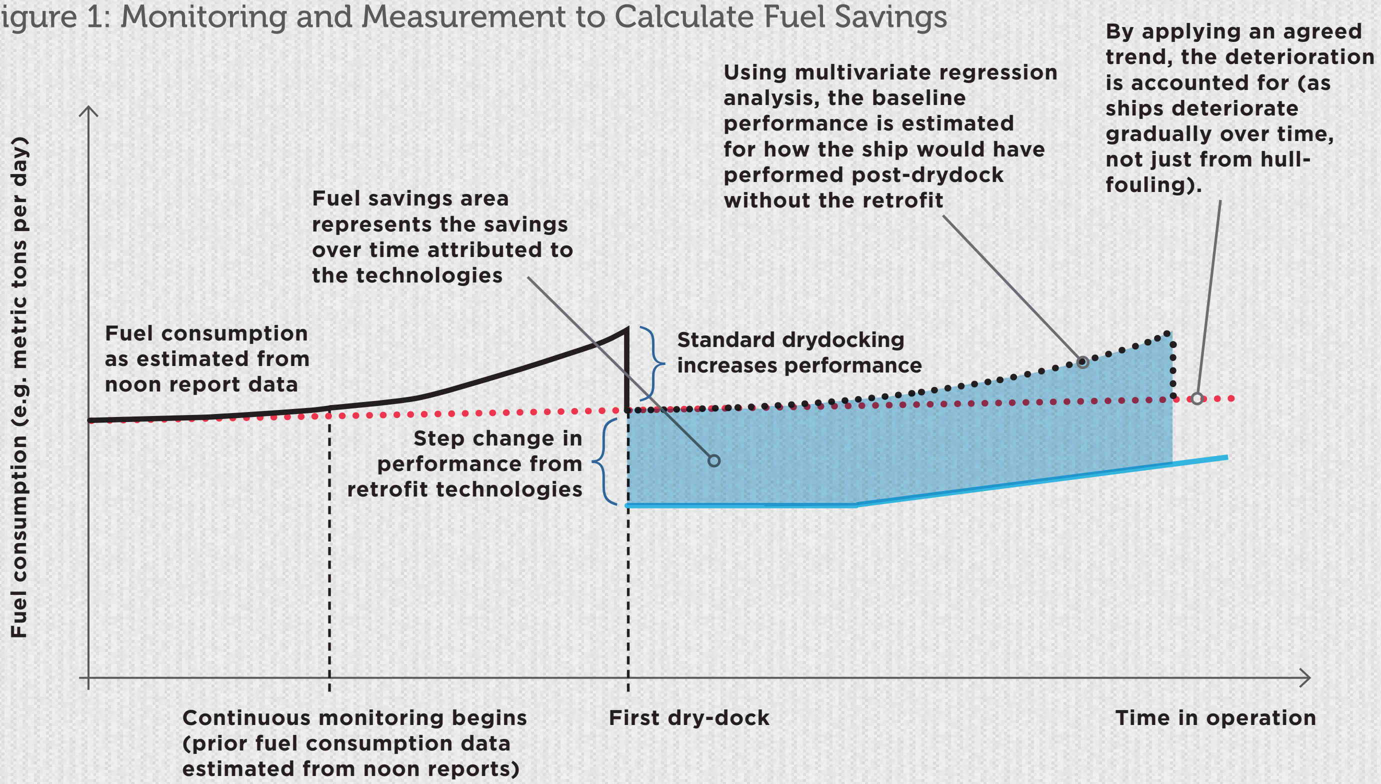
[5] Carbon War Room, while interested in researching LNG fuel conversion options and the financing mechanisms associated, focuses solely on fuel efficiency technologies within the shipping industry.

Figure 1: Monitoring and Measurement to Calculate Fuel Savings



KEY: The solid black line represents the ship's pre-dry-dock fuel consumption, whereas the dotted black line represents the estimation for how the ship would have performed post-dry-dock without the retrofit. The blue line represents the consumption post retrofit. The red line is the ship's underlying gradual deterioration (other than hull fouling)

Third-Party Financing Models

The shipping industry can adapt third-party financing models from the built environment and renewable energy sectors to overcome the issue of the significant capital costs of deploying retrofits. These sectors have also overcome split-incentive issues and incorporated measurement and verification technology into the financial package. This paper presents two such models, one tailored to facilitate the adaptation of fuel efficiency technologies, the other specific to alternative fuel engine conversions.

- **Model 1: The Self-Financing Fuel-Saving Mechanism (SFFSM)—**This model is inspired by the Energy Service Companies (ESCO) model, as illustrated by Figure 2. The SFFSM facilitates the adoption of fuel efficiency technologies by either long-term time-chartered ships or owner-operated ships.

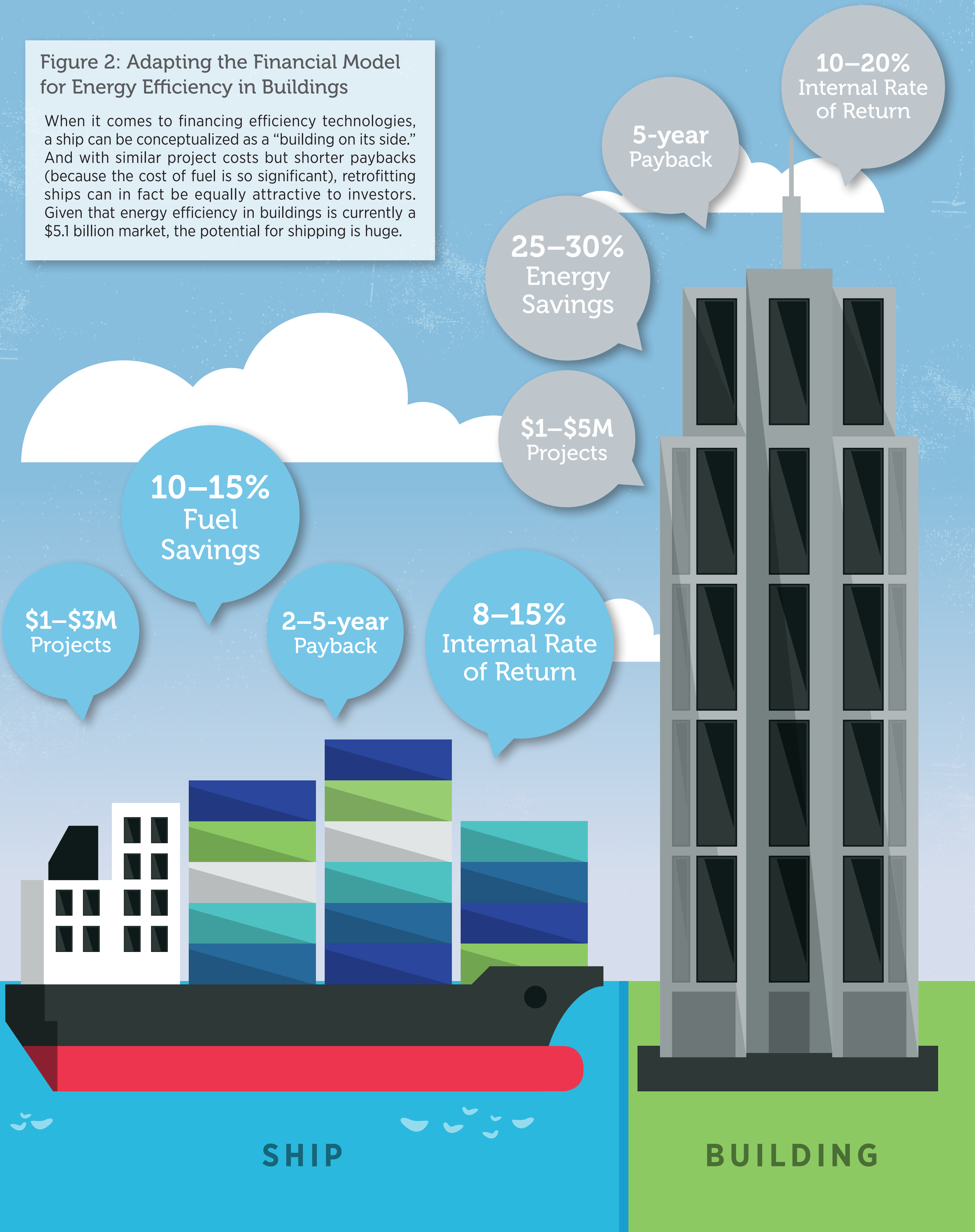
    - The SFFSM secures the upfront capital investment cost of retrofit fuel efficiency technologies from a third-party financier.
    - Financiers recoup their return from the fuel cost savings generated by the gains in fuel efficiency afforded by the technologies.
    - The innovation of the SFFSM is its focus on data, from collecting a ship's baseline performance statistics and incorporating those into the calculation of return rates, to including measurement and verification techniques in order to accurately assess the efficiency gains achieved by the retrofit technologies. The assessment methodology, developed by University College London's Energy Institute specifically for the SFFSM, is capable of quantifying fuel savings using new data collection technologies and methods (see Figure 1).

- **Model 2: The Emission Compliance Service Agreement (ECSA)—**This model facilitates dual-fuel LNG engine conversion.

    - The ECSA uses third-party finance to enable vessels to convert to running primarily on LNG, though they retain the ability to switch to conventional bunker fuels if necessary.
    - LNG fuel meets International Maritime Organization (IMO) emission regulations, and in some regions is cheaper than low-sulfur bunker fuel and heavy fuel oil.
    - Under the ECSA, financiers receive their returns by hedging against the pricing spread between low-sulfur bunker fuels and natural gas.

Figure 2: Adapting the Financial Model for Energy Efficiency in Buildings

When it comes to financing efficiency technologies, a ship can be conceptualized as a "building on its side." And with similar project costs but shorter paybacks (because the cost of fuel is so significant), retrofitting ships can in fact be equally attractive to investors. Given that energy efficiency in buildings is currently a $5.1 billion market, the potential for shipping is huge.



Introduction

Improving fuel efficiency is now imperative to remaining competitive. Fortunately, retrofit technologies that are profitable and applicable to a great percentage of the bulk, container, and tanker ships exist today

The last 10 years have seen a series of market factors fundamentally reshape the global shipping industry. Most importantly, the income streams of shipping companies have suffered greatly within the global economic contraction. Simultaneously, bunker fuel[6] prices have risen substantially, environmental regulations have tightened, and shipping companies have become increasingly aware of their industry's impact on the climate and environment. As a result, improving fuel efficiency or otherwise managing fuel costs is now imperative to remaining competitive on the seas.

Fortunately, a number of retrofit technologies with the potential to greatly increase the profitably of bulk, container, and tanker ships exist and are widely available on the market. Retrofitting the existing fleet is essential to developing a healthy shipping industry for the coming decades. Efficient newbuild ships do offer a step change in efficiency, but they will not, on their own, make the entire industry economically and environmentally sustainable. The retrofitting of older ships with new technologies must also be pursued in order to avoid a "two-tier" market in which only the newest half of the global fleet is truly competitive.

Of the range of retrofit options available, this paper focuses on two:

1. **Technologies for fuel efficiency:** These are installed in suites or bundles that are custom-tailored for a given ship. These technologies include options for improving both operational practices and physical aspects of the ship's design. Increased efficiency allows a ship to do the same amount of work with less fuel, thereby saving money and emissions.

2. **Technologies for alternative fuels:** Specifically, ones known as "dual-fuel LNG engine conversions," whereby a ship's engine is converted to run on liquefied natural gas (LNG). LNG has a much lower carbon content than bunker fuel, in addition to a significantly lower SOx and NOx content, and is substantially cheaper than the low-sulphur bunker fuels required in a few key geographies, particularly North America.

While these retrofit options could greatly improve a shipowner's ability to stay profitable under current market and policy conditions, they are not being widely adopted by the industry and very little capital is flowing towards their implementation—a situation that can be attributed to some significant and pervasive market barriers.

The overarching barriers discussed in this paper include a lack of access to capital and credit for financing these expensive retrofits, and the "split-incentive" (sometimes called "principal-agent") problem. An additional barrier specific to the fuel efficiency technology option involves the lack of a rigorous, robust, and reliable methodology to calculate the actual fuel savings that result from the adoption of those technologies, and the associated need to accurately measure a ship's baseline fuel consumption. Meanwhile the dual-fuel LNG engine conversion option has the specific barrier of the need for a new global fueling infrastructure and a guaranteed supply of LNG fuel.

This paper suggests that *innovative financial models* adapted from other sectors can support the movement of capital towards these money-saving and carbon-reducing retrofits in the shipping industry. These models, which use third-party finance and can be structured as "off-balance-sheet," can be adapted from the built environment and renewable energy sectors in order to overcome the general barrier of the significant capital costs of maritime retrofit technologies, as well as the split-incentive barrier. Additional efforts will be required to address other barriers and complexities specific to the shipping industry and each individual technology. Nevertheless, this paper finds that these models are, today, sufficiently capable of underwriting and apportioning the risks of market-ready and economically viable retrofit technologies so as to substantially accelerate their deployment.

Specifically, this paper analyzes two financial models (one for each of the two technology options discussed above) that will reduce fuel payers' operating costs and require zero CapEx from the shipowner or charterer. Both models are "self-financing," as they involve a mechanism for sharing future fuel cost savings in order to bring in the third-party capital needed to cover upfront costs. In fact, cost savings are at the core of these models, as they are designed to ensure that compensation of involved parties is proportionate both to their costs and to the risks that they are taking, with the net savings after those deductions going back to the fuel payer.

This paper suggests that innovative financial models adapted from other sectors can support the movement of capital towards these money-saving and carbon-reducing retrofits in the shipping industry

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[6] "Bunker fuel" is a general term for a variety of types of heavy fuel oils that are used to fuel ships, including Heavy Fuel Oil (HFO), the highest density and most polluting fuel, which is produced as residual fuel during the crude oil refining process.

The beneficiaries of innovative self-financing models such as these include the shipowner, the fuel payer (owner or charterer), the financier, and the technology vendors. The vendors will increase their revenues, the financiers will enjoy attractive returns, and the charterers will save on fuel costs, while the shipowners will ultimately benefit from improving their vessel such that it either has greater fuel efficiency or burns cheaper fuel, while meeting regulatory compliance.

The first financial model discussed in this paper supports the retrofitting of fuel efficiency technologies onto existing ships, and was developed by a consortium of the Carbon War Room (CWR) in cooperation with PricewaterhouseCoopers (PwC) and University College London (UCL). The model put forth by this consortium is called the Self-Financing Fuel-Saving Mechanism (SFFSM), and provides financing suitable for retrofits on either long-term time-chartered ships or owner-operated ships. The SFFSM aims to offer 100% of the needed capital investment via a third party, and financiers in this model enjoy their returns from the fuel savings generated by efficiency gains. This paper also mentions another model for fuel efficiency retrofits, known as Save As You Sail (SAYS), which was developed by the Sustainable Shipping Initiative. SAYS is a solution for retrofitting vessels operating in the short-term time-charter market. This paper focuses mainly on the details of the SFFSM, with some additional description of SAYS, and a brief discussion of the relative merits and differences between the two.

The second financial model discussed in this paper uses third-party finance to enable dual-fuel LNG engine conversion retrofits, which entail converting vessels to run primarily on LNG, but with the ability to switch to conventional bunker fuels if necessary. Known as the Emission Compliance Service Agreement (ECSA) model, this system was designed by Clean Marine Energy and was originally intended for the North American market, where a combination of upcoming emissions regulations and low natural gas prices have created a favorable landscape for LNG-fuel-based retrofits. Under the ECSA model, financiers receive their returns by hedging against the pricing spread between low-sulfur bunker fuels and natural gas fuels. The ECSA model provides shipowners with certainty about their fuel costs over the long term by contracting a dedicated natural gas supply for converted ships, and also ensures their compliance with IMO emissions regulations.

Methodology

The ideas in this paper were developed through a review of the financial models developed by a variety of organizations, including CWR, Clean Marine Energy, and the Sustainable Shipping Initiative. The pros and cons of their approaches were reviewed with the following parameters in mind:

- **Does the model address the market barriers identified?**
- **Does the model support the technology options identified?**
- **Will the model make those technologies attractive to key industry actors?**

Further Research

This paper is not a full review of all of the existing retrofit-financing initiatives in the industry, nor is it a review of all available maritime fuel efficiency technologies or maritime alternative fuels. The dynamics of the different markets within the shipping industry mean that there will never be a "one-size-fits-all" financial model. Rather, different solutions will complement each other and may even work together (e.g., a dual-fuel LNG engine conversion could be implemented at the same time as fuel efficiency retrofits). Furthermore, these new financial models are continuously evolving, as experiential learnings are gleaned from their initial deployments. The aim of this paper is therefore to share the existing knowledge of and experience with just two of these models and to stimulate a discussion around them, thereby creating further opportunities for their deployment, testing, and refinement.

Further research that would complement or build upon this paper might include an exploration of the detailed fuel savings per ship/per trip/per technology etc., as well as an understanding of the impact of fuel price volatility on the shipping sector. In addition, further research into LNG-specific topics might include an economic analysis of LNG opportunities for shipping, as well as an environmental impact assessment of the development of LNG for shipping.

> The dynamics of the different markets within the shipping industry mean that there will never be a "one-size-fits-all" financial model


3S
3P
2S
2P

Current Trends and Their Impacts

Fuel costs account for as much as half of a container ship’s operating expenses, and for some ships that percentage is even greater

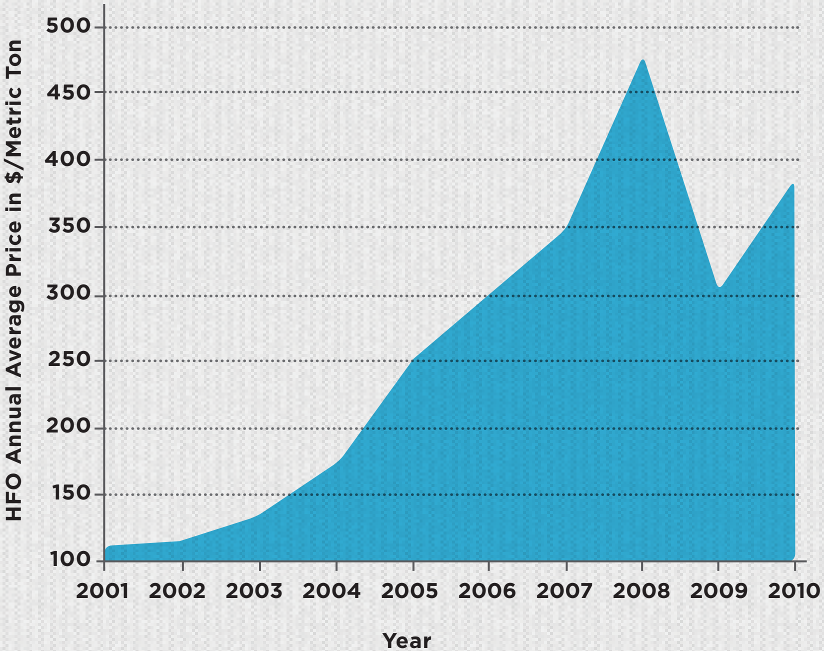
The last 10 years have seen a series of trends fundamentally reshape the global shipping industry, including a substantial rise in the price of bunker fuel, a tightening of environmental regulations, and a new focus by shipping companies themselves on the climate impacts of their industry. These three trends have come in the midst of a global economic contraction that caused a drop in the income streams of shipping companies. Together these factors have, of late, created a strong motivation for the industry to seek out cost-saving opportunities such as retrofit technologies.

1. Rising Fuel Costs

Due to the rising price of bunker fuel (Figure 3), fuel costs have become a significant proportion of a ship's total operating expenses over the past decade and, as a result, an increasingly important factor in determining a shipping company's revenue, revenue projections, and profitability. The World Shipping Council recently reported that fuel costs account for as much as *half* of a container ship's operating expenses, and for some ships that percentage is even greater (WSC 2009).

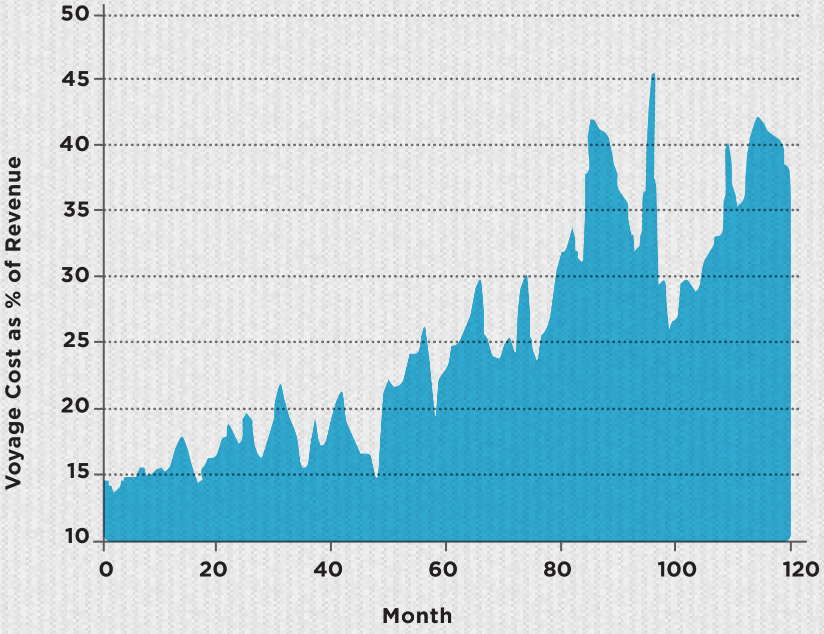
Figure 4 illustrates the degree to which fuel costs (expressed as a share of total revenue) have grown in significance in the last decade. The leading analysts of energy commodities (e.g., IEA, EIA) all forecast that oil prices will continue to increase over time as supply struggles to keep up with the growing energy demand of an expanding global economy. In today's volatile shipping market, where tanker and dry bulk daily earnings can vary significantly from one quarter to the next (PwC 2011), shipowners and operators face a particularly strong incentive to minimize their exposure to the additional source of uncertainty and financial risk created by this new instability in oil prices. In this context, new technologies that increase a ship's fuel efficiency or otherwise stabilize its fuel expenditures—thereby reducing fuel's percentage of operating expenditures—could have a significant impact on a company's bottom line.

Figure 3: Conventional Bunker Fuel (HFO) Annual Average Price in $/Metric Ton Over the Last Decade



Source: Clarkson's.

Figure 4: Fuel Costs as % of Revenue for Chemical Tankers



Source: The plot is for chemical tankers on the Houston/Rotterdam route from 2000–2010. Freight rate data sourced from Clarkson's Shipping Intelligence Network; fuel cost is estimated from annual fuel prices; ship's speed and fuel consumption from Clarkson's World Fleet Register.

2. New Regulations

Emission Control Areas

Emission Control Areas (ECAs), which regulate the quality of fuel burned within defined "special areas" to reduce marine emissions and air pollutants, are enforced in many of the world's waterways that are close to populated areas. ECAs impose additional operating costs on the ships that must travel through them, as most ships must at some point on their routes. To date, ECAs have been enacted by the IMO (within Annex VI of the International Convention for the Prevention of Pollution from Ships) in the Baltic Sea (2006), the North Sea/English Channel (2007), North America (2012) and the US-Caribbean Sea (expected in 2014). Currently, ships must burn fuel that has a sulfur content of less than 1% when operating in ECAs, but that sulfur limit will drop to 0.1% on 1 January, 2015. Shipowners operating wholly or partially in ECAs have three main options by which to comply with 2015 ECA regulations (<0.1% sulfur content):

1. Switch from HFO to a low-sulfur fuel when traveling through an ECA—both Marine Gas Oil (MGO) and Marine Diesel Oil (MDO)[7] with sulfur contents of <0.1% are available on the market and do not require any engine retrofits to use.
2. Stick with a fuel that is >0.1% sulfur and invest in an "exhaust gas scrubber" retrofit technology.
3. Perform a retrofit conversion of a ship's engine so that it is capable of running on LNG or another low-sulfur alternative fuel for travel through an ECA.

Currently, the majority of the international fleet practices the first option of "fuel switching" from HFO to MGO and MDO. However, more and more sea lanes are adopting ECA standards, thus increasing the frequency with which ships must switch fuels, driving up demand for low-sulfur MGO and MDO fuels and correspondingly driving up the prices of those fuels, which already command a premium compared to HFO (Figure 5). These factors will likely make the alternative options of retrofitting a ship with either exhaust gas scrubbers or an engine conversion more economically attractive.

Figure 5: Price Spreads between HFO and MGO

	Heavy Fuel Oil (IFO 380)	Low-Sulfur Fuel: Marine Gas Oil (MGO)
Singapore	**$602.00**	**$926.50**
Rotterdam	**$601.50**	**$908.50**
Houston	**$590.50**	**$1,021.00**

Price spreads between Heavy Fuel Oil (IFO 380) and Low-Sulfur Fuel (MGO) per metric ton
Real-time prices in USD for July 2013 (Source: Bunkerworld).

Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan

In addition to creating stricter and more numerous ECAs as a method for reducing SOx, in 2013 the IMO's Marine Environment Protection Committee enacted two measures aimed at addressing the CO_2 emissions of the shipping industry. The first of these measures, known as the Energy Efficiency Design Index (EEDI), sets a minimum design standard for all newbuilds that is based on a ship's design efficiency measured in CO_2 per metric ton nautical mile (MEPC 62, 2011). The EEDI is mandatory and its standards will be tightened every five years between 2015 to 2030.

The second of these measures, the Ship Energy Efficiency Management Plan, applies to all existing vessels in addition to newbuilds, and requires ships to have a plan on board but does not impose any limits on the amount of CO_2 emitted (MEPC 62, 2011), with the aim of encouraging increased efficiency through operational measures (e.g., better fuel/energy management as implemented by the crew).

In October 2012, Cargill, Huntsman, and UNIPEC UK publicly announced that they would no longer charter the least efficient ships in the global fleet

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[7] Marine Gas Oil and Marine Diesel Oil are available in low-sulfur specifications.

3. The "Triple Bottom Line"

Though perhaps more slowly than other, more consumer-oriented industries, the shipping industry of late is embracing the idea that considering the "triple bottom line" in making corporate policy decisions, such as by choosing to invest in increased fuel efficiency and thereby reducing CO_2 emissions, represents a way for companies to increase their market share and revenue.

In particular, demand-side stakeholders within the industry (e.g., retailers and charterers) have increasingly expressed their desire for more efficient vessels through a variety of market signals. For example, retailers including IKEA and Wal-Mart, as part of the Clean Cargo Working Group (see: *bsr.org/en/our-work/working-groups/clean-cargo*), are collaborating with leading container shippers to reduce their carbon footprints. Meanwhile, in the tank and bulk charter market, charterers are beginning to factor vessel efficiency into their commercial decision making. Exemplifying this trend, Cargill, Huntsman, and UNIPEC UK publicly announced in October 2012 that they would no longer charter the least efficient ships in the global fleet. Cargill, in particular, implemented a company policy against chartering "F"- and "G"-rated ships, as defined by the "A to G" Greenhouse Gas Emission Rating established by RightShip and CWR (see: *shippingefficiency.org*). Finally, other industry players including ports and banks have begun to embed efficiency information into their commercial operations. Ports, such as Prince Rupert and Metro Vancouver are now offering discounts to more efficient vessels, while the KfW IPEX Bank has evaluated the vessels in its shipping portfolio using the EEDI methodology. This increased demand for more efficient vessels provides further incentive to owners and operators to retrofit.

One major shipping company that has already begun to enjoy success as a result of having embraced the concept of the "triple bottom line" is Maersk. In 2013, Maersk met its internal target to reduce its emissions from its 2007 levels by 25% before 2020. It was able to achieve its goal seven years ahead of schedule by implementing a variety of different efficiency initiatives, including slow steaming and the removal of bulbous bows from the majority of its fleet (Maritime Executive 2013). Maersk has announced that its commitment to reduce its carbon footprint has benefited its business in a variety of ways, including making the company more cost-competitive and improving customer relations. Through slow steaming alone, Maersk generated an annual cost saving of $300 million (SSI 2011). Case studies of successes such as this are influencing the rest of the industry to look for ways to follow suit.

Retrofit Technology Options

Given that charterers and shippers, banks, ports, and other stakeholders are increasingly scrutinizing the comparative fuel bills of vessels, the first shipowners to take action to make their ships more fuel efficient will be rewarded with increased market competitiveness

In light of market and regulatory trends, owners of older vessels may struggle to stay in operation and compete with the more efficient new vessels slated to come online in the next decade. Fortunately, a number of technology options are widely available on the market that can be retrofitted (installed onto existing ships), and thus offer an alternative solution to continued investment in more efficient newbuilds, which only serves to exacerbate the current overcapacity within the industry. Given that charterers and shippers, banks, ports, and other stakeholders are increasingly scrutinizing the comparative fuel bills of vessels, the first shipowners to take action to make their ships more fuel efficient will be rewarded with increased market competitiveness.

The best retrofit technologies for staying profitable under today's conditions of high fuel prices and increasing regulations include the following options:

1. Installing technologies that improve a ship's fuel efficiency (these can act upon both design and operational inefficiencies).

2. Switching to cheaper fuels with lower carbon and sulfur content, either drop-in fuels or those that require engine conversion, such as LNG.

3. Installing emissions-reduction technologies (exhaust gas scrubbers, etc.).

4. Adopting renewable energy sources to augment propulsion (kites and flettner rotors to harness the wind, etc.) or auxiliary power (solar panels, etc.).

As mentioned, this paper will focus specifically on financial models for improving fuel efficiency (option 1) or switching to fuels with lower carbon content (option 2), both of which allow ships to decrease their operating costs and potentially even increase their revenue through expanded market share. The installation of emissions-reduction technologies (option 3), such as scrubbers, may be pursued via a financial model quite similar to Clean Marine Energy's ECSA that allows for engine conversions. Financial models for renewable energy sources (option 4), are less prevalent in the industry today and therefore not covered in this paper, mainly because few renewable energy technologies have been deployed on vessels at commercial scale. Options 3 and 4 are both, however, being pursued in other projects of CWR and industry stakeholders.

The following subsections offer an overview of the two technology options considered by this paper, and a summary analysis of their likely economic and environmental costs and benefits.

1. Fuel Efficiency Technology Retrofits

A range of retrofit technologies are widely available on the market that can improve a vessel's daily fuel consumption without impacting deliveries, processes, or any other aspect of business.

A number of efficiency technologies have already seen some moderate uptake by shipping companies, and therefore offer illustrative case studies of fuel-saving successes. Many of these technologies can only be installed while the ship is in dry-dock, which is an expensive process requiring a ship to be taken out of service. As a result, in most cases the installation of retrofits only becomes economically viable when it is aligned with a vessel's pre-scheduled dry-dock. Fortunately, most vessels, on average, enter into dry-dock every five years[8] to undergo planned maintenance and address hull fouling,[9] which in and of itself can have a significant degrading impact on a vessel's fuel consumption.

[8] Bulk, tanker and containerships require two dry-dockings in a five-year period with no more than three years between dry-dockings, but there are exceptions, such as the use of underwater inspections for one of the surveys (in the five-year dry-dock cycle) for vessels under 15 years old.

[9] The term generally used to describe the settlement and growth of marine plants and animals on ships' submerged hulls. Fouling severity depends on many factors, e.g., water salinity, light, temperature, pollution and nutrient availability, with the most severe fouling occurring in tropical, shallow waters (International Paint 2013).

A Snapshot of the Most Common Fuel Efficiency Retrofit Technologies

Propeller Boss Cap Fins

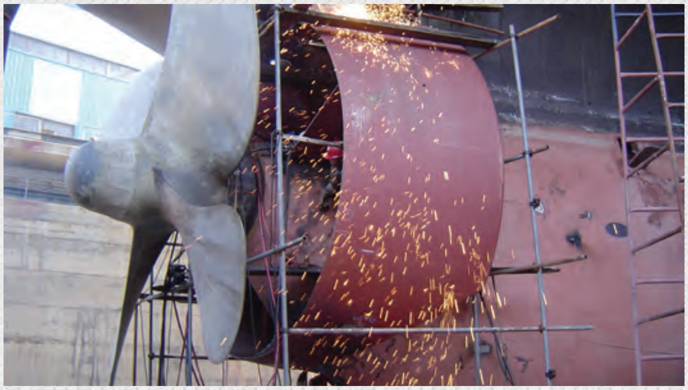
Propeller boss cap fins consist of small fixed fins attached to the propeller hub. A standard propeller generates a vortex at the center of its wake. By adding fins to the propeller boss cap, some of this rotational energy can be recaptured and used for propulsion work (Fathom 2013).

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

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).



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).

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).

Retrofitting vessels with, for example, a bundle of all the technologies listed here (which is by no means an exclusive list of available options), offers a solution for older vessels to stay in operation and deliver fuel efficiencies that are competitive with the new "eco-build" vessels now coming online, and may prevent those older vessels from being laid-up[10] or scrapped prematurely.

Costs and Benefits of Fuel Efficiency Technology Retrofits

A variety of factors determine the costs (e.g., cost of technology and installation costs) and benefits (e.g., cost savings) of fuel efficiency retrofits, including: a given ship's type, size and age; its number of days at sea per annum; its baseline fuel consumption; and, of course, the fuel prices where it is operating.

Shipowners have much to gain from increasing the fuel efficiency of their vessels. In the current market, vessels that are more fuel efficient are more likely to be hired, and in some cases can even command a higher day rate (Smith *et al.* 2013). Retrofitting can also result in increased asset value, particularly if owners are able to demonstrate efficiency improvements to banks. This can be done by contracting a classification society to verify the fuel efficiency improvements pre- and post-retrofit, so long as continuous monitoring equipment is installed along with the fuel efficiency technologies. Finally, fuel efficiency upgrades may confer additional soft benefits to shipowners, such as the marketing and publicity value of "greening" their fleet.

In the current market, vessels that are more fuel efficient are more likely to be hired, and in some cases can even command a higher day rate

2. Alternative Fuel Engine Conversion Retrofits

For many vessels operating wholly or part time in ECAs, converting to dual-fuel engines presents an opportunity to meet ECA standards while reducing operating costs. A variety of factors determine if it is profitable to convert a vessel to run on alternative fuels, including a given ship's type, size, and age, the amount of time it usually spends in an ECA, and, if converting to LNG, the regional cost and availability of that fuel. In light of these factors, fuel conversion should be considered on a vessel-by-vessel basis.

Switching to alternative low-sulfur fuels, such as LNG or biofuels (which can, in certain geographies, both cost less than petroleum-based fuels and emit less carbon), would allow for a ship to save money while reducing its emissions and complying with 2015 ECA regulations. While biofuels have the technical potential to be drop-in fuels (i.e. their use would not require an engine conversion—they could be burned in the same engine that previously burned a petroleum-based fuel), there are currently no commercially viable biofuel bunker production facilities in the world. Therefore, as the commercial market for alternative biofuels for shipping is nonexistent, this paper focuses on a technology known as "dual-fuel LNG engine conversion," which does require a retrofitting of the ship's engine.

Dual-Fuel LNG Engine Conversion Retrofits

Currently, LNG-fueled engines are manufactured by established engine manufacturers, such as Wärtsilä, Rolls-Royce, and MAN Diesel & Turbo. There are two different types: dual-fuel engines that are able to run on LNG or conventional bunker fuel; and "LNG lean-burn mono-fuel engines" that can only burn LNG fuel. Dual-fuel engines allow for vessels to run primarily on LNG while retaining the ability to switch to conventional bunker fuels when/if necessary. The financial model featured in this report focuses on these dual-fuel LNG engine conversions, as LNG is not currently available in all sea lanes and retaining the ability to switch fuel is necessary at present for a global fleet.

Ships have been running on LNG since 2001 and, as of October 2013, 42 ships in the world were using LNG as a fuel when and where possible (European Shortsea Network 2013). Converting a vessel to run on LNG requires not only modifications to the ship's engine but also, for example, the installation of a sophisticated system of special fuel tanks, a vaporizer, and double insulated piping. A variety of factors, including the ship's type, size, and age, determine whether or not a vessel is suitable for LNG conversion, as some ships may not be able to accommodate retrofitted fuel tanks, while the expected lifespan of other ships may not justify the cost of conversion (DNV 2011).

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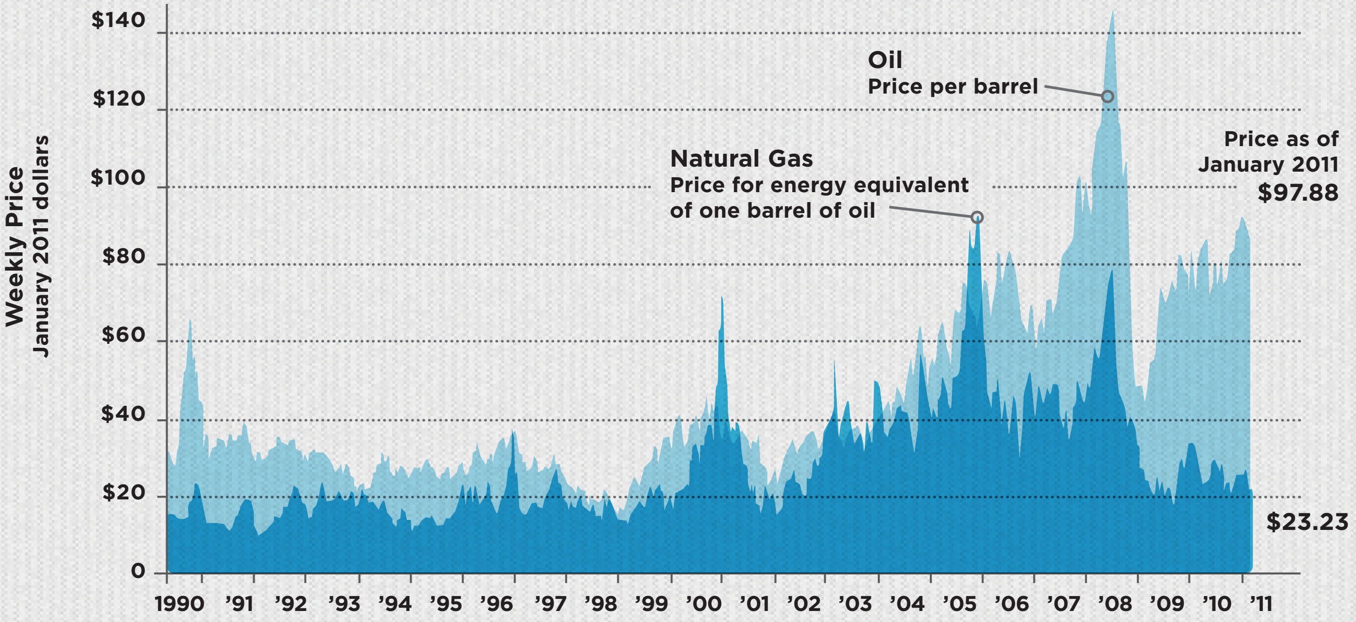
[10] Not actively employed.

Figure 6: US Historical Oil and Gas Prices Illustrating the Price Decoupling of Natural Gas and Oil



Source: Bloomberg Financial Markets; New York Times, 25 February 2011.

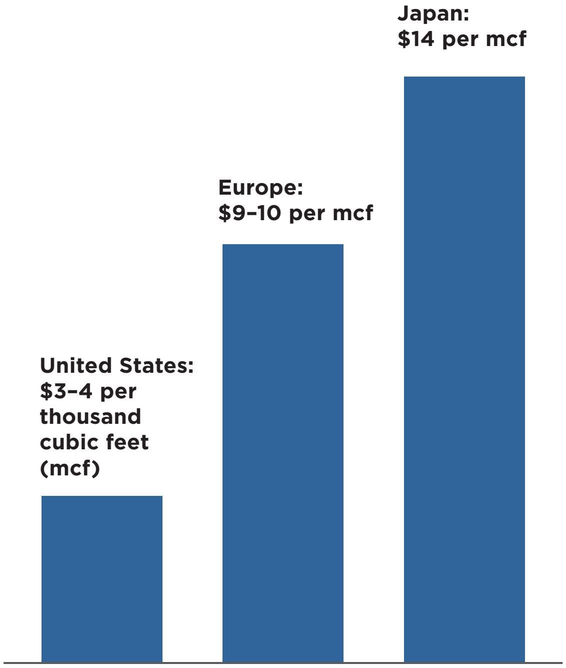
Costs and Benefits of LNG-Based Engine Conversion Retrofits

For ships operating wholly or part time in ECAs, converting to dual-fuel LNG engines presents an opportunity to meet ECA standards while reducing operating costs. Essentially, LNG conversion accomplishes the same goals as fuel switching between HFO and low-sulfur fuels. On the one hand, LNG conversion retrofits have a high upfront cost. On the other hand, LNG is today much cheaper than low-sulfur fuels in many regions (see Figure 6). Therefore, the most important factor in determining the economic viability of an engine conversion retrofit is the fuel price differential between low-sulfur fuel and LNG.

Currently, the LNG market has significant regional price differences, with North American prices being the cheapest, followed by European prices and then Asian prices (Figure 7), so the savings to be had by converting will vary around the world.

From an air pollution perspective, natural gas is significantly cleaner when burned than traditional marine bunker fuel. Specifically, LNG emits 25% less $CO_{2,}$ 90% less NOx, 99% less SOx, and 100% less particulate matter than the equivalent amount of bunker fuel.[11] However, the use of natural gas entails its own set of environmental and GHG challenges, particularly that of potential methane leakages during natural gas extraction and/or transportation, and the potential for methane slippage[12] at the engine's exhaust for certain engine types, which may negate the majority of the climate benefits conferred by the lower emissions of LNG when burned (ICCT 2013). While a suite of technologies do exist that could improve natural gas extraction emissions profiles, they are not being widely used anywhere in the world today, and this paper does not consider them in its assessment of the potential environmental and cost benefits associated with the use of natural gas by the shipping industry.

Figure 7: Liquefied Natural Gas: Estimated Regional Price Differences



Source: Federal Energy Regulatory Commission Market Oversight, June 2013.

There are two main types of natural gas: conventional and unconventional. The extraction of unconventional shale gas has significant additional environmental impacts besides the potential for methane emissions inherent in the use of any type of gas, and a significant debate around the near- and long-term environmental implications of developing unconventional resources is ongoing, including concerns over air quality, water resources, and community impacts (Howarth *et al.* 2011). It should be noted that shipowners using LNG as a bunker fuel will not have any control over the source of the fuel that their vessels consume (conventional or unconventional).

Finally, the recent and rapid expansion of natural gas exploration and drilling means that the regulatory landscape of natural gas extraction will likely be uncertain in the short term. Further regulations could add to the cost of LNG—for example, the IEA estimates that precautions to manage some of the negative environmental and health impacts of unconventional shale gas would add 7% to its cost in the United States, resulting in a somewhat reduced price gap between LNG and MGO.

Comparable Alternatives to Engine Conversion: Scrubber Retrofits

In markets that have limited access to cheap natural gas (e.g., Northern Europe), shipowners may consider installing "scrubber" technology to lower emissions and comply with regulations within ECA zones.[13] Scrubbers allow ships in these ECAs to continue to burn traditional bunker fuel, yet still benefit from the savings created by the price difference between (cheaper) traditional bunker fuel and the low-sulfur diesel that would be required without scrubber technology. It might likewise be more financially rational to install a scrubber rather than convert the engine to use alternative fuels in the case of older vessels that only have five to 10 years left in their useful life. For the sake of this paper, however, the scrubber technology option will not be explored further, as the financial model for scrubbers is similar to that for dual-fuel LNG conversion (in that the payback and return are generated from future fuel cost savings).

> The recent and rapid expansion of natural gas exploration and drilling means that the regulatory landscape of natural gas extraction will likely be uncertain in the short term

[11] This does not incorporate lifecycle GHG emissions, including potential methane leakage.

[12] Methane slip occurs at the point of combustion, and refers to the trace of gas fuel that passes non-combusted through the engine and is emitted with the exhaust gas.

[13] While scrubbers will reduce NOx, SOx and particulate matter emissions, they do not reduce CO_2 emissions. They also entail specific operating costs, including the disposal of a sulfur-rich sludge waste and increased power consumption (DNV 2011).

Current Barriers to Implementing and Financing Retrofits

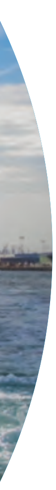
While the two sets of proven retrofit solutions described previously can help shipowners stay profitable under today's market and policy conditions, there is currently very little capital flowing towards their implementation.

Through an analysis of available literature (e.g., Wang *et al.* 2010; Faber *et al.* 2011 & 2012; Maddox Consulting 2012), including the results of a survey with nearly 150 global shipping companies (Rehmatulla 2012; Rehmatulla & Smith 2012; Rehmatulla, Smith & Wrobel 2013), two general market barriers were identified as the main reasons why these retrofits are not occurring at a much faster pace. One additional specific barrier was identified for each of the two retrofit options discussed in this paper.

1. General Barrier: Access to and Cost of Capital

The capital-intensive nature of maritime retrofit technologies poses a significant barrier to their deployment, particularly given the capital-constrained nature of the shipping industry today. Ship financing is a concentrated industry, with the top 40 banks holding more than 90% of the world's $500 billion in shipping debt. Many of these sources of financing are reducing their shipping commitments, leaving shipping companies with restricted access to capital and credit. For example, the top 10 lenders have reduced their shipping loan books by $50 billion (or 10%) since 2008 as a result of the global financial crisis (Devabhaktuni & Kennedy 2012).

Though exacerbated by the recent slowdown in the global economy, these capital constraints are inherent to the shipping industry, as they stem from the risk and uncertainty of both the performance of the retrofit technologies and from a ship's overall revenue. While some companies may be financially able to finance the retrofit from their own balance sheet, using third-party financing allows companies to free up their own capital for other uses. However, it is currently very difficult for a shipowner to obtain outside financing for new equipment (i.e. retrofits), even though the new equipment would make the asset more valuable and more appealing to charterers and would free up the shipowner's cash to cover debt service.



When financing retrofit technologies either on or off the balance sheet, there are risks associated not only with financing the retrofit but also with managing the risk—a process about which there is little track record or experience from which to learn within the industry. As a result, most banks are hesitant to be the first movers in financing retrofits, and they will not invest if they cannot be certain about the return on investment of a given technology or bundle of technologies. Private equity firms may be more willing to take on this risk for technologies with limited data or track records.

In addition, the cost of capital varies among shipping companies of different sizes and standings—with blue chip and large companies facing lower costs of capital. For example, in August 2012 Maersk confirmed they could borrow from banks at 3.5%, while some unnamed Greek shipowners were paying a margin of 300 basis points over the London interbank offered rate (Lloyd's List 2012).

Finally, obtaining capital for the financing of retrofits onto existing ships is complicated by the need to manage relationships between various lenders. For example, if a shipowner is interested in taking out a loan to pay for a retrofit, the original lender will have senior lien on the mortgage of the asset and typically would be unwilling to give approval for a second mortgage.

This paper later explores the built environment and the challenges and opportunities offered by energy efficiency retrofit technologies in that sector as analogous to the situation of fuel efficiency retrofits in the maritime shipping sector. The similarities allow for the slightly more developed financial models currently driving retrofits in the built environment to be adapted to shipping. For example, in the built environment (e.g., buildings), existing mortgages are a major barrier to obtaining the capital for energy efficiency retrofits, and are addressed in one of three ways:

1. By the provision of off-balance-sheet finance that is structured as an Energy Service Agreement.[14]
2. By utilizing PACE (Property Assessed Clean Energy), a financial model that enables liens to be senior to the first position of mortgage holders.
3. By negotiating/working with the mortgage lender to show that the energy savings that result from the retrofit will improve the cash flow of the building and make it more likely that the lender will get repaid on their mortgage.

These three methods for overcoming the capital barrier for building retrofits all have the potential to be adapted for the shipping industry.

Since 2008, the top 10 lenders have reduced their shipping loan books by $50 billion (or 10%) as a result of the global financial crisis

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[14] An Energy Service Agreement is a contract that permits energy efficiency to be packaged as a service that building owners pay for through savings and that generally requires no (or minimal) upfront cost to the owner. It is an alternative to using equity or a traditional loan to retrofit a building.

2. General Barrier: Split Incentives

Split incentives (also commonly known as the "principal-agent problem") refer to the difficulties that arise from a contract in which the two parties have different motivations and aims (IEA 2007). In the shipping industry, it occurs as a result of the different types of contracts between shipowners/operators and charterers, which disconnect the entity investing in efficiency with the entity directly paying for fuel, e.g., the time charter.

Typically, a shipowner would be responsible for financing any retrofit technologies, but their charterers would enjoy the resulting savings on their fuel bill. This gives shipowners little incentive to invest in retrofits, as it makes no economic sense for them to spend their money on saving fuel when someone else is paying for it.

Shipowners are further disincentivized from investing in retrofits by virtue of the fact that, historically, neither charter rates nor second-hand ship prices have consistently reflected the fuel efficiency of a given vessel (Smith *et al.* 2013). As a result, only shipowners who have long-term agreements with charterers or who operate their own vessels would be able to recoup the cost of their technology investment via fuel cost savings (CE Delft 2009). While information and transparency surrounding vessel efficiency are improving in the sector, the UCL Energy Institute's recent shipping efficiency report found that efficiency is still not being consistently and fully factored into daily charter rates (UCL 2013; Agnolucci, Smith & Rehmatulla).

Finally, in some cases the payback period predicted for a retrofit may be longer even than the time a given owner plans to control a given ship, as ship ownership typically lasts five to eight years for many different ship types (Stott 2013).

From the perspective of the charterers, the split incentive is exacerbated by a persistent uncertainty around retrofit payback periods in light of today's standard practices with respect to charter[15] lengths. In most cases, it is not commercially attractive for a charterer to take on financing in order to invest in ships they do not own, as current charter durations last anywhere from several months to 10 years, while current data on the effectiveness of any given technology installed in isolation may not suggest a comparably short payback time for the investment. Most charterers will be unwilling to finance a retrofit if a ship's charter expires before the estimated payback time is passed and profits are accrued (Blumsetin 1980; Fisher & Rothkopf 1989; Howarth & Winslow 1994; CE Delft 2009; Rehmatulla & Smith 2012).

The savings available from a retrofit can vary significantly from one ship type and size to another

3. Barrier Specific to Fuel Efficiency Retrofits: Lack of Measurement and Verification Methods

Fuel efficiency technologies abound, but the claims they make about their efficiency-improving values are equally numerous,[16] and shipowners and financiers alike need valid performance data before adopting them. In an environment of competing and often difficult-to-understand data from technology producers, the industry is sceptical of efficiency claims (Rojon & Smith 2014; Faber *et al.* 2009; Thollander, Palm & Rohdin 2010).

To secure capital, investment projects must be expected to yield a return in excess of some pre-defined minimum level. Unfortunately, isolating the cost-saving benefits of a retrofit intervention from the many drivers of fuel consumption (e.g., speed, weather, and operating area) is challenging, and often can only be done with levels of uncertainty similar in size to the predicted fuel saving that is being measured, particularly for ships without modern continuous monitoring systems. Moreover, the savings available from a retrofit can vary significantly from one ship type and size to another (e.g., from a container ship to a tanker), and can also depend on the starting specifications of the ship, making savings claims difficult and expensive to verify and/or guarantee.

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[15] Arrangement for a ship to carry a certain cargo on a particular route; such deals usually cover a single trip. In a spot charter, the shipowner pays fuel and port charges, distinguishing spot business from time charters or long-term charters, where the charterer will pay for the fuel and port charges.

[16] Fathom Shipping, information specialists on maritime eco-efficiency, have identified more than 220 products across more than 60 technology categories, from more than 100 providers, currently available on the maritime market.

[17] Bunkering is the process of supplying fuels to ships for their engines (that is, not to be transported as cargo)—in this case supplying LNG from the on-shore LNG facility to a ship's bunker tanks.

In addition, the industry has no publicly available data that demonstrates or compares the performance of fuel efficiency technologies when they have been installed in packaged bundles. Technology producers currently make performance claims based on the installation of only their own technology onto an otherwise baseline ship. But the greatest efficiency gains will always be achieved by installing a suite of technologies and upgrading various facets of ship design at once, particularly given that the dry-docking periods required to perform most retrofits are expensive. Unfortunately, the efficiency gains of these technologies when installed in a bundle, though greater, will not be the additive sum of the gains of individual technologies. Compounded by the issue of low trust in producer data, the absolute nonexistence of data on the performance of technologies in bundles presents a problem for shipowners attempting to judge the real opportunity available to them in retrofitting their ship—and in attempting to finance that upgrade.

Industry-wide efforts have arisen in an attempt to combat some of these informational issues, in particular efforts to create standards for measurement, such as the International Organization for Standardization's initiative to develop a common industry standard for measuring changes in hull and propeller performance (Lloyd's List 2013e). While the development of measurement standards will be beneficial, using the financial models suggested in this paper to facilitate the adoption of fuel efficiency retrofits will require the installation of continuous data-monitoring systems in order to collect data on technology bundles and verify savings.

4. Barrier Specific to Dual-Fuel LNG Engine Conversion Retrofits: Lack of LNG Bunkering Infrastructure

The most pressing barrier to the adoption of LNG fuels by the shipping industry is the lack of bunkering[17] infrastructure to support LNG supply and delivery. That is to say, LNG infrastructure does not currently exist to deliver gas where marine vessels need it. While a significant increase in the number of bunkering terminals is expected in the coming decade, especially within ECAs, the present uncertainty of LNG fuel supply poses a critical barrier to engine conversion (Eide, M *et al.* 2012).

Unlike the other three barriers discussed above, the lack of bunkering infrastructure will not be entirely overcome by the financial models presented in the next chapter of this paper. However, LNG infrastructure is already developing on its own. For example, there are several natural gas liquefaction terminals planned and/or currently under construction in strategic US ports, specifically in the Gulf Coast, Great Lakes, Southeast and Pacific Northwest (Lloyd's List 2013a). With respect to other bunkering regions, the Singapore Maritime Port Authority plans to open an LNG import terminal in 2013, and has already made significant investments in including LNG bunkering capabilities into the plans at their facilities (Lloyd's List 2013d). In Europe, Belgium, Poland, the Netherlands, and Sweden, among others, have already developed or have plans to develop LNG infrastructure (Lloyd's List 2013c). The EU Transport Council has recently announced plans for all 139 EU ports to be fitted with LNG bunkering infrastructure by 2025, an initiative for which the European Commission is setting aside €2.1 billion (Weekblad Schuttevaer 2013).

The EU Transport Council has recently announced plans for all 139 EU ports to be fitted with LNG bunkering infrastructure by 2025

Innovative Financial Models

In light of current market and regulatory forces, fuel efficiency and/or engine conversion retrofits offer an option for increasing the profitability of the existing fleet, though significant and pervasive market barriers are hindering the adoption of these technologies. The next section of this paper will discuss examples of innovative models built around third-party financing that have accelerated the deployment of various renewable energy and fuel or of energy efficiency technologies in other sectors—models that CWR believes can, if properly adapted, overcome shipping's market barriers and achieve similar accelerations for the industry.

Adapting Third-Party-Finance Models from Other Sectors

Third-party-finance models have revolutionized the deployment of clean technologies in many key sectors and industries, including the renewable energy market and the built environment sector. To take the renewable energy market as an example, in 2003 Sun Edison introduced new third-party financing mechanisms to enable solar installations with no upfront costs to the user. This solar Power Purchase Agreement (PPA) has since become the dominant financing mechanism for solar installations.

Similar models are already being adopted by other industries, such as the commercial buildings market. In the buildings market, Energy Service Companies (ESCOs) provide third-party financing for retrofits that improve the energy efficiency of a building, so that the landlord or tenants do not need to be burdened with the upfront costs of the retrofits on their own balance sheets.

Third-party-finance models like these are now being introduced into the shipping industry, making it important to understand and overcome the specific challenges associated with the original models, as well as with the task of translating them to shipping.

PPAs and ESCO Models

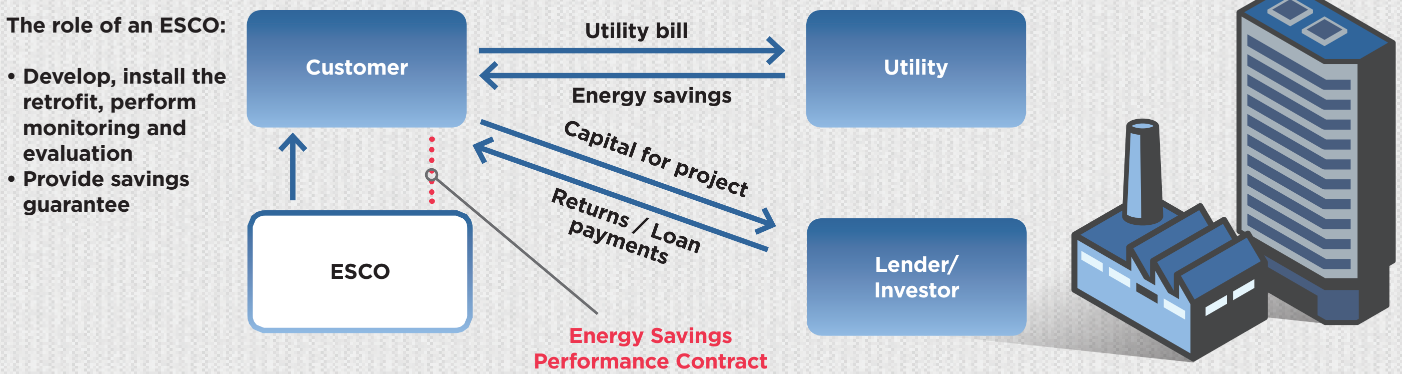
A solar PPA is an agreement that enables an unrelated third party to finance and install solar generation capacity for the benefit of an electricity consumer. The agreement specifies that the third party will pay for and own the solar technology, and that the electricity consumer will purchase the electricity generated by the solar installation for a fixed period of time, thereby generating the payback and returns for the third party. By transferring the upfront capital costs of the solar project to a third-party entity, one either with greater access to or lower costs of capital, solar PPAs represented a significant innovation in cleantech financing, and new solar installations in the US have grown by an average of 61% per year since their introduction (SEIA 2013).

ESCO models perform a role similar to PPAs in that they also enable third parties to finance the deployment of new technologies, in this case technologies that improve the energy efficiency of commercial buildings. Energy Services Companies (ESCOs) are, typically, large companies that specialize in demand-side energy services and that have been assisting their customers with energy efficiency retrofits for decades.

The current ESCO model for energy efficiency in the built environment is focused on providing performance guarantees that help backstop energy efficiency upgrades, making it easier for projects to acquire financing. Under this model, an ESCO will typically enter into a performance contract with the asset owner. In one variation of this performance contract model, the ESCO, generally through third-party-finance partners, will invest all of the capital necessary to perform the retrofit. Alternatively, the asset owner may finance the project themselves via internal capital, a tax-exempt capital lease, or bond financing through a bank. In either case, the performance contract is in place to help give the capital provider more comfort that the project will generate enough savings to offset the costs of the retrofits. If the retrofits ultimately underperform, the ESCO will make a payment on the shortfall, as Figure 8, overleaf, illustrates.

> By transferring the upfront capital costs of the solar project to a third-party entity, one either with greater access to or lower costs of capital, solar PPAs represented a significant innovation in cleantech financing

Figure 8: ESCO Flow of Payments



Source: Wilson Sonsini Goodrich & Rosati.

Typically, an ESCO will provide energy efficiency services using one of three structures:

1. In a "guaranteed savings structure," the asset owner receives a guaranteed amount and the ESCO gets the additional savings.

2. In a "shared savings structure," the asset owner and the ESCO agree to split the savings according to a percentage, such as 50/50.

3. In a "paid-from savings structure," the ESCO receives a guaranteed amount and the asset owner gets the additional savings.

The primary advantage of performing a retrofit through a performance contract with an ESCO is that the ESCO has the expertise and experience needed to design and implement high-quality retrofit projects and to guarantee the savings from those projects. In some cases, the ESCO may also assist the asset owner with sourcing traditional financing or other incentives by connecting them with banks or utilities with which the ESCO has developed relationships. The ESCO market for built environment retrofit project installations and services exceeded $5.1 billion in 2011 and is expected to reach $16 billion by 2020 (Pike Research 2012).

The ESCO market for built environment retrofit projects, installations, and services exceeded $5.1 billion in 2011 and is expected to reach $16 billion by 2020

Both the solar PPA and the ESCO models are in the process of reaching maturity as asset classes. This transformation in the solar industry was driven by gains in the transparency and auditability of panel performance;[18] the correlating development in the commercial building space has been the development of better and more appropriate measurement procedures to verify efficiency gains from retrofit technologies. This growing transparency has made both the solar PPA and the ESCO models more attractive financial vehicles to banks, insurance companies, and large corporations, as they can feel confident that the projects initiated under these models will provide them with steady returns and an attractive risk profile. In turn, this has dramatically lowered the cost of capital for those projects, from 10–20% to 6–8%. The ESCO and solar PPA markets are currently evolving even further, as hedge funds and private equity funds (which represent $4.2 trillion in investible assets) are beginning to compete for access with pension, mutual funds, and insurance funds (which represent $80 trillion in investible assets).

These third-party-finance models can be adapted from the built environment and renewable energy sectors to overcome the issue of the significant capital costs of deploying retrofits in the shipping industry, although certain barriers and complexities specific to the shipping industry will need to be addressed. For example, adapting the ESCO model will require the development of new shipping-specific methodologies and technologies to measure and monitor the performance of the efficiency technologies. In addition, for fuel efficiency retrofits, the shipping industry will need to develop a methodology by which performance gains can be attributed to specific technologies when installed in bundles, and generally to deal with the many variables and data uncertainties associated with vessels operating on the seas. This paper finds that while these challenges are real, the potential opportunity offered by retrofits, in terms of both financial and emissions savings, is even greater (Figure 9).

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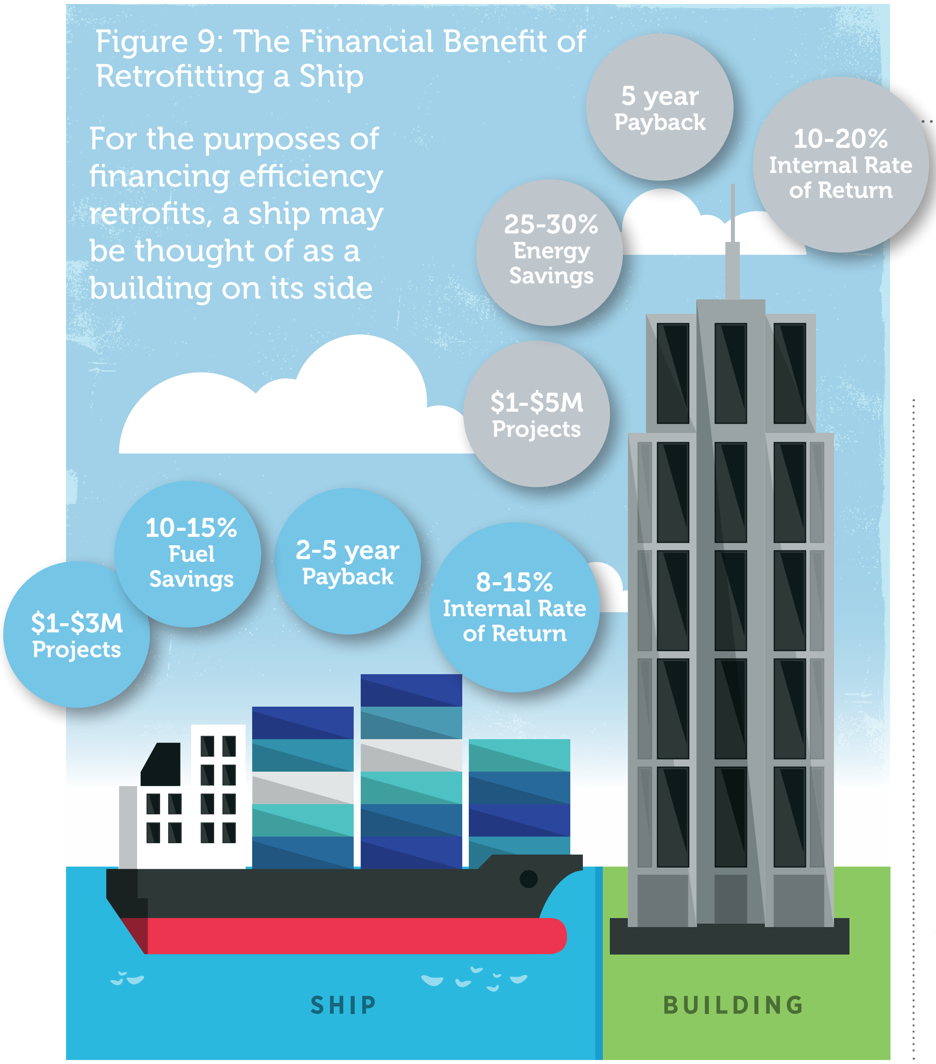
[18] Panel performance (the amount of electricity that is generated from a solar panel), is impacted by a variety of factors, including the efficiency of the panel, panel orientation, panel pitch, temperature and shade.

Figure 9: The Financial Benefit of Retrofitting a Ship



For the purposes of financing efficiency retrofits, a ship may be thought of as a building on its side

Third-Party Financing of Retrofits for the Shipping Industry

Currently, several shipping technology providers[19] are working with lenders and banks to assist in the loan procurement for the purchase of their products. For example, MAN Diesel & Turbo, an engine manufacturer, has financed the installation of MAN Diesel fuel-saving technologies onto 30 vessels in this manner (Lloyd's List 2013b).

While such models based on more typical financing have the potential to continue to facilitate fuel cost savings for the shipping industry, more nuanced and innovative financial models are also needed in order to address the range of market barriers and fully realize the emissions- and cost-saving potential of retrofits. Figure 10 gives an overview of the two main models analyzed by this paper—the Self-Financing Fuel-Saving Mechanism (SFFSM), designed for fuel efficiency retrofits, and the Emission Compliance Service Agreement (ECSA), designed for dual-fuel LNG engine conversion retrofits.

Figure 10: Fundamental Features of Third-Party-Finance Models for Retrofits

Technology	Third-Party-Finance Model Example in this Paper	Pathway for Payback	Methodology for Data Collection	ECA Compliance?	Estimated Fuel Cost Savings	Emissions Reductions per Vessel
Combined Suite of Fuel Efficiency Retrofits	Self-Financing Fuel-Saving Mechanism	Third-party investors finance the tech installation and receive payback from the ongoing fuel savings conferred by the techs. Additional savings accrue to the fuel payer	Develop baseline performance methodology and install continuous monitoring equipment for measurement and verification of efficiency gains	Not directly—these technologies instead reduce total fuel consumption and thereby lower the cost of switching to low-sulfur fuel in ECAs	Common technology suites achieve around a 10–15% decrease in fuel consumption levels	Depends on technology suite; generally in the range of 5–15% CO_2 savings per annum over lifetime of the technology[20]
Dual-Fuel LNG Engine Conversion Retrofit	Emission Compliance Service Agreement	Third-party investors finance the tech installation and receive payback from a hedge against the price spread between low-sulfur diesel and LNG	Standard fuel consumption data collected; no additional measurement and verification required	LNG brings a vessel into compliance with 2015 SOx emissions regulations	20–40% (depending on geography and the pricing / availability of LNG)	25% CO_2* 99% SOx 100% PM 90% NOx *Assuming no methane slippage

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[19] To CWR's knowledge, these include MAN Diesel & Turbo (engine and propeller manufacturer), Wärtsilä (engine and propeller manufacturer), and Jotun (hull coating company).

[20] Premium hull coatings will only deliver the projected savings over the dry-dock period, while other technologies (boss cap fins, propellers) will deliver the savings over the lifecycle of the vessel.

The Self-Financing Fuel-Saving Mechanism: A Model for Fuel Efficiency Retrofits

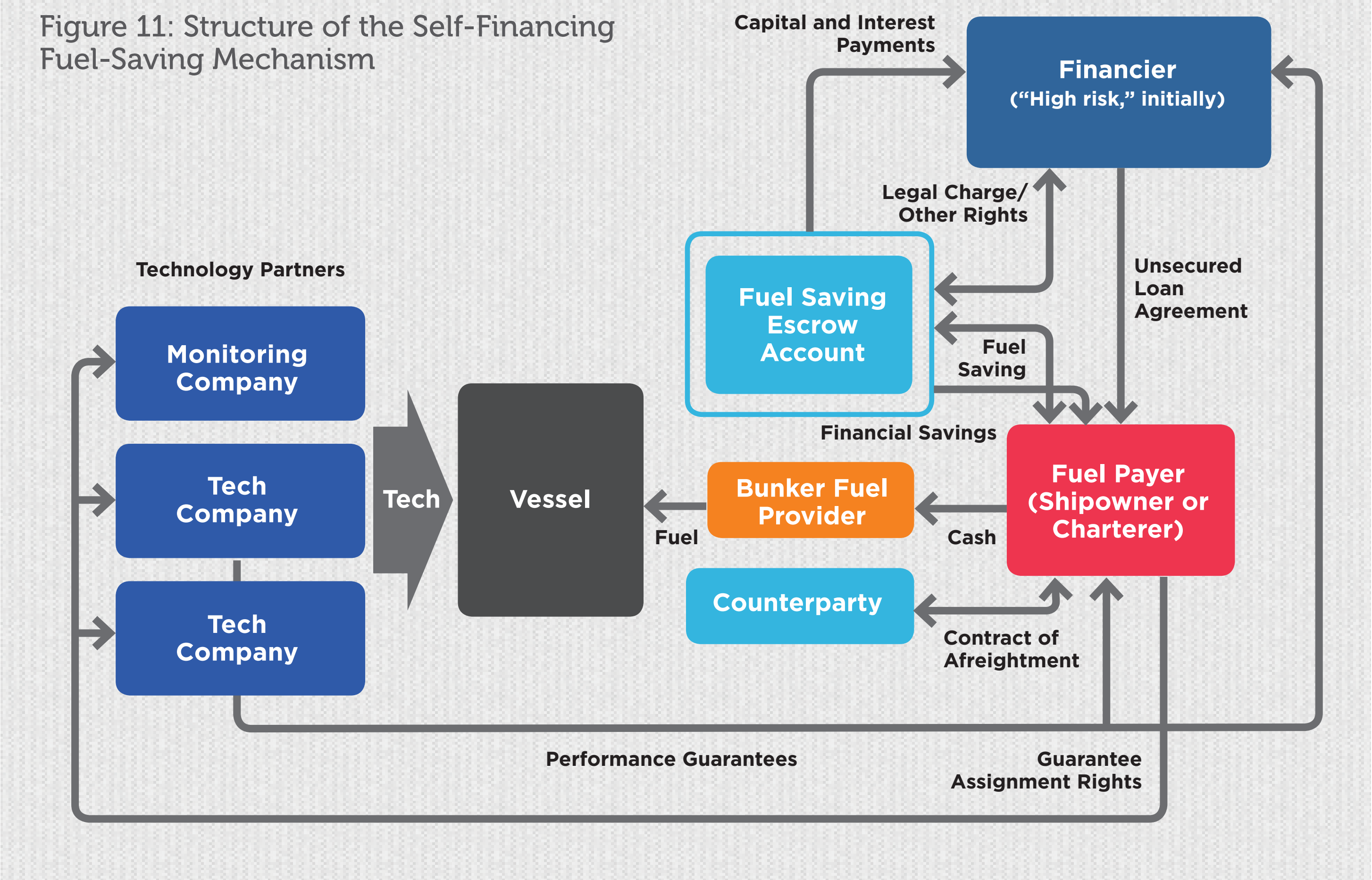
The CWR has partnered with PwC, University College London (UCL), and a consortium of other stakeholders to develop a fuel efficiency retrofit-financing model, called the Self-Financing Fuel-Saving Mechanism (SFFSM). This financial model is technology agnostic and is optimized to support the installation of a bundled suite of technologies that act upon different aspects of fuel inefficiency. Two key features of this model are a guarantee of fuel savings from the technology vendors and a sophisticated new data collection methodology that uses continuous monitoring equipment to accurately quantify and verify the fuel savings.

Illustrative Financials of the SFFSM

The SFFSM features a tripartite contractual agreement (see Figure 11) between the technology partners, the fuel payer, and the financier. The retrofit technology companies supply/fit the vessel with their respective equipment at the vessel's next scheduled dry-dock, and they provide performance guarantees to the shipowner or charterer (the fuel payer)—which will be verified by the monitoring company, whose technologies will also be installed at that time. The fuel payer is then the counterparty with the financier, and pays the technology providers at normal cost for their respective products.

The cost savings resulting from the efficiencies achieved (fuel savings) over a defined period are deposited into and accrue within a Special Purpose Vehicle (SPV)[21] or escrow account.[22] The fuel savings are then distributed to the financier at predetermined and agreed-upon periods to generate their payback and returns. Like in the ESCO model used in the built environment sector, the SFFSM can be financed using one of three structures:

Figure 11: Structure of the Self-Financing Fuel-Saving Mechanism



1. In a "guaranteed savings structure," the fuel payer receives a guaranteed amount and the financier gets the additional savings.
2. In a "shared savings structure," the fuel payer and the financier agree to split the savings according to a percentage, such as 50/50.
3. In a "paid-from savings structure," the financier receives a guaranteed amount and the fuel payer gets the additional savings.

Scaling the SFFSM will require significant funding, as each vessel's retrofit will cost circa $300,000–$1.5 million, and around 9,500 vessels could be retrofitted each year.

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The projected payback period of the SFFSM for a given vessel is critically dependent on the following criteria:

- The percentage of fuel saved versus the predicted "baseline" fuel consumption that would have occurred if that vessel had been dry-docked but not retrofitted.
- The vessel's number of days at sea per year.
- The vessel's daily fuel consumption in tons (which will be dependent on how the vessel is operated).
- Bulk fuel costs per ton in the geography where the vessel is operating.

Key Features of the SFFSM

Along with the introduction of third-party financing, the innovation of the SFFSM is its focus on data—from collecting a ship's baseline performance statistics and incorporating those into the calculation of return rates, to including measurement and verification techniques in order to accurately assess the efficiency gains achieved by the retrofit technologies. The methodology for doing this, developed by UCL's Energy Institute specifically for the SFFSM, aims to quantify fuel savings using new data collection technologies.

Over the past decade, an increasingly varied and sophisticated suite of energy management software products have been developed for the maritime market that monitor, control, and optimize every aspect of vessel operation. These systems provide a platform for collecting and processing deep knowledge of vessel performance, such that the vessel's owners and operators may know where the fuel is consumed and whether it was used efficiently and optimally or not. These products vary in complexity, from simpler systems that extract real-time data on fuel burn per mile, to complex systems that not only collect data on a range of both vessel and external parameters (such as wind, waves, sea current, trim, and vessel manoeuvring) but that also serve to improve the operational efficiency of the vessel through both voyage optimization (optimizing route or speed) and trim optimization.[24] Monitoring systems are a required part of the SFFSM, and therefore those technologies, if not already fitted, will be covered by the same third-party funding package that is covering the other fuel efficiency technologies.

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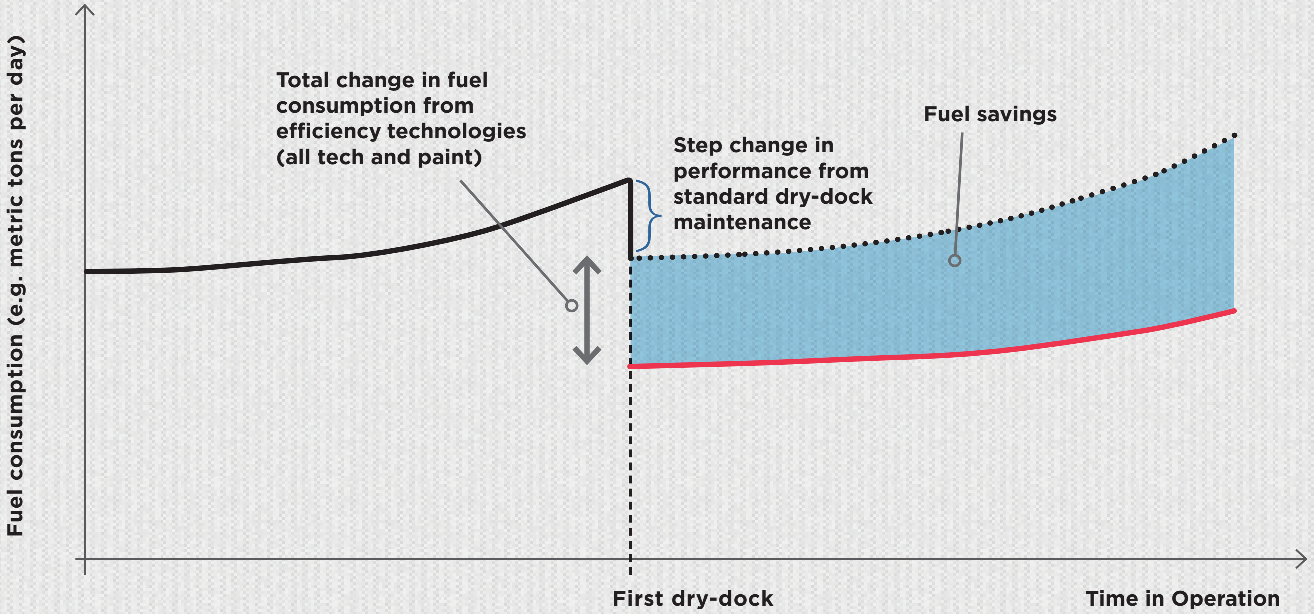
[21] An SPV is typically used for the purpose of financing a project and/or establishing a structured investment vehicle that is separate to the parties and companies that set them up for tax and accounting purposes.

[22] An escrow account is an arrangement made under contractual provisions between transacting parties, whereby an independent and trusted third party receives and disburses money for the transacting parties.

[23] There are approximately 47,500 existing bulk, tanker and container vessels. Assuming each vessel dry-docks every five years, 9,500 vessels would approach dry-dock each year.

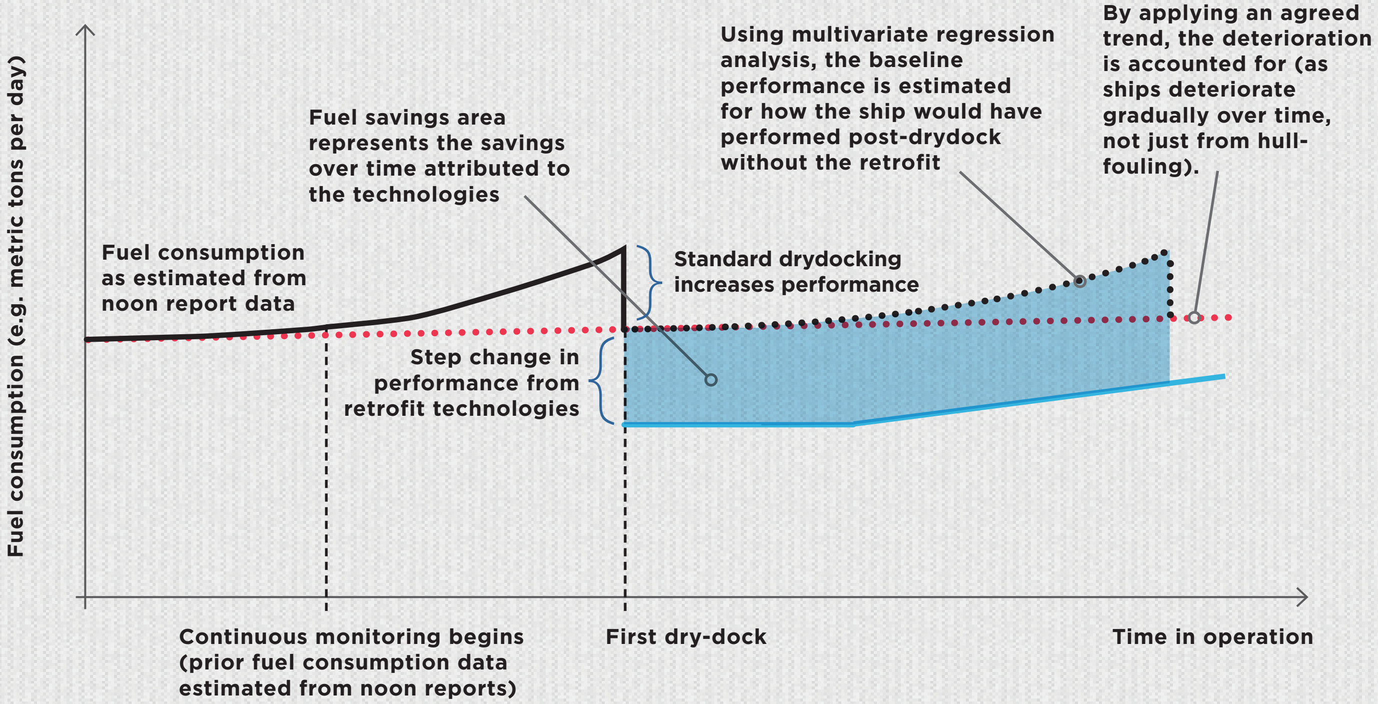
[24] "Trim optimization" assists in operating the ship in optimal trim and floating position depending on the ship's characteristics and external factors (e.g., weather). "Trim" refers to the balance of a ship, and the difference between the draft at the bow and at the stern (attitude); adjusting the trim can minimize water resistance.

Figure 12: Baseline Performance and the Consequence of Fuel Efficiency Interventions



KEY: The solid black line represents the ship's baseline fuel consumption pre-retrofit, whereas the dotted black line represents the estimation for how the ship would have performed post-dry-dock without the retrofit. The solid red line represents the consumption post retrofit.

Figure 13: Monitoring and Measurement to Calculate Fuel Savings



KEY: The solid black line represents the ship's pre-dry-dock fuel consumption, whereas the dotted black line represents the estimation for how the ship would have performed post-dry-dock without the retrofit. The blue line represents the consumption post retrofit. The red line is the ship's underlying gradual deterioration (other than hull fouling)

Method for Verifying a Technology's Fuel Savings

In order to verify the fuel savings resulting from a retrofit, the SFFSM uses two stages of data collection:

1. Establish a baseline forecast for the fuel consumption of the ship with no retrofits.

2. Measure the actual fuel consumption achieved for the ship by the retrofits.

Fuel efficiency retrofits are expected to occur at a regular dry-dock. In order to ensure that the performance of products that have benefits over the full dry-dock cycle (e.g., hull coatings) can be verified, the baseline forecast must cover the duration of a whole docking cycle (e.g., up to five years). Figure 12 shows the actual performance of a ship before the dry-dock during which efficiency retrofits are completed (black solid line), the forecast performance post-dry-dock in the event no retrofit is applied (black dotted line), and the actual measured fuel consumption post-dry-dock (red solid line). The cumulative difference between the baseline forecast and the measured fuel consumption is then the fuel savings.

Ideally, the baseline fuel consumption is quantified using data from continuous monitoring equipment. However, if the equipment is not installed pre-retrofit, noon reports can be used to understand the ship's fuel performance over time and the influence of variables such as ship speed and weather on fuel consumption. Also, baseline fuel consumption will be measured from a full dry-dock cycle pre-retrofit, given that a ship's fuel performance will change over time. This is mainly due to the fact that hulls are often cleaned and recoated when ships are dry-docked for routine purposes, and such treatment normally results in a step change in fuel performance (see Figure 13). Fuel performance also degrades slowly but consistently over the life of a ship, due to long-run deterioration (for example, wear in the main engine and other machinery, hull plate deformations). When verifying the performance of a retrofit intervention, it is important that the verification method does not unfairly attribute either the benefits of a standard dry-dock performance gain or the long-term deterioration trend to the retrofit intervention. Figure 13 depicts how these two exogenous influences on fuel performance can play out.

Uncertainty

There is some uncertainty inherent in any measurement, and in the monitoring and performance analysis of a ship's fuel consumption this uncertainty can be significant, to the point that the margin of error might be similar in magnitude to the percentage gains in performance potentially conferred by the retrofit itself. Reducing the uncertainty of ship performance data is critical to financing fuel efficiency retrofits, and therefore continuous monitoring technologies are greatly preferable to noon reports in establishing baseline consumption and any improvements post-retrofit. A recent report that performed a statistical analysis of the fuel consumption datasets of a large group of ships, in order to estimate the typical magnitudes of uncertainty, discovered that "data acquisition from an onboard continuous monitoring system yields a material reduction in the uncertainty" relative to the use of noon reports (Aldous *et al.* 2013). However, even with continuous monitoring systems, that research ultimately concluded that it will never be possible to calculate the fuel savings resulting from an intervention without some level of uncertainty.

Incorporating Operational Changes into the Baseline Forecast of Fuel Consumption

A ship's fuel consumption is influenced not only by the technologies installed on the vessel but also by the conditions of its operation. For example, ship speeds, trim, loading, and weather conditions can all cause variation in the fuel consumption of a single ship over time. Furthermore, a ship's operational geography, as well as the proportion of time it spends loaded, in ballast condition, or at anchor, all influence the rate of fouling on its hull and therefore the performance of, say, a coating system. Finally, a ship's trading patterns and operational conditions may vary significantly year on year in response to the dynamics of the market and the charters in which it is employed. An industry-wide example of such variation is seen in the case of slow steaming, a practice adopted by many shipping fleets following the financial crisis in 2008 that resulted in significant decreases (30% and above) in fuel consumption. It is therefore very important to recognize and incorporate variations in a ship's operating profile from one dry-dock cycle to the next into the baseline forecast of its fuel consumption. Building on the aforementioned research into uncertainty by Aldous *et al.* (2013), a number of multivariate linear regression models have been developed that are capable of using the preceding dry-dock cycle's data to isolate the influences of key dependent variables (speed, weather, loading etc.) on fuel consumption. Having isolated the influence of these variables on the ship's performance, these new regression models can be used to calculate a baseline forecast for fuel consumption under the operational conditions of the ship for the period after the retrofit, even if those conditions are not identical to the conditions of previous periods.

The SFFSM: Impact on Market Barriers

The SFFSM offers the shipping industry a method for overcoming its barriers of capital and split incentives, and also allows the fuel efficiency technology sector to address its specific barrier of a lack of measurement and verification methods.

General Barrier: Access to and Cost of Capital

In designing the SFFSM, CWR addressed the lack of access to capital by collaborating with PwC and private equity financiers, based on findings that most traditional banks are currently hesitant to fund fuel efficiency retrofit projects on a large scale. Private equity firms are mainly attracted by the short paybacks of these retrofits, especially in light of the performance guarantees provided by the technology vendors under the SFFSM.

General Barrier: Split Incentives

The SFFSM attempts to bridge a common disconnect between the economic incentives of the entity responsible for any technical/capital investments into a ship and its fuel efficiency and of the entity responsible for the fuel costs of that ship's operation. The SFFSM is fundamentally designed to serve charterers, as they are the predominant fuel payer in the industry, and can ask for the model to be applied to vessels carrying their cargoes. The SFFSM currently only works for vessels on long-term charters, or else on owner-operated vessels, as the financier will only invest in vessels that have a guaranteed contract of affreightment.[25]

Barrier Specific to Fuel Efficiency Retrofits: Lack of Measurement and Verification Methods

To overcome a lack of data regarding the performance of fuel efficiency technologies, technology providers working with the SFFSM must be able to guarantee that their respective technologies will deliver a certain percentage of fuel savings when installed as part of a bundle of retrofits. Accurately verifying those fuel savings once the technologies are installed is fundamental to the SFFSM, and, as explained in a previous subsection, the SFFSM therefore requires that advanced new continuous monitoring equipment be installed onto each retrofitted vessel.

Historically, fuel consumption measurement practices have been highly variable. In particular, the performance data of fuel efficiency technologies has been constrained to hypothetical conditions only (e.g., acceptance trials for a newbuild vessel), and therefore has not given investors much confidence in a technology's actual abilities on the less-predictable ocean. Fortunately, the advent of sophisticated monitoring systems has provided a data source that, with rigorous deployment and processing, allows for the calculation of fuel savings with a manageable level of uncertainty.

Save As You Sail: An Alternate Financial Model for Fuel Efficiency Retrofits

The SFFSM is designed to work either for vessels on long-term charter or else for owner-operated vessels, as the financier in the SFFSM is only able to confidently invest in vessels that have a guaranteed service contract that will ensure the vessel will be in use for the entire length of the financing period.

The Sustainable Shipping Initiative has developed a similar financing model for installing fuel efficiency retrofit technologies onto vessels with short-term charters. This model, called "Save As You Sail" (SAYS), is different from the SFFSM in that it focuses on the short-term time-charter market (charters that last generally between one and two years) and is designed to overcome the specific split-incentive challenges of that market (Figure 14). Under SAYS, the shipowners themselves access the capital for the retrofits, as SAYS allows them to recoup their investment over the span of multiple time charterers. With a SAYS package, shipowners agree upon a "SAYS fee" (an added monthly cost that charterers pay to the shipowners). Charterers should theoretically agree to pay that additional fee given that the fuel cost savings that they will enjoy by using an efficient ship will exceed the amount of the SAYS fee. Those estimated savings are based on past performance monitoring data. Any outstanding charter party agreements can be amended to include the SAYS fee, and the SAYS fee will be built into the future charters of that ship as well.

Under SAYS, up to 80% of the upfront costs of the technologies are covered by a loan from ABN Amro bank, with the remainder paid by the shipowner. Over two or three years, the shipowner pays back the loan plus the fixed-rate interest.

The SAYS model specifically focuses on time charters shorter than three years. For this model to be effective, charterers will need to accept an arrangement where they pay more for vessels that are more fuel efficient. The SAYS model currently does not offer a solution for securing the second and third charterers post-retrofit, and so until the charter market guarantees that there will always be someone willing to pay a higher fee for a more efficient vessel, the owner will run the risk of their ship not being chartered again when their first charter contract concludes. If proven in concept, and if owners and lenders receive stronger indications that they will be able to secure their next charters, then this model could be successful in enabling capital to move towards vessels that would otherwise suffer greatly from the split-incentive and lack-of-capital barriers.

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[25] A contract between a shipowner and charterer in which the shipowner agrees to carry goods for the charterer or else gives the charterer use of the entire ship for a specific period of time

Figure 14: Save as You Sail Model

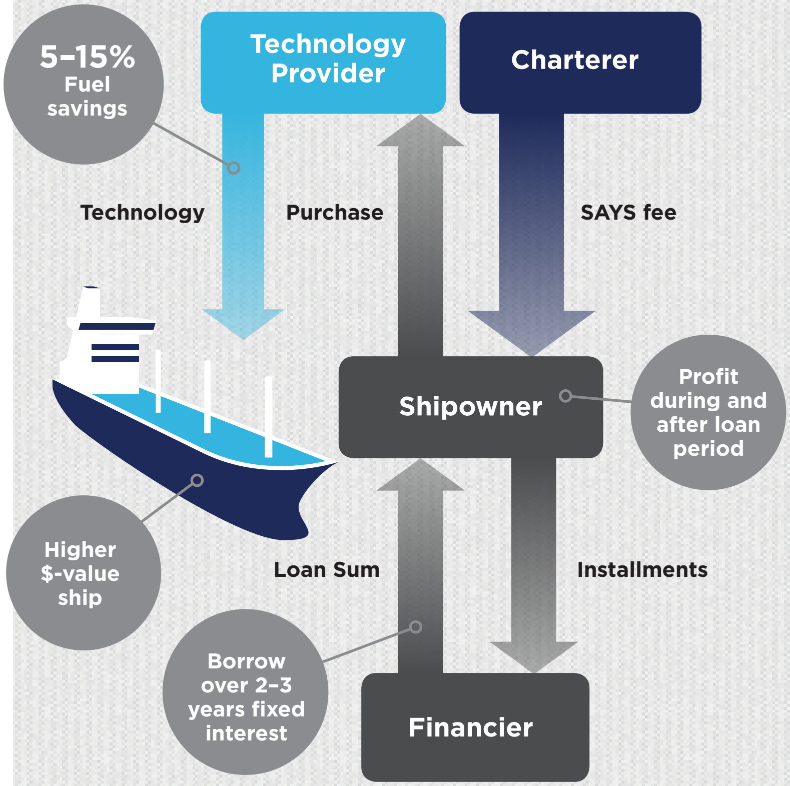
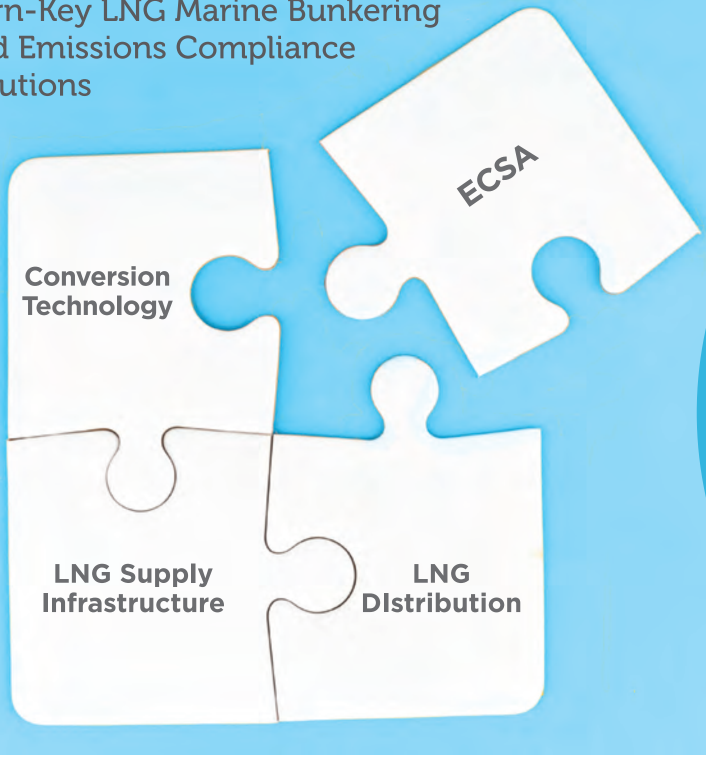


Figure 15: Clean Marine Energy's Turn-Key LNG Marine Bunkering and Emissions Compliance Solutions



The Emission Compliance Service Agreement: A Financial Model for Dual-Fuel LNG Engine Conversion Retrofits

Clean Marine Energy is a private company based in the United States that offers turn-key LNG marine bunkering and emissions compliance solutions for shipowners operating in the US domestic market by providing "no-cost" conversion financing and by guaranteeing that shipowners will have secure fuel supply and distribution for their converted ships. Clean Marine Energy has developed a new financial model, the Emission Compliance Service Agreement (ECSA) that facilitates the conversion of vessels to run on LNG fuel by means of a dual-fuel engine retrofit (Figure 15). The ECSA allows third-party financing to cover the upfront cost of dual-fuel engine conversion, eliminating the need for any upfront capital expenditure on the part of the shipowner (currently the ECSA model is only suitable for use by owner-operated vessels, as it does not include any mechanisms for ships on time charters). The financier's payback and return are generated by future fuel cost savings—essentially by a hedge against the price spread between low-sulfur diesel and LNG. For its part, Clean Marine Energy guarantees supply and delivery of LNG to the converted vessel through its supply and distribution partner ecosystem, as well as advisory services with which the maritime industry may evaluate the benefits of using third-party finance for fuel conversion projects versus simply relying on internal capital.

> The SFFSM offers the shipping industry a method for overcoming its barriers of capital and split incentives, and also allows the fuel efficiency technology sector to address its specific barrier of a lack of measurement and verification methods

Key Features of the ECSA

In piloting the ECSA, Clean Marine Energy is pooling the conversion of several vessels, thereby allowing it to take advantage of economies of scale and package the large-scale investment so as to attract third-party capital providers that are already comfortable with similar financing models, such as for energy efficiency retrofits in buildings via ESCOs. Clean Marine Energy serves a function similar to that of an ESCO by providing "emission compliance (through fuel conversion) as a service" to marine vessels (Figure 16).

Clean Marine Energy is also partnering with infrastructure capital providers and LNG suppliers to build out the fueling infrastructure necessary for ships, overcoming some of the current barriers to LNG supply. As each vessel is retrofitted, a roster of that vessel's expected port locations will be analyzed to estimate the location and volume of its likely LNG demands over its remaining operational life. Clean Marine Energy then matches this demand with a guaranteed supply, assisting in the development of bunkering infrastructure as needed.

To assist shipowners faced with the challenge of ECA compliance but who may not be good candidates for LNG conversion, perhaps because they operate only part time in an ECA and/or in an area where LNG prices are relatively expensive, Clean Marine Energy is also financing the retrofit of vessels with the exhaust gas "scrubber" technologies mentioned earlier. Much like a dual-fuel engine conversion, the ECSA financing mechanism allows third-party capital providers (e.g., private equity, banks) to cover the upfront cost of scrubber installation, with their paybacks generated from the cost differential between traditional bunker fuel and the low-sulfur diesel that the ship would have had to use had the scrubber technology not been installed.

Illustrative Financials of the ECSA

Upon signing an ECSA, the shipowner agrees to pay a set premium over the market rate for LNG for their expected fuel consumption by volume over three to five years (depending on a specific vessel's consumption and capital requirements). Even with the premium, the shipowner will enjoy 5–10% fuel cost savings for the duration of the ECSA term, compared to the price of the low-sulfur diesel that they would otherwise be buying. After the ECSA term,[26] the shipowner will simply purchase LNG at its market rate and receive 100% of the fuel cost savings for the remaining life of their ship (Figure 17). If the ship switches to regular marine diesel at any time during the ECSA term, an additional premium will be applied to the price of that fuel. The ECSA is intended to help accelerate the maritime industry's adoption of LNG fuel by mitigating the capital barriers to retrofit engine conversion.

Fuel savings under the ECSA are based on both vessel/engine type and sailing schedule, but they are expected to average 30% below the projected cost of low-sulfur diesel over the long term, as noted earlier in this paper.

The projected payback period for shipowners under the ECSA is critically dependent on the following factors:

- The capital required for the design and installation of the engine conversion equipment itself, which is vessel specific, and dependent on the size of the LNG storage tanks required for a given vessel's voyage range.
- The fuel price spread between low-sulfur diesel oil and natural gas in a given geography.
- A given vessel's number of days at sea per year.
- A given vessel's daily fuel consumption in metric tons.

[26] Completion of the ECSA term is based on meeting a volumetric threshold of LNG burned—a more fuel-efficient ship would simply have a longer ECSA term.

Figure 16: Structure of the ECSA

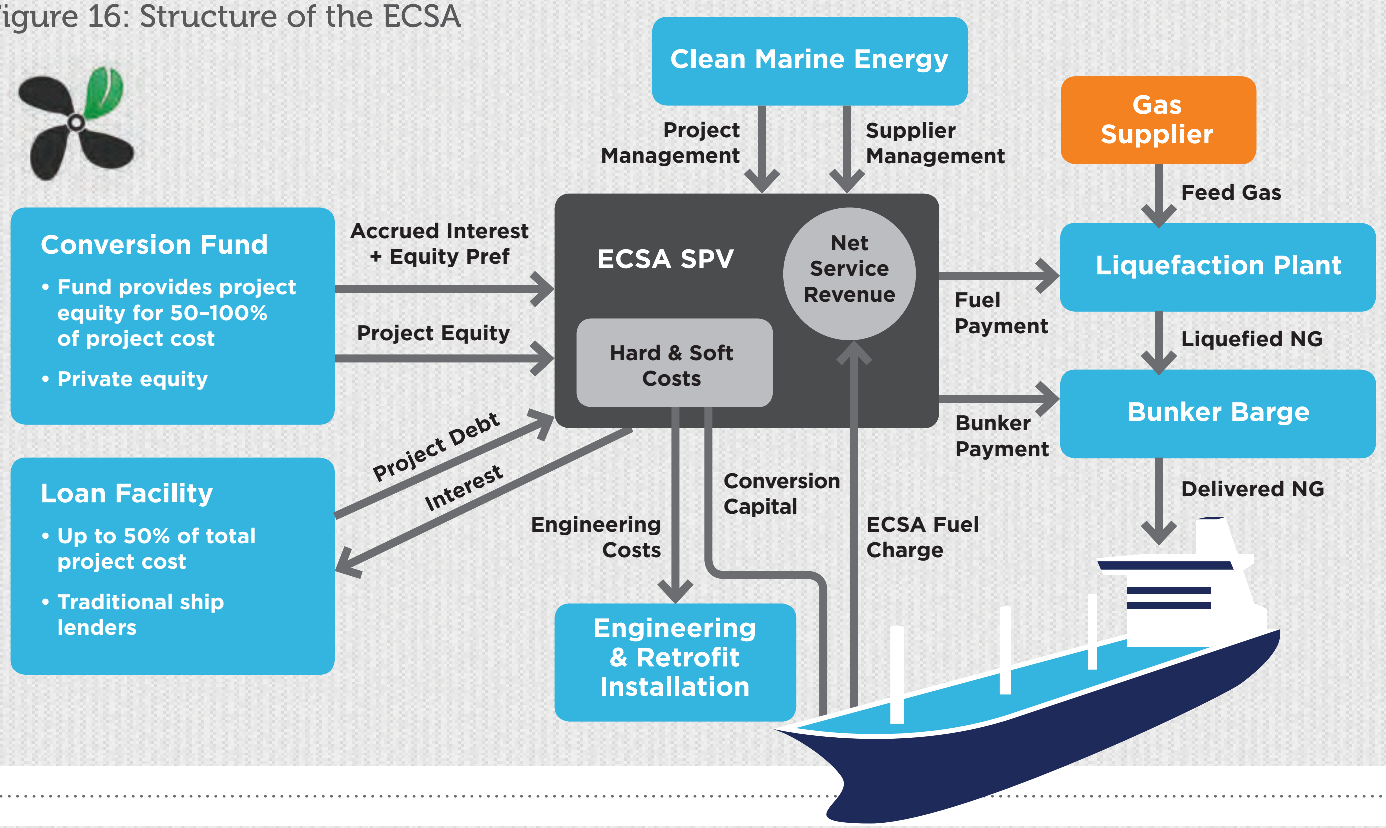
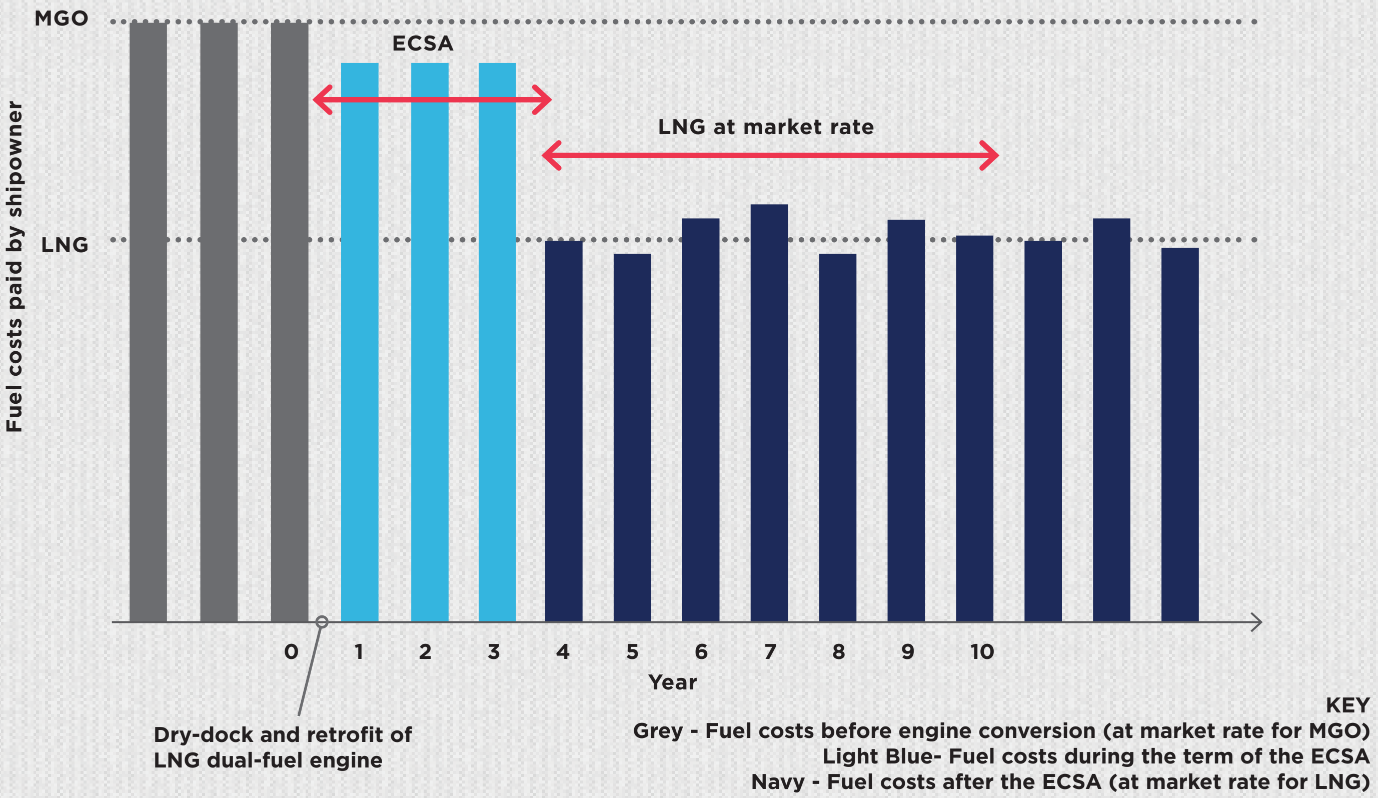


Figure 17: Fuel Costs under the ECSA



CASE STUDY

Clean Marine Energy Pilot Project

CLEAN MARINE ENERGY has engaged in a pilot program with a ship operating on the Great Lakes, a region within the North American ECA, to demonstrate the viability of LNG dual-fuel engine conversions under the ECSA. The Great Lakes Trader/Joyce L. Van Enkevort is an articulated tug barge built and operated by Van Enkevort Tug and Barge, Inc. and owned by Great Lakes Maritime Leasing, LLC. The vessel trades dry bulk goods, servicing the mining, construction, and steel industries in the Great Lakes, and was chosen for this pilot demonstration for the following reasons:

- The economics of the region support retrofitting old ships versus building new ships, as Great Lakes vessels typically have a long lifespan (often exceeding 60+ years), are costly to build, and operate full time within ECA regions.
- Due to ice build-up on the Lakes, most vessels tend to come off hire for several weeks every winter, thus creating a window for conversion with low opportunity costs.
- The Great Lakes Trader/Joyce L. Van Enkevort is 40,000 deadweight tons (DWT) and consumes a large volume of fuel, thus the savings generated by operating with it LNG fuel are significant.
- Several suppliers have announced plans to build facilities that would supply LNG around the Great Lakes shipping area.

A feasibility study was conducted with several of Clean Marine Energy's contractor partners that confirmed the vessel would be a suitable candidate for retrofit engine conversion. The final steps of the retrofit are expected to take place during an upcoming, already-scheduled downtime, when permanent fuel tanks and equipment will be installed. The retrofit will be financed under the following conditions:

- Upfront capital cost of conversion will be financed 100% by Clean Marine Energy; ship will purchase LNG fuel from an established supplier through the ECSA mechanism.
- ECSA agreement will have a term of five years.
- 5% immediate fuel cost savings to the shipowner (for the term of the ECSA).
- Projected 30% savings in annual fuel costs to the shipowner after the ECSA term, for the remaining life of the asset.
- Four to six months for engineering (using a "riding gang," which are groups of workmen who are brought on board a ship for specific maintenance or other purposes); 30 days out of service to retrofit.
- Expected completion in Q1 2015.

The ECSA: Impact on Market Barriers

The volatile price of LNG, a lack of fuel supply or fueling infrastructure, and the high upfront costs of engine conversion have historically made it uneconomical for a ship to pursue this type of retrofit technology. The new ECSA model overcomes those barriers by providing the upfront capital needed for conversion and then guaranteeing the supply and distribution of LNG to converted ships.

General Barrier: Access to and Cost of Capital

Clean Marine Energy offers a financing structure that covers 100% of fuel conversion capital costs so that shipowners immediately see fuel savings based on the price advantage of LNG versus low-sulfur diesel. Clean Marine Energy recovers its capital expenditure by sharing in the fuel savings with shipowners for a few years, and then passes 100% of the fuel savings on to the owner. Additionally, to meet the challenges faced by shipowners of obtaining internal company approval for third-party financing, Clean Marine Energy also provides advisory services for shipowners seeking to understand the case for fuel conversion and all of their options for financing such a retrofit.

General Barrier: Split Incentives

As mentioned, the present ECSA model does not address the split-incentives problem, and ships that are chartered instead of owner-operated would still face this barrier in considering an alternative-fuel-based retrofit as a pathway to managing fuel costs and emissions. However, the ECSA could theoretically be adapted to work for chartered ships in future models.

Barrier Specific to LNG Dual-Fuel Engine Conversion Retrofits: Lack of Bunkering Infrastructure

Clean Marine Energy and their strategic partners are rapidly developing LNG liquefaction and bunkering services to guarantee LNG supply to shipowners. Infrastructure build-out will occur in phases, with the first supply lines constructed in ECA areas where regulations are strict and traffic is high, such as the Mississippi River, Gulf of Mexico, or Great Lakes ECAs.

Renewable Bunker Fuels: An Alternate Financial Financial Model for Alternative Fuels

Thus far this paper has discussed a potential financial model for LNG-based engine conversions. In the future, alternative shipping fuels like biofuels could offer a cost-competitive and cleaner solution than LNG or diesel, particularly for vessels operating in ECAs. This is especially true because biofuels should be "drop-in" fuels: that is, a ship that currently runs on HFO could switch to run on biofuels without a costly engine conversion.

A 2012 report on the potential of biofuels for maritime shipping concluded that a strong market for such fuels should exist in light of current policy and support schemes, the high operational costs of HFO, and the environmental benefits of moving away from fossil fuels of all kinds. However, biofuels for shipping are not currently being produced at commercial scale, and the production costs of marine biofuels today are therefore higher than those of fossil fuels. Eventually, additional technological development and production scaling, and therefore cost reductions, could allow marine biofuels to be quite cost-competitive with LNG or HFO (Ecofys 2012).

Once marine biofuel production reaches technologically viable levels, innovative financial models will likely be needed for those fuels to be produced in great enough quantities to achieve true economies of scale and widespread adoption. CWR is currently developing such models to address the similar situation now faced by drop-in biofuels in the aviation industry (see box on Long-Dated Futures Contracts), and some of the findings of that work could be useful in encouraging the development of shipping biofuels.

Long-Dated Futures Contracts

CWR AND ITS PARTNERS have been working to enable the eventual large-scale production of advanced renewable jet fuels by designing a financial structure that will provide a powerful independent hedge for airlines against the potential price volatility of those fuels in the interim. CWR has been exploring the possibility for renewable jet fuel producers and airlines (jet fuel payers) to enter into long-dated futures contracts for those biofuels.

Future-contract models could also serve to encourage advancement in and wider production of shipping biofuels, but right now neither those fuels nor the nascent financial models that would support them are well developed enough for further consideration in this paper. However, much like oil refineries, most biorefineries produce multiple grades of fuel products, and therefore the efforts of CWR and its partners in the aviation industry will, if successful, improve the global market for the "whole barrel" of renewable fuels and co-products, some of which may be suitable for use as marine bunker fuels.

> Once marine biofuel production reaches technologically viable levels, innovative financial models will likely be needed for those fuels to be produced in great enough quantities to achieve true economies of scale and widespread adoption

Analysis of the Models

The cost to retrofit an engine is a substantially bigger investment than the cost of fuel efficiency technologies on a per-ship basis

The innovative financial models presented in this paper offer different mechanisms by which maritime vessels may decrease their operating expenses and their emissions per nautical mile, while at the same time increasing the value of a shipowner's asset. This chapter presents a comparative analysis of the two models to highlight the relative merits of each and their applicability to specific industry actors or financial challenges.

Figure 18: Criteria of Ideal Vessels

Financial Model	Defining Vessel Criteria	Vessel Age	Target Vessels	Dry-Dock Required?
SFFSM for Fuel Efficiency Retrofits	Approaching dry-dock, long-term time charter (4+ years) or owner-operated; predicted 5–15% fuel savings with < 2-year payback	5+ years old	All	Requires dry-dock, aligned with pre-existing scheduled maintenance
ECSA for LNG Dual-Fuel Engine Conversion	High fuel consumption (30,000+ DWT, 10,000+ horsepower) Slow-speed, 2-stroke engine	Less than 10 years old	Vessels operating primarily within ECA	Depends on vessel; generally does not require dry-dock Aligned with 5-year special survey

Each of the models is financed in a similar manner; however, the cost to retrofit an engine is a substantially bigger investment than the cost of fuel efficiency technologies on a per-ship basis.

Figure 19: Top-Level Financial Features

Financial Model	Finance Provider	Security Provisions	Type of Finance	% of Upfront Capital Provided by Financier	Financing Period	Revenue Model	Range of Investment Size	Counter-party
SFFSM for Fuel Efficiency Retrofits	Private equity and bank loans	Guarantee from credit-worthy partners	Equity and/or fixed-interest, fixed-term loan	100%	2–5 years	Revenue generated from fuel savings generated by the gains in fuel efficiency afforded by the technologies	$500,000–$3 million	Owner or charterer (fuel payer)
ECSA for LNG Dual-Fuel Engine Conversion	Private equity and institutional	Guarantee from credit-worthy partners	Fixed-cost, fixed-term loan	100%	3–7 years	Revenue generated from fuel cost savings, specifically the price difference between low-sulfur diesel and LNG	$5–20 million	Owner or charterer (fuel payer)

Germany's built environment sector offers an illustrative example of how using public funding to finance retrofits can have a catalytic effect on private investments

Figure 20: Key Risks and How the Models Address Them

The linchpin of each of these models is the creation of systems to limit the risks associated with all of the parties.

	Risks					
Financial Model	Low Technological Performance	Petroleum-Based Fuel Prices Increase	Petroleum-Based Fuel Prices Decrease	Counterparty Defaults	Vessel Off Hire	Vessel Non-Sailing But On Hire
SFFSM for Fuel Efficiency Retrofits	Vendors of fuel efficiency technologies manage this risk by providing guaranteed percentages of fuel savings	No risk; the financier and fuel payer, in fact, save more	Fuel-saving escrow account generates less revenue, extending payback time to financier	Finance provider manages the risks	Mitigated by fuel payer guaranteeing minimum days at sea per year based on historical data	Mitigated by fuel payer guaranteeing minimum days at sea per year based on historical data
ECSA for LNG Dual-Fuel Engine Conversion	Engine manufacturers manage this risk by providing performance guarantees	No risk; the fuel cost spread is locked for the term of the ECSA, on top of floating index	No risk during contract term; after contract term this simply makes LNG fuel consumption more attractive	Finance provider manages the risk	No risk; take or pay contract	No risk; take or pay contract

The Role of Public Finance in Funding Retrofits: A Case Study from the Built Environment

Fuel efficiency and alternative fuel retrofit technologies for maritime vessels are well- proven to save fuel costs while reducing emissions. The shipping industry needs to widely adopt these technologies if it is to succeed in addressing its current economic challenges of rising fuel costs, mounting environmental regulations, and the global challenge of climate change. Though CWR does not focus on public policy, this paper recognizes that it will be necessary to address the current lack of public funding for retrofits. Public funding would serve to lower the risk and cost of capital, allowing these financial models to be much more widely utilized.

Germany's built environment sector offers an illustrative example of how using public funding to finance retrofits can have a catalytic effect on private investments. The German state development bank, KfW, is the main institution with designated finance for building efficiency projects and other energy-related investments in Germany. Since 1996, KfW has gained substantial experience incentivizing investments into thermal efficiency retrofits in the residential sector through preferential loans and grants. In 2010, KfW provided $11.6 billion in lending and grants to retrofit more than 952,802 residential units (Neuhoff *et al.* 2012).

KfW is, likewise, one of the top 10 shipping financiers worldwide, and though it recently announced that it is considering expanding the amount of money it lends to shipping, it did not specifically mention any funding for retrofits (Reuters 2013). If KfW or a similar financial institution were to extend its concessionary loans and state guarantees to finance existing vessel retrofits, it could accelerate the number of shipping retrofits financed around the world and make a substantial environmental and monetary impact.

Conclusion and Recommendations

A 10% increase in efficiency, assuming 225 days at sea with a pre-dry-dock consumption of 31 metric tons of fuel per day, will deliver fuel cost savings of $500,000 per year, while also preventing the emission of 2,148 metric tons of CO_2 into the atmosphere

In today's maritime industry, innovative financial mechanisms can be used to accelerate the deployment of clean, retrofit technologies, thereby generating significant fuel cost savings and driving sustainable growth. These investments do not rely on carbon markets or other subsidies. Many of these technologies deliver paybacks within two years and confer in a higher asset value, all while reducing a vessel's carbon footprint—making them highly attractive investments.

The shipping industry needs to widely adopt these financial models—and retrofit technologies more generally—in order to address the current economic challenges of rising fuel costs, mounting environmental regulations, and the global threat of climate change.

This paper considered two specific financial models for retrofits that will improve the profitability of the existing shipping fleet. One, the Self-Financing Fuel-Saving Mechanism, facilitates the adoption of fuel efficiency technologies, while the other, the Emission Compliance Service Agreement, is designed for alternative fuels, specifically LNG dual-fuel engine conversions.

More research into these financial models is required, including an in-depth analysis on the impact of price volatility (including in time charter rates and in fuel prices) and its costs to the shipping sector. In addition, more research should be done to understand the precise fuel savings offered by various retrofit options on a vessel-by-vessel basis. Particularly for fuel efficiency technologies, the analysis of post-retrofit data that covers an entire dry-docking cycle will provide the industry with further transparency on the performance of these technologies, the opportunity for investors, and how best to operate vessels post-retrofit. With respect to LNG as an alternative fuel, future research should look not only at the economic opportunity of LNG but also at its environmental impact, as there are a variety of environmental issues associated with natural gas and shipping that must be researched further. As the usage of LNG as a bunker fuel increases, best practices must be developed and enforced to minimize the potential negative environmental and climate impacts of LNG.

Nevertheless, this paper ultimately finds that the savings potential of retrofit technologies is such that the market alone provides sufficient incentive for their adoption, though a favorable regulatory climate will positively contribute. However, certain market barriers, particularly lack of capital, split incentives, lack of measurement and verification methods, and a lack of LNG infrastructure, need to be overcome. The costs, both economic and environmental, of petroleum-based maritime fuels today are such that taking serious, collaborative steps towards overcoming these barriers is an industry imperative.

But the potential opportunity is massive. For example, the aggressive implementation of a suite of fuel efficiency technologies that delivers a fleet-wide 10% efficiency improvement would allow the existing international shipping fleet to save $16.6 billion on fuel costs per annum and reduce its greenhouse gas emissions by up to 87 million metric tons of CO_2 per annum, while still enjoying strong annual growth.

Proven fuel efficiency and alternative fuel retrofit technologies offer significant opportunities for cost savings in the maritime shipping industry, especially at today's HFO prices of just over $600 per ton (Singapore). Although there may be a large upfront cost, the payback period of many efficiency retrofit technologies is anywhere from 12 months to three years for a shipowner, which is considerably less than the average 25–30-year lifetime of a ship.

Installing a complimentary suite of fuel efficiency retrofits (e.g., a Mewis Duct®, a propeller boss cap fin, premium hull coating, and continuous monitoring and optimization software) onto a 46,000 DWT bulk carrier can cost over $1,000,000 per vessel. Theoretically, this full suite of technologies will increase that vessel's fuel efficiency by 10% and, assuming 225 days at sea with a pre-dry-dock consumption of 31 metric tons of fuel per day, will deliver fuel cost savings of $500,000 per year, while also preventing the emission of 2,148 metric tons of CO_2 into the atmosphere. The payback period of this suite of technologies is therefore in the range of two to three years. Fleet-wide investment into fuel efficiency solutions can yield even greater savings.

By contrast, investing in a dual-fuel LNG engine conversion on a 46,000 DWT bulk carrier that operates wholly in a North American ECA can cost around $10,000,000. The cost spread between LNG and low-sulfur fuel in that geography will optimally deliver savings of $3,000,000, while also preventing the emission 5,250 metric tons of CO_2 per year and ensuring IMO emission compliance.[27] The payback period of dual-fuel LNG engine conversion for a 46,000 DWT vessel operating wholly in a North American ECA is therefore three to four years.

Note that both of the example calculations offered here depend entirely on a wide range of variables for a given vessel, including the price of fuel, days at sea per annum, daily fuel consumption, and the amount of time spent in an ECA.

The financial models reviewed by this paper were chosen because they demonstrate innovative thinking around third-party financing. The retrofit market is in a state of ongoing development, and these financial models are likewise continuously evolving, creating additional opportunities for their piloting, testing and refinement.

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[27] However, "methane slip" during LNG production may negate the climate-related benefits of this CO_2 reduction.

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ABOUT THE CARBON WAR ROOM

The Carbon War Room is a global nonprofit founded by Sir Richard Branson and a team of like-minded entrepreneurs that accelerates the adoption of business solutions that reduce carbon emissions at gigaton scale and advance the low-carbon economy. The organization focuses on solutions that can be realized using proven technologies under current policy landscapes.

The Carbon War Room identifies and works in sectors where emissions can be reduced profitably, and where there are barriers preventing greater adoption of low-carbon solutions. Within these sectors, we launch Operations and collaborate with the sectors' stakeholders. The War Room's current Operations include Maritime Shipping Efficiency, Building Efficiency, Renewable Jet Fuels, Smart Island Economies, and Trucking Efficiency.

For more background on Carbon War Room and the Shipping Efficiency Operation please go to carbonwarroom.com and shippingefficiency.org.

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UCL ENERGY INSTITUTE

The UCL Energy Institute was established as UCL's response to the global challenges of mitigating climate change and providing energy security in the 21st century, as well as to support the UCL Grand Challenges. UCL has a substantial track record of energy research and world-leading competencies in a wide range of disciplines; the mission of the UCL Energy Institute is to build on this foundation by coordinating and stimulating research on energy and carbon emissions reductions across the university. The Institute helps build multi-disciplinary teams and supports academics in applying their skills to the energy problem.

UCL Energy Institute, together with UCL Engineering Department and UCL Laws, is part of a £4 million multi-disciplinary research project, Shipping in Changing Climates, predominantly funded by the RCUK Energy Programme, which brings together the UCL researchers with Manchester, Southampton, Newcastle and Strathclyde, in close collaboration with a core industry stakeholder group of Shell, Lloyd's Register, Rolls Royce, BMT and Maritime Strategies International.

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LIST OF ACRONYMS AND ABBREVIATIONS USED IN THIS PAPER

CapEx	Capital Expenditure
CO_2	Carbon Dioxide
ECA	Emissions Control Area
EEDI	Energy Efficiency Design Index
ESCO	Energy Service Companies
ECSA	Emission Compliance Service Agreement
HFO	Heavy Fuel Oil
IMO	International Maritime Organization
LNG	Liquefied Natural Gas
MDO	Marine Diesel Oil
MGO	Marine Gas Oil
NOx	Nitrogen Oxides
PM	Particulate Matter
PPA	Power Purchase Agreement
SAYS	Save As You Sail
SFFSM	Self-Financing Fuel-Saving Mechanism
SOx	Sulfur Oxides
SPV	Special Purpose Vehicle
UCL	University College London

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