INTRODUCTION
The theme of this issue is green shipping.

International shipping plays an essential role in the facilitation of global trade. It is the most cost effective and energy-efficient way to move large volumes of cargo, making a vital contribution to international trade and being a key pillar in the development of a sustainable global economy. The goal is to scale up cleaner practices on board, at port and throughout the lifetime of a ship. Shipping policies are not yet applied worldwide, but they must become so in order to be effective. A scientific study published by the European Parliament days before the Paris climate conference in December 2015 showed that shipping could be responsible for 17 per cent of global CO₂ emissions in 2050 if left unregulated. The study found that the shipping sector's GHG emissions have risen 70 per cent since 1990 and are projected to grow by up to a further 250 per cent by 2050. Shipping currently accounts for nearly 3 per cent of global CO₂ emissions – higher than those of Canada, Brazil, Indonesia, Mexico, France or the United Kingdom.
Presently, shipping and aviation emissions are not addressed by global climate change agreements, including the deal made in Paris last December. In Paris, the International Maritime Organization (IMO), which regulates international shipping, and the International Civil Aviation Organization (ICAO) were jointly awarded the satirical “Fossil of the Day” award by the Climate Action Network (CAN). This came after the IMO announced that the only global legally-binding energy efficiency measures it has adopted will require ships built in 2025 to be 30 per cent more energy efficient than those built in 2014.

The IMO did not pledge any emissions cuts at the Paris climate conference. It has nonetheless evolved to tackle the challenges of a post-Paris world. At the international level, the maritime industry is anticipating global regulations from the IMO limiting sulphur emissions from the present 3.5 per cent to 0.5 per cent, to commence either in 2020 or 2025. Existing ships are now required to have an energy efficiency management plan in place, including improving voyage planning, cleaning the underwater parts of the ship and the propeller more often, introducing technical measures such as waste heat recovery systems, or even fitting a new propeller.

There has been implementation of stricter environmental rules such as the 0.1 per cent cap on sulphur emissions in the Emission Control Areas (ECA) of Northern Europe and Northern America. Countries in Asia have also taken steps to reduce port and shipping emissions. For example, Hong Kong capped sulphur emissions to 0.5 percent for vessels at berth to improve its air quality. China published new regulations designating three areas as sulphur control areas effective as of 1 January 2019 and recently started enforcing a 0.5 per cent sulphur cap at eleven key ports in the Yangtze River Delta area for vessels at-berth.

Such developments necessarily drive demand for solutions to meet these stricter requirements. Here in Singapore, the Maritime and Port Authority (MPA) recently extended and enhanced its Maritime Singapore Green Initiative (MSGI), launched in 2011. In July, France’s High Level Climate Champion under the United Nations Framework Convention on Climate Change (UNFCCC), Her Excellency Ambassador Laurence Tubiana, was given a tour of Singapore’s harbour, in recognition of MSGI’s success in incentivising maritime companies to adopt clean and green shipping practices.

In September 2015, Singapore jointly hosted the Future-Ready Shipping 2015 Conference, an international conference on maritime technology transfer and capacity building with the IMO. About 200 maritime leaders and professionals attended, kick-starting a global dialogue on removing barriers to energy-efficiency technologies and measures. The Global Environment Facility (GEF), United Nations Development Programme (UNDP) and IMO launched its project entitled “Transforming the Global Maritime Transport Industry towards a Low Carbon Future through Improved Energy Efficiency” (GloMEEP Project) at this event. The goal of this project is to assist developing countries implement the energy efficiency measures adopted by the IMO.

Strong support from the maritime industry and encouraging results from MSGI’s Green Ship Programme (GSP), Green Port Programme (GPP) and Green Technology Programme (GTP) led the MPA to extend the MSGI up to the end of 2019. The MPA is also introducing two new programmes under the MSGI: The Green Awareness Programme (GAP) and The Green Energy Programme (GEP).

Through the GEP, Singapore aims to promote adoption of alternate or cleaner marine fuels as well as wider adoption of energy efficient operational measures in anticipation of developments on the global sulphur emissions cap. To this end, Singapore is committed to LNG bunkering. As a marine fuel of choice, LNG is said to virtually eliminate sulphur emissions and its use in shipping would significantly reduce NOx and CO2 emissions. Further to this, there is a good track record for LNG being transported as cargo and used as fuel in LNG carriers. This gives confidence to the industry that LNG can be widely adopted as a marine fuel going forward.

The first article in this issue by Dr. Aykut Ölger, Professor, Naval Architecture and Maritime Technology and Dr. Momoko Kitada, Assistant Professor, both from the World Maritime University in Sweden, focuses on the motivational drivers of energy efficient ship design and operations. Despite existing international regulations on maritime energy management, implementation barriers or failures exist which are obstructing the implementation of the measures, such as informational problems, split incentives, access to and cost of capital. They conclude by emphasising the need for creating further scientific knowledge about maritime energy management.

The second article by Dr Michael Traut, Research Associate at the Tyndall Centre for Climate Change Research, School of Mechanical, Aerospace and Civil Engineering, University of Manchester in the United Kingdom, examines international shipping regulations in the wake of the Paris Agreement. The article explains the ongoing debate over whether to improve monitoring, reporting and verification (MRV) of shipping emissions following the adoption of the Paris Agreement. It then goes on to argue that instead of relying solely on multilaterally agreed regulations, national governments and regional entities can and should do more to incentivise greener shipping practices.

The third piece by Dr. Nishatabbas Rehmatuulla, Research Associate at the Bartlett School of Environment, Energy and Resources of the Faculty of the Built Environment and the University College London Energy Institute in the United Kingdom, examines future trends in green shipping. He posits that gains from efficiency and technological innovations can help achieve, to a large extent, the transition to a sustainable shipping sector. His article relates the use of global shipping system models such as GloTraM to observe the effects on scientific knowledge about maritime energy management.

The final article by Commander (Dr.) Kapil Narula, Research Fellow at the National Maritime Foundation in New Delhi, studies the role of regulatory mechanisms in clean shipping. It touches upon the United Nations Convention on the Law of the Sea (UNCLOS) and its role in the protection and preservation of the marine environment alongside the IMO as the United Nations’ specialised agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships. While pointing out that shipping emissions were left out of the Paris Agreement, he notes the great trust and responsibility that this decision confers on the IMO to lead the sector towards lowering its emissions. The article concludes on a positive note by highlighting recent developments in response to stricter regulations and rules that have come into effect under the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI.

We hope you find these articles of interest and we welcome your views and comments.

Melissa Low (ESI Research Associate)
Maritime transportation contributes to over 70 per cent of global trade by value.¹ This large share of maritime transportation implies a high responsibility for seeking a greener operation of ships. In this regard, energy efficiency is becoming a growing concern in the maritime industry. But how can we achieve it? This article discusses the motivational drivers of energy management in the shipping sector.

**Why is Energy Efficiency Needed for Ships?**

Over the past decade, increasing attention has been paid to air pollution resulting from international shipping. SOx and NOx are the major air pollutants, and these create health problems for human beings whereas greenhouse gases (GHGs) cause climate change. According to the latest (the third) GHG study of the International Maritime Organisation (IMO),² the total annual amount of CO₂ emissions resulting from international shipping is close to one billion tons, which corresponds to 2.7 per cent of the total CO₂ emissions produced globally in the world. With the steady increase in the world’s population and seaborne transportation, CO₂ emissions will continue to increase. Minimisation or reduction of GHGs can be achieved through increasing the energy efficiency of ships.

The maritime industry has been restricted by many international environmental regulations in recent years, from ship recycling, to air pollution, to noise. GHGs from international shipping have been regulated since 1 January 2013 through an index called the “Energy Efficiency Design Index (EEDI)” and “Ship Energy Efficiency Management Plan (SEEMP)”. The EEDI is used as a measure for ship design while the SEEMP is used for ship operation. One of the key concepts for compliance of these measures is to increase energy efficiency in both ship design and operation.

Some people believe that fossil-based fuels are limited and will run out in the future.³ Thus, it is necessary to find new and clean sources and/or to employ new technologies and good practices that can increase the energy efficiency of ships. Indeed, following the COP21 Climate Change Conference held in Paris in late 2015, energy efficiency and management became key strategies for all sectors.

**How to Achieve Energy Efficiency in Shipping**

Energy efficiency is increased through a reduction of inputs for the same output or an increase in output using the same quantity of inputs. Input here refers to fuel consumption. How can a ship’s fuel consumption be reduced? The answer is to modify both the ship design and its operation.

According to the Second GHG Study of the IMO,⁴ 40 to 50 per cent of the total energy produced on board a ship goes to propelling her. The rest is lost as heat and exhaust. Energy efficiency potentials lie mainly in modifications to ship propulsion and resistance. There are different techniques developed for different resistance components. For example, ship hull form optimisation is a promising and widely applied solution for minimising wave-making resistance. At the same time, viscous resistance can be minimised through traditional means, like good coating, or a novel way such as air lubrication.

Energy efficient ship design and operation are two key components of green shipping. Therefore, despite the successful results of energy efficiency enhancement measures adopted during ship design, there is still room for saving energy during ship operation. For example, fuel consumption can be reduced with good voyage planning and/or ship handling. Weather routing, i.e., factoring in the environmental conditions of various routes is a widely used example of voyage planning, whereas trim optimisation and efficient ballast exchange processes are the common examples of optimised ship handling. Maintenance of the hull and machinery is as important as voyage planning and ship handling. Hulls that are not properly maintained or cleaned can result in increased fuel consumption of up to 10 to 15 per cent, even 30 to 40 per cent in severe cases.
Barriers to Energy Efficiency

Maritime energy management cannot be accomplished by only economic and environmental drivers. A multi-disciplinary approach is needed which takes into account other elements including, but not limited to, safety, security, and other social aspects. Despite a number of regulations pertaining to the energy efficiency of ships, the actual implementation process is not as uniform as expected. This problem is known as the "energy efficiency gap" and analysis of the barriers to energy efficiency has become a niche area for research. The barriers include safety and reliability (whether energy efficiency is based on reliable methods and does not compromise safety), technical uncertainty (the interaction between different ship components when new or unproven technologies are introduced), behavioural barriers (the interaction within the shipping firm and the availability of information across the organisation), market constraints (split incentives which question who pays the costs), financial and economic constraints (investment costs and companies’ economic viability due to market conditions and fuel prices), and complexity (the instalment and operation of energy efficiency measures so that they work as a system). In addition, today’s managers’ difficulties in supervising the work done by subsidiary or outsourced firms can be a barrier. Without understanding such barriers, the successful implementation of energy efficiency measures cannot be achieved.

This is also true for business and management. So-called “triple bottom-lines” of corporate social responsibility (CSR) are known as “profit, planet, and people”. These 3Ps are recognised as the main areas where today’s modern corporations are expected to ensure the accountability of their business practices. Hence, not only "profit" (economy) and "planet" (environment) but also "people" (human element) are keys to the promotion of energy efficiency in shipping. 

It is important to emphasise that while we must try to maximise the energy efficiency of ships in order to make them greener, we cannot compromise the safety of ships. For example, when the trim is optimised for a ship, it will have an impact not only on fuel consumption but also on safety performance. Therefore, making right and rational decisions under trade-off situations, such as safety versus energy efficiency is another challenge that ship designers and operators face. 

The Need for Research into Maritime Energy Management

It is obvious that more research is necessary to create scientific knowledge about maritime energy management. Policy-makers and practitioners, designers and users, managers and workers, and even the public and private sectors need to communicate with each other in order to learn how energy efficiency can be achieved at a large scale for sustainable shipping. One of the efforts of the World Maritime University (WMU), established by the IMO in 1983, is to offer postgraduate-level courses on this topic and also invite speakers from around the world to present their best practices and latest research outcomes at a conference to be held in Malmö, Sweden, 24-25 January 2017 (see the flyer on this page). This conference will span a range of topics, including regulatory frameworks; energy efficient ship design and operation; energy management in ports and shipyards; economics, human elements and theoretical aspects of maritime energy management; alternative fuels and marine renewable energy; and offshore and ocean energy. A selection of academic papers will be published as a volume of the WMU book series by Springer in the spring of 2018.

The above-mentioned energy saving methods each have different fuel consumption saving figures, from 3 to 4 per cent for trim optimisation, and 8 to 10 per cent for hull form optimisation. When all the various energy-saving potentials gained from improved ship design and operation are aggregated, the combined potential lies between 25 and 75 per cent. 

5 ibid.
9 ibid.
Climate Change: A Challenge for International Shipping Too

In December 2015, parties to the United Nations Framework Convention on Climate Change unanimously adopted the Paris Agreement (UNFCCC, 2015). This Agreement aims at “holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels”.1

To achieve this goal, drastic cuts to global greenhouse gas emissions are required. While the Paris Agreement focuses on individual nations’ emissions, it makes no mention of international shipping and aviation. Parties’ individual nationally determined contributions (INDCs) constitute the main mechanism in the Paris Agreement to realise emissions reductions. This has led to the call for an “Intended IMO Determined Contribution” from shipping to the global emissions reduction effort.2

The question of what might constitute a “fair share” of the burden for international shipping is often approached from one of two perspectives. One begins with stated climate change mitigation goals. Then, assumptions are made about the relative size of cuts to shipping emissions vis-à-vis the average of all other sectors in order to determine targets for the international shipping sector that reconcile global emissions trajectories with those goals. For example, Smith et al. assume that international shipping achieves the same proportional emissions reductions as the global average to determine targets for the sector.3 The other complementary perspective begins with the status quo, including current trends and technological developments, to assess what emissions reductions may be feasible. For example, Eide et al.4,5 take a cost effectiveness approach, modelling a range of technological, operational, and fuel options, and respective uptake as a function of a carbon price, to determine the potential for fleet-wide emissions reduction. In a similar vein, the 3rd IMO GHG Study couples a set of future sea transport demand scenarios with a set of assumptions on fleet-wide efficiency gain and uptake of LNG as a fuel, out to the middle of the 21st century.6

As laid out by Bows-Larkin et al.,7 a large discrepancy is found between the two approaches: taking the first, much deeper cuts to emissions are required, and much sooner, than appears “feasible” under the second. For example, in a scenario limiting the average global temperature increase to 1.5°C, the analysis by Smith et al. indicates that the operational efficiency, in terms of CO$_2$ emitted per ton-mile of cargo carried, must be reduced by 75 per cent between 2012 and 2030.3 To achieve this, radical technological and operational changes would be required. In terms of overall emissions from international shipping, the historical trend would have to be reversed. The same holds true for the future of all human activity and the world’s climate. In 2015, the average global temperature had increased by more than 1°C since pre-industrial times.8 Across the range of four Relative Concentration Pathways (RCP) – climate scenarios considered by the Intergovernmental Panel on Climate Change – it is set to reach 1.5°C around 2030.9
Taken together, the INDCs as they stand, amount to an emissions scenario that is closer to the high end. Yet, “The Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall undertake its first global stocktake in 2023.” This suggests that it may soon become apparent that the Paris Agreement’s 1.5°C goal may fail, or else require another than the straightforward interpretation that global, annual average temperature increase never exceed 1.5°C.

Clearly, there will be change, either due to departure from historical trends and successful climate change mitigation, or else due to impacts from climate change that are more extreme than the limits the world has set itself. While international shipping is not mentioned in the Paris Agreement, it too contributes to increased greenhouse gas levels in the atmosphere and it is not isolated from global socio-economic developments. Therefore, it too, is bound to change and be forced to navigate conflicting challenges.

### Adjusting the Regulatory Framework

At the global level, the International Maritime Organization (IMO) is responsible for regulating international shipping. In 1997, the Kyoto Protocol mandated countries to work with the IMO to “pursue limitation or reduction of emissions of greenhouse gases.”

Greenhouse gas emissions have since been a perennial discussion topic at MEPC (Marine Environment Protection Committee) meetings at the IMO. But only in 2011 did the IMO adopt a measure to reduce greenhouse gas emissions, comprising a technical design standard (the Energy Efficiency Design Index, or EEDI) and a vague operational measure (the Ship Energy Efficient Management Plan, or SEEMP), which have been regarded as falling short of what is required. Beyond these measures, it has proved difficult to reach agreement on action to mitigate against climate change. A debate on the uptake of a market-based measure has become dormant. Similarly, a request by the Marshall Islands at MEPC 68 to discuss the setting of an emissions target for the shipping sector was declined.

Instead of sweeping measures, the debate has focused on measures to monitor, report, and verify emissions (MRV) and, since the adoption of the Paris Agreement, on how to determine a “fair share”, as requested in a paper to MEPC 69 by Belgium, France, Germany, the Marshall Islands, Morocco, and Solomon Islands. These sponsors represent “developed” nations (as per the terminology of the UNFCCC) with relatively large economic output and a significant share of historical greenhouse gas emissions, small island nations particularly at risk from climate change impacts, and other nations recognising the economic opportunities of renewable energy and green shipping. On the other side, “developing” nations have argued for “a resolution on financial, technological and capacity-building support from developed countries” before considering measures to reduce greenhouse gas emissions from ships. In their paper to MEPC 64, Brazil, China, India, Peru, Saudi Arabia, and South Africa stressed their need to achieve economic growth, and that “economic and social impacts of response measures” to climate change be considered.

Besides member states, many other stakeholders, such as industry associations or environmental groups, have consultative status at the IMO, and together represent a range of interests and priorities, which can only be negotiated at a political level. While the point has been made that international shipping would best be regulated at the global level, there is also scope for action at the
regional or national level.\textsuperscript{15,16} For example, France has adopted rules on reporting greenhouse gas emissions,\textsuperscript{17} as has the EU.\textsuperscript{18}

**In Search of Progress**

Seeking to make progress towards “greener” shipping, some nations run programmes to financially support innovation, like Singapore with its Maritime Singapore Green Initiative. Such initiatives seek to both address negative externalities and create positive spillover effects. The case is even stronger when considering the reality of climate change. Avoiding dangerous climate change implies a move away from fossil fuels and associated CO\textsubscript{2} emissions. Even if there is a risk of greenhouse gas emissions outgrowing a budget reconcilable with its temperature goals, the Paris Agreement has settled the case for decarbonisation. That is, from a societal perspective it is desirable to make shipping more sustainable and, focusing on the environmental aspect of sustainability, “greener”; and there is the argument that, in the longer term, renewable energy and more sustainable operations will be a requisite for business success. However, participants in shipping markets often find it difficult to take such a long term perspective, in particular in markets characterised by oversupply, when short term profits or otherwise determine whether companies survive.

Research can provide a long term perspective (and spell out the challenges that lie ahead), as well as identify and develop technological, operational, or other solutions that address these challenges. It can also facilitate more efficient markets where barriers to uptake exist, as exemplified by the articles written by Rehmatulla, and Ölçer and Kitada in this issue of the ESI Bulletin.

**Conclusions**

In the Paris Agreement, the world has set itself ambitious climate change mitigation goals. Across all sectors, there is a gap between historical emissions trajectories and the deep cuts to greenhouse gas emissions required to achieve the goals. In contrast with other sectors, however, international shipping (together with international aviation) is not covered under the Paris Agreement.

Therefore, a political debate is needed urgently. The cuts to greenhouse gas emissions and ultimate decarbonisation needed to reconcile international shipping with the goals of the Paris Agreement are unlikely to be realised without regulatory measures. Because such measures may affect a range of stakeholder or national interests, only a political debate can determine a compromise. What the Paris Agreement has unambiguously established is an interest in progress representing almost the entire population of the world.

If decarbonisation is the obvious aim, how to achieve it is less obvious. While the political debate can establish the regulatory framework to facilitate progress towards decarbonisation, research can help identify technological and operational solutions, help overcome barriers preventing markets from working as efficiently as possible, and offer a long term perspective.

While often portrayed as a cost and a burden in the short run, the longer term perspective shows that greener shipping is not just a necessity, but could also hold opportunities.

The shipping sector carries about 80 per cent of the volume of international trade in goods and is linked to nations’ socio-economic development. However, at the same time there are a multitude of environmental challenges such as air quality at ports, noise pollution, water pollution (e.g. oil spills), marine biodiversity (e.g. invasive species) and greenhouse gas (GHG) emissions. Indeed, shipping can have global as well as local environmental impacts. In 2012, the international shipping sector emitted 796 million tons of
CO\textsubscript{2}, or about 2.2 per cent of the total CO\textsubscript{2} emissions, 10.6 million tons of SO\textsubscript{x} (as SO\textsubscript{2}) accounting for approximately 13 per cent of global SO\textsubscript{x} from anthropogenic sources, and approximately 18.6 million tons of NO\textsubscript{x} (as NO\textsubscript{2}) representing 15 per cent of global NO\textsubscript{x} from anthropogenic sources.\textsuperscript{2} Under business as usual scenarios and depending on future economic and energy developments, CO\textsubscript{2} emissions from the shipping sector are forecast to grow between 50-250 per cent in the period up to 2050. Thus, this sector’s contribution to global emissions is expected to increase to significant levels as other sectors under national inventories decarbonise.

Future Course of Travel
The Paris Agreement limits the increase in global temperatures to no more than 2°C, aiming for 1.5°C above pre-industrial levels and thus provides some direction as to the course of action that the shipping sector needs to take. This ambition requires deep decarbonisation across all sectors, including shipping. Smith et al. (2015)\textsuperscript{3} show that under both the 2°C and 1.5°C framing of climate change (emissions budgets), taking into account the latest IPCC (Intergovernmental Panel on Climate Change) and IMO (International Maritime Organisation) studies, and shipping maintaining its current share of 2.3 per cent of global emissions, the shipping sector must halve its emissions by 2050 under the 2°C scenario and achieve carbon neutrality by 2050 under the 1.5°C scenario. Translating this at the ship level, the aggregate average operational CO\textsubscript{2} intensity for all ship sizes of containerships, tankers and dry bulk (which account for 60 per cent of the shipping sector’s emissions) requires a reduction of 80-90 per cent on 2012 levels by 2050 in the 2°C scenario and net zero emissions in the 1.5°C scenario.

The Role of Technologies and Operations
Gains from efficiency and technological innovations can help to a large extent to achieve the transition to a sustainable shipping sector. However, innovation in shipping is mainly driven by market factors, e.g. fuel price (which can constitute about 50 per cent of the cost of operating a ship). Examples of where market factors, such as high fuel prices, have led to innovation include the period 1980 to 1985, when interest in wind propulsion as a secondary/hybrid means of propulsion increased and the recent market conditions (high fuel prices and low freight rates) which have led to various operational efficiencies such as slow steaming, Just In Time, etc. Thus, shipping innovation is more sensitive to market conditions relative to other factors, e.g., regulation, demand-side push, etc. As a cyclical industry,\textsuperscript{4} this poses a risk to the take-up of innovations as a means to curb CO\textsubscript{2} emissions in shipping. An example of the latent emissions risks occurred over the 2007-2012 period, which saw a decrease in the CO\textsubscript{2} intensity of the fleet but an increase in the total installed power in the shipping fleet.\textsuperscript{5} This means that if market conditions reverse, the efficiencies that are not locked in can be lost.

Haji et al. (2015)\textsuperscript{6} use GloTraM, to observe the effect on technology up-take by varying investment parameters, market barriers, offsetting, carbon price and bio-energy availability. GloTraM is a holistic model which combines multi-disciplinary analysis and modelling techniques to estimate foreseeable futures of the shipping industry to produce a range of scenarios (for more information, see: https://www.ucl.ac.uk/energy-models/models/glotram). The results show that under business as usual for two ship types (containerships and drybulk), only a few operational measures are implemented, but in the scenario with more favourable returns to shipowners, i.e., time charter premiums for energy efficiency being fully passed to shipowners through higher charter rates,\textsuperscript{7} the ship types investigated have the highest take-up of technologies, ranging from design measures to hydrodynamic measures. A recent survey of shipowners and operators by Rehmatulla (2015)\textsuperscript{8} attempts to understand the present day take-up of technologies indicated in Figure 1. For the aforementioned sectors, the results show significant heterogeneity within the
market. For example, the dry bulk sector saw relatively higher take-up of the hydrodynamic technologies compared to the tanker sector (see Figure 2). The survey also shows that, in general, the uptake of energy efficiency technologies is low and the technologies that have higher uptake have small energy efficiency gains at the ship level. The current use of alternative fuels and renewable energy sources is very low. This finding is further evidenced by the disconnect that exists between the present day stakeholder attitudes, and the future direction of travel required. Smith & Rehmatulla (2015) show that even in the most moderate scenario (low demand growth and doubling of shipping sector’s share of emissions), the carbon intensity reduction required from shipping far exceeds the levels envisioned as “commercially viable” by members of green/sustainability coalitions.

**Concluding Remarks**

A major challenge lies ahead for the shipping industry. Rising GHG emissions need to be halted and then reversed. Continuing on the business-as-usual course and postponing further action will increase the rate of decarbonisation required. Current regulations alone will not lead to the required emissions trajectory. Whilst the IMO mulls over future policies (e.g., global SOx limit, MRV and CO₂ targets), it is clear that decarbonising and greening the shipping sector will involve moving away from fossil fuels. Breakthroughs could come from step change technologies as well as dependable operational improvements.

**Figure 2: Implementation of Hydrodynamic Energy Efficiency Technologies**

Introduction

A ship can be classified as a “green ship” if it has a low environmental impact. A ship emits GHGs such as CO$_2$, HFCs and PFC’s, acidifying substances such as SOx and NOx, particulate matter (PM$_{10}$ and PM$_{2.5}$) and ozone precursors such as NOx and VOC. Worldwide, from 2007 to 2012, international shipping accounted for 15 per cent of the annual NOx emissions from anthropogenic sources, 13 per cent of SOx and 3 per cent of CO$_2$. Ships also discharge black and grey water, bilge water and ballast water at sea which impact marine biodiversity. Other environmentally damaging substances from ships include solid waste and sewage, chemicals from under water coatings and leakages of oil and lubricants.

While there is no agreement on what can be quantified as “low environmental impact”, a ship which has an environmental impact which is “lower than the industry average” can be classified as a “green ship”. With the adoption of existing technology, a green ship can reduce SOx and NOx emissions by 90 per cent or more, and can reduce CO$_2$ emissions by around 30 per cent by implementing energy efficient technologies. Typically, these ships also use electricity generated from renewable energy when at ports and undertake environmentally safe disposal of the ship at the end of its life cycle.
Regulatory Mechanisms

A strong component of environmental protection is enshrined in the United Nations Convention on the Law of the Sea (UNCLOS) and Part XII specifically deals with the protection and preservation of the marine environment. The International Maritime Organisation (IMO) which is a specialised agency of the United Nations for regulating the shipping industry is responsible for prevention and control of pollution from ships through its implementation arm, the Marine Environmental Protection Committee (MEPC). While the IMO has introduced various regulations for clean shipping, the scope of this article is restricted to the regulations pertaining to limiting air borne emissions.

(a) Clean Fuel and Emission Control Areas (ECAs)

Ships use heavy fuel oil (HFO), which is one of the dirtiest fuels in the world. Prior to 2005, merchant ships used bunker fuel with a sulphur content of over 4.5 per cent m/m (equal to 45,000 ppm (parts per million)) as compared to the allowable limit of 10 ppm in diesel (Euro 5). In order to clean up the shipping industry, it was decided to lower the sulphur content in fuels used by ships in a phased manner to 3.5 per cent m/m after 1 January 2012 and further to 0.5 per cent m/m after 1 January 2020. Similar regulations were applied to control NOx emissions (measured in g/kWh) and tier II regulations were applicable, globally, to ships constructed from 1 January 2011 to 31 December 2015.

Figure 1: Allowable Sulphur Content in Fuels Used on Board Ships

Apart from this, a number of ECAs were promulgated for limiting SOx emissions. In addition, stringent tier III regulations to further lower NOx emissions have been introduced in North American and United States Caribbean ECA for ships constructed from 1 January 2016. Expansion of the ECA to Singapore, Australia and the Mediterranean region is also under active consideration.

Figure 1 shows the regime for reduction in sulphur content for fuel used on board ships inside and outside the ECAs. Fuels having up to only 1.5 per cent m/m sulphur content were permitted to be used on board ships operating in the ECAs. This limit was reduced to 1 per cent in 2010 and further to 0.1 per cent m/m on 1 January 2015 and this has significantly reduced these emissions.

(b) Controlling GHG Emissions

Emission intensity of CO\textsubscript{2} from shipping is the lowest amongst all modes of transport (rail, road and air) and varies from 5 to 55 g CO\textsubscript{2}/ton-km for different types of ships. Despite this, if the international shipping sector was a country, it would have been the fifth largest GHG emitter in terms of absolute emissions. Emissions from international shipping are not included in the national GHG emission accounting mechanisms and therefore nation states do not have an obligation to lower emissions from this sector under the Kyoto Protocol. Notwithstanding this, the shipping sector led by the IMO ratified and adopted a legally binding GHG emission reduction regime and other regulations for cleaning the industry well before the diplomatic success of COP 21. Unlike the Kyoto Protocol, where the burden of reducing emissions was shared by developed countries and economies in transition, these regulations for the shipping sector are equally applicable to all 180 countries that are member states of the IMO.

The IMO adopted MARPOL Annex VI in July 2011 (resolution MEPC. 203(62)), adding a new chapter 4 to Annex VI on “Regulations on Energy Efficiency for Ships” wherein it made the use of the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP) mandatory in order to reduce fuel consumption on board ships for all new ships over 400 gross tons (GT) with effect from 1 January 2013.

(i) Energy Efficiency Design Index

The EEDI is a tool for monitoring and reducing the carbon emissions from ships by improving their energy efficiency. The EEDI is a performance-based mechanism that specifies the energy efficiency standards that are to be achieved by ships. The choice of technologies or operational measures by which the ship achieves these targets is left to the ship owners and operators. The EEDI regulation applies to all new ships and varies with ship type, size and function. The EEDI proposes a minimum energy efficiency level (measured in CO\textsubscript{2} emissions per ton-mile) for each class of ship, which is set as a reference baseline. The standards to be attained by ships which are constructed in different time periods are established and are expressed as per cent emissions reductions from these baselines. A ship’s attained EEDI (based on sea trials of new ships) must be below the required EEDI for that ship type and size, i.e.,

\[
\text{Attained EEDI} \leq \text{Required EEDI} = (1- X)/100 \times \text{Reference baseline}, \quad \text{where } X \text{ is the reduction factor.}
\]

These reduction factors are in the range of 0-10 per cent for ships built between 1 January 2015 to 31 December 2019, up to 20 per cent for ships built between 2020 and 2024, and up to 30 per cent for ships built after 1 January 2025. It is envisaged that these regulations will lead to a reduction in the emission intensity of the shipping fleet over time.

(i) Ship Energy Efficiency Management Plan (SEEMP)

While the EEDI sets the targets that are to be achieved, the SEEMP is a management tool for assisting the crew in managing the energy efficiency of ships. Unlike the EEDI, SEEMP is applicable to all merchant ships, both new and existing, of 400 GT and above. The SEEMP establishes a mechanism for measuring the operational energy efficiency of the ship, setting targets and monitoring the performance against the set targets in four distinct steps, viz. planning, implementation, monitoring and self-evaluation. The IMO has suggested use of an Energy Efficiency Operational Indicator (EEOI) as a monitoring and/or benchmark tool, to measure the energy efficiency of each voyage of the ship. This EEOI from operational data can then be used for subsequent comparison of emissions from each voyage.
**The Way Ahead**

The shipping industry is also slowly transitioning to distilled fuels such as marine diesel oil (MDO), marine gas oil (MGO) and LNG fuelled ships in response to the new regulations. However, there are many challenges in adopting alternate fuels, ranging from the relatively higher cost of clean fuels, high capital cost of undertaking modifications to the existing systems to include fuel switching options, technical limitations, restrictions on availability of low sulphur fuel, limited monitoring capability of states to ensure that they follow the applicable emission control regimes, and legal and enforcement capacity of institutions amongst others.

The recent COP 21 agreement has left the shipping industry outside its ambit and has placed great trust on the IMO to lead the sector towards lower emissions. The process adopted by the IMO for consultation and engagement with various stakeholders such as national governments, ship builders and ship owners, industry players, civil society and international environmental organisations has delivered substantial results and it is hoped that the shipping industry will adopt aggressive measures to further lower its emissions. While the set of existing technologies does not provide many options for the shipping industry to switch from fossil fuels, renewable energy such as wind (kite sails, sail ships), fuel cells and solar energy offer some potential options. Notwithstanding, the trend of green ships has caught on in the industry and a zero emission ship running on clean energy may not be very far away in the future.

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**Staff Presentations and Moderating**

27 **July** Shi Xunpeng presented “Asia’s Hub Initiatives and Their Impact”, at the **1st Meeting of the Multilateral Joint Study for LNG Markets** organised by the Institute of Energy Economics, Japan (IEEJ)/Economic Research Institute for ASEAN and East Asia (ERIA).

19 **July** Shi Xunpeng presented “The Impact of China’s Gas Market Uncertainties”, at the **28th China Economics Association in Australia (CESA) Annual Conference** organised by CESA.

15 **July** Philip Andrews-Speed presented “Climate Change and Energy” at Singapore’s Ministry of Foreign Affairs, Foreign Service Advanced Programme, Singapore.

14 **July** Shi Xunpeng commented on “Addressing Energy Challenges in Emerging Asia”, at the **5th Asia Roundtable in Tokyo** organised by OCED/AMRO/ADB/ADBI/ERIA.


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**Staff Publications**

**Internationally Refereed Journal Articles**


**Books and Book Chapters**


**Recent Events**

**8 July**, Analysing Long-Run Trends of Energy Demand in the Manufacturing Industries of India (ESI Seminar)

Dr. Shyamasree Dasgupta, Assistant Professor, School of Humanities and Social Sciences, Indian Institute of Technology, delivered a presentation on the pattern of energy demand in India’s seven most energy-intensive manufacturing industries, namely, cement, iron and steel, fertiliser, aluminium, chemical, pulp and paper and textiles. After applying Index Decomposition Analysis (IDA) to study the extent to which the energy intensity trends have contributed in the decoupling of industrial activity growth from growth in energy use, her results showed that the declining energy intensity has been able to neutralise a major portion of the growing energy demand resulting in stronger decoupling trends, especially in recent years.


Professor Günther Handl, the Eberhard P. Deutsch Professor of Public International Law at Tulane University Law School delivered a presentation on the critical role of off-site emergency preparedness and response (EPR) in nuclear accident management notwithstanding continuous improvements in nuclear safety worldwide. He highlighted that EPR is a matter of intrinsic international concern, not only between neighbouring states, but globally as shortcomings in EPR anywhere tend to undermine confidence in nuclear safety everywhere. He then discussed the major international public policy and legal challenges that have presented themselves in the aftermath of Fukushima: the drive to harmonise EPR and the intrinsic difficulties in reaching that goal; transboundary emergency notification/communication arrangements bilaterally, regionally and globally, that are insufficiently anchored to a firm legal basis; enhanced independent peer review and regular testing to ensure quality and reliability of EPR plans; and stronger state support for the International Atomic Energy Agency’s (IAEA) international emergency assistance mechanism. In the end, while EPR notionally remains, of course, a national responsibility, many of its key aspects are increasingly being “internationalised”.


**Staff Media Contributions**

Philip Andrews-Speed was interviewed by the Oil and Gas Middle East Magazine on Oman-China oil relations, 2 August.

Philip Andrews-Speed was interviewed by China Radio International on the UK’s Hinkley Point Nuclear Plant, 2 August.


Philip Andrews-Speed was interviewed by Radio Free Asia on China on the costs of overcapacity of coal-fired power plants, 18 July 2016.

Christopher Len was quoted by the Wall Street Journal in “South China Sea Tensions Leave Oil Potential Untapped”, 12 July 2016.

Philip Andrews-Speed was interviewed by Radio Free Asia on China’s teapot oil refineries, 20 June 2016.
New Staff

YUAN Jun

Dr. YUAN Jun joined ESI in August 2016. He completed his PhD in Industrial and Systems Engineering at the National University of Singapore in 2013, and was awarded "The National Semiconductor Gold Medal". The focus of his PhD was statistical modelling, applied statistical methods and simulation optimisation. His Bachelor's degree was in Industrial Engineering and Management from Shanghai Jiao Tong University in 2008. In 2007, he participated in an exchange programme with Hong Kong University of Science and Technology.

Before joining the ESI, he was a research fellow at the Centre for Next Generation Logistics and the Centre for Maritime Studies, both at NUS, and contributed to several projects including modelling and optimisation in energy efficiency, maritime issues and healthcare systems. He co-founded a supply chain company in 2013 where the integrated solutions were provided to industrial clients. His main research interests include maritime energy and environmental systems modelling, data analysis, and smart energy.

Contact

- Collaboration as a Partner of ESI (research, events, etc)
- Media Enquiries
- ESI Upcoming Events
- Join ESI Mailing List

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The ESI Bulletin on Energy Trends and Development seeks to inform its readers about energy-related issues through articles on current developments. Our contributors come from ESI's pool of researchers, local and overseas research institutes, local government agencies and companies in the private sector. You can download past issues from www.esi.nus.edu.sg.

We welcome your feedback, comments and suggestions. The views expressed in each issue are solely those of the individual contributors.

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