

To what extent has progress been made by the International Maritime Organization (IMO) in reducing CO₂ emissions from global shipping?

Lisa Bayley-Craig

Thesis submitted to the University of Ottawa
in partial Fulfillment of the requirements for the
Master of Science Degree in Environmental Sustainability

Institute of the Environment
Faculty of Science
University of Ottawa

© Lisa Bayley-Craig, Ottawa, Canada, 2020

ACKNOWLEDGEMENTS

I would like to thank God for his love and continued presence in my life, I would not have made it this far without Him. In addition, thanks must also be given to my family, friends, former classmates, professors and the staff of the Institute of the Environment who have all been instrumental in providing me with a wealth of knowledge and/or inspiration during my studies, and during the writing of this paper. Thanks, especially must be given to my Thesis Supervisor, Marel Katsivela for her advice, guidance and patience during the past year, which has greatly contributed to this informative thesis.

ABSTRACT

90% of global trade is transported by cargo ships, with fossil fuel being the dominant energy source used. As global trade increases, shipping will be in greater demand resulting in increased emissions of carbon dioxide and other pollutants negatively impacting the environment and human health. Carbon dioxide (CO₂), our area of interest, is the number one contributing gas to global warming. We, therefore, examine the role of the International Maritime Organization (IMO) in reducing CO₂ emissions from shipping, and determine the progress made so far.

Our research reveals that progress in this area is on a slow trajectory. The current IMO regulations focus solely on energy efficiency measures that do not appear to be as successful as envisioned in reducing CO₂ emissions. In addition, the concept of decarbonization of the sector, which would lead to zero emissions, is delayed. With this in mind, we provide recommendations regarding future IMO actions.

TABLE OF CONTENTS

| | |
|---|-----|
| ACKNOWLEDGEMENTS | ii |
| ABSTRACT..... | iii |
| TABLE OF CONTENTS..... | iv |
| List of Tables | vi |
| List of Figures | vi |
| Abbreviations | vii |
| Chapter 1 – Introduction | 1 |
| 1.1 The Negative Effects of CO ₂ Emissions..... | 1 |
| 1.2 Maritime Shipping and its contribution to global emissions | 6 |
| 1.3 The Object of the Research Undertaken..... | 15 |
| 1.4 Chapter Summary..... | 17 |
| 1.5 Methodology | 18 |
| 1.6 Theoretical Framework | 19 |
| Chapter 2 - The International Maritime Organization (IMO) and its role in reducing CO ₂ emissions from global shipping | 21 |
| 2.1 An Introduction to The International Maritime Organization (IMO)..... | 21 |
| 2.2 The IMO Conventions on Mitigating Emissions from Shipping | 25 |
| 2.2.1 The International Convention for the prevention of Pollution from Ships (MARPOL)..... | 25 |
| 2.2.2 MARPOL Annex VI - Prevention of Air Pollution from Ships | 28 |
| 2.2.3 Integrated Technical Cooperation Programme (ITCP)..... | 41 |
| 2.2.4 Global Maritime Energy Efficiency Partnership (GloMEEP) project | 43 |
| 2.2.5 Global Maritime Technology Cooperation Centre (MTCC) Network (GMN) | 47 |
| 2.3 The IMO and Autonomous or Unmanned Ships..... | 51 |
| Chapter 3 - Results and Analysis | 57 |
| 3.1 Introduction | 57 |
| 3.2 CO ₂ Emissions from global shipping for the period 2007-2015..... | 58 |
| 3.3 The players involved in the IMO’s law-making process | 68 |
| 3.4 The IMO’s authority to enforce their regulations | 70 |
| Chapter 4 – The Way Forward..... | 79 |

Bibliography 96

List of Tables

| | |
|---|----|
| Table 1: A comparison of global CO ₂ shipping emissions with total shipping and international shipping CO ₂ emissions (values in millions tonnes CO ₂)..... | 59 |
| Table 2: Comparison of Global CO ₂ emissions for shipping from 2007-2015 | 62 |

List of Figures

| | |
|---|----|
| Figure 1: 2015 CO ₂ emissions for Global Shipping | 13 |
| Figure 2: 2015 global CO ₂ emissions by countries | 14 |
| Figure 3: 2013-2015 Average percent share of CO ₂ emissions by ship class (left) and flag state (right)..... | 65 |

Abbreviations

| | | |
|-----------------|---|--|
| AER | - | Annual Efficiency Ratio |
| AIS | - | Automatic Identification System |
| BAU | - | Business as usual |
| BC | - | Black Carbon |
| CCPA | - | Canadian Centre for Policy Alternatives |
| CFCs | - | Chlorofluorocarbons |
| CH ₄ | - | Methane |
| CNN | - | Cable News Network |
| CO | - | Carbon Monoxide |
| CO ₂ | - | Carbon Dioxide |
| COLREG | - | Convention on the International Regulations for Preventing Collisions at Sea |
| CSC | - | International Convention for Safe Containers |
| CSR | - | Corporate Social Responsibility |
| ECAs | - | Emission Control Areas |
| EDGAR | - | Emissions Database for Global Atmospheric Research |
| EEDI | - | Energy Efficiency Design Index |
| EEOI | - | Energy Efficiency Operational Indicator |
| EESH | - | Energy Efficiency per Service Hour |
| EIAPP | - | Engine International Air Pollution Prevention |
| EMP | - | Eco Marine Power |
| EMSA | - | European Maritime Safety Agency |

| | | |
|---------------|---|--|
| DECA | - | Domestic Emission Control Area |
| FOC | - | Flag of Convenience |
| FORS | - | Fuel Oil Reduction Strategy |
| FSI | - | Flag State Implementation |
| GEF | - | Global Environment Facility |
| GEF-UNDP -IMO | - | Global Environment Facility-United Nations Development Programme-International Maritime Organization |
| GHGs | - | Greenhouse Gases |
| GIA | - | Global Industry Alliance |
| GISIS | - | Global Integrated Shipping Information System |
| GloMEEP | - | Global Maritime Energy Efficiency Partnership |
| GMN | - | Global Maritime Network |
| GSPs | - | Green Shipping Practices |
| HFO | - | Heavy Fuel Oil |
| IGOs | - | Intergovernmental Organizations |
| kW | - | kilo-watt |
| ICCT | - | International Council on Clean Transportation |
| IEA | - | International Energy Agency |
| IHSF | - | IHS Fairplay |
| ILWU | - | International Longshore and Warehouse Union-Canada |
| IMCO | - | Inter-Governmental Maritime Consultative Organization |
| IMO | - | International Maritime Organization |
| INGO | - | International Non-Governmental Organizations |

| | | |
|------------|---|---|
| IPCC | - | Intergovernmental Panel on Climate Change |
| IRENA | - | International Renewable Energy Agency |
| ISPI | - | Individual Ship Performance Indicator |
| ITCP | - | Integrated Technical Cooperation Programme |
| LDCs | - | Least Developed Countries |
| LNG | - | Liquefied Natural Gas |
| Load Lines | - | International Convention on Load Lines |
| LPCs | - | Lead Pilot Countries |
| LPG | - | Liquefied Petroleum Gas |
| LPIR | - | Legal, Policy and Institutional Reforms |
| MARPOL | - | International Convention for the Prevention of Pollution from Ships |
| MAS | - | Management and Automation System |
| MASS | - | Maritime Autonomous Surface Ships |
| MBMs | - | Market-based Measures |
| MDO | - | Marine Diesel Oil |
| MGO | - | Marine Gas Oil |
| MEPC | - | Marine Environment Protection Committee |
| m/m | - | mass by mass |
| Mph | - | Miles per hour |
| MSC | - | Maritime Safety Committee |
| MT | - | Multimodal Transport |
| MTCC | - | Maritime Technology Cooperation Centre |

| | | |
|-------------------------------------|---|---|
| Mtonne | - | Million Tonnes |
| MUNIN | - | Maritime Unmanned Navigation through Intelligence in Network |
| n.d | - | no date |
| NGOs | - | Non-Governmental Organizations |
| NMVOG | - | Non-Methane Volatile Organic Compounds |
| NOAA | - | National Oceanic and Atmospheric Administration |
| NOx | - | Nitrogen Oxide |
| NO _x Technical Code 2008 | - | Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines |
| NO ₂ | - | Nitrogen Dioxide |
| N ₂ O | - | Dinitrogen Oxide |
| OECD | - | Organization for Economic Cooperation and Development |
| ODS | - | Ozone Depleting Substances |
| PM | - | Particulate Matter |
| PM _{2.5} | - | Fine Particulate Matter |
| PSC | - | Port State Control |
| PV | - | Photovoltaic |
| R&D | - | Research and Development |
| RCP | - | Representation Concentration pathways |
| rpm | - | Revolutions Per Minute |
| SAR | - | International Convention on Maritime Search and Rescue |
| SDGs | - | Sustainable Development Goals |

| | | |
|-----------------|---|--|
| SEEMP | - | Ship Energy Efficiency Management Plan |
| SFOCD | - | Ship Fuel Oil Consumption Database |
| SIDS | - | Small Island Developing States |
| SOG | - | Speed Over the Ground |
| SO _x | - | Sulphur Oxide |
| SO ₂ | - | Sulphur Dioxide |
| SOLAS | - | International Convention for the Safety of Life at Sea |
| SPACE STP | - | Protocol on Space Requirements for Special Trade Passenger Ships |
| SSP | - | Shared Socioeconomic Pathways |
| STCW | - | International Convention on Standards of Training, Certification and Watchkeeping for Seafarers |
| STCW-F | - | International Convention on Standards of Training, Certification and Watchkeeping for Fishing Vessel Personnel |
| STP | - | Special Trade Passenger Ships Agreement |
| Tonnage | - | International Convention on Tonnage Measurement of Ships |
| UN | - | United Nations |
| UNFCCC | - | United Nations Framework Convention on Climate Change |
| UNDP | - | United Nations Development Programme |
| U.K. | - | United Kingdom |
| U.S or U.S. A | - | United States of America |
| USCG | - | United States Coast Guard |
| VOC | - | Volatile Organic Compounds |

- WMU - World Maritime University
- WWF - World Wildlife Fund Canada

Chapter 1 – Introduction

In this thesis we seek to determine the progress made by the International Maritime Organization (IMO) in reducing carbon dioxide (CO₂) emissions from global shipping. To achieve this, we examine many diverse aspects which include: the IMO's regulations, strategies, global partnerships, and projects; the history and structure of the IMO; the IMO's authority to enforce their regulations; the players involved in the IMO's law-making process; the negative effects of CO₂ emissions; maritime shipping and its contribution to global CO₂ emissions; the challenges or barriers which may prohibit the reduction of CO₂ emissions; CO₂ emissions data from global shipping from 2007-2015; future prediction of CO₂ emissions from shipping; and recommendations regarding future IMO action which can be taken to mitigate CO₂ emissions.

We will begin by first looking at CO₂ emissions in general and in the area of shipping and address their negative impact.

1.1 The Negative Effects of CO₂ Emissions

Barbir, Veziroğlu, and Plass (1990) advise that the greatest damage to the environment is the burning of fossil fuel for energy consumption resulting in the production of harmful greenhouse gases (GHG). These gases include CO₂ – the number one contributing gas to global warming-, sulfur dioxide (SO₂), methane, nitrogen dioxide (NO₂), and chlorofluorocarbons (CFCs). The authors also inform us that increased burning of fossil fuels results in excessive amounts of CO₂ being released in

the atmosphere. When this combines with the other greenhouse gases, [for example nitrogen, methane and chlorofluorocarbons (CFCs) – artificial chemicals], it results “in thermal changes by absorbing the infrared energy the earth radiates back into the atmosphere, causing global temperature increase” (Barbir et. al.1990 p. 739).

To put this in perspective, we will explain the greenhouse effect. “When the Sun’s energy reaches the Earth’s atmosphere, some of it is reflected back to space and the rest is absorbed and re-radiated by greenhouse gases. Greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, ozone and some artificial chemicals such as chlorofluorocarbons” (Australian Government Department of the Environment and Energy, n.d. p. 1). According to Zhong and Haigh (2013), Rehkopf (2003) and the Australian Government Department of the Environment and Energy (n.d.), the absorbed energy is responsible for warming the earth’s atmosphere and surface, making it habitable for life to exist on earth. However, the authors also note that anthropogenic (human) activities such as the burning of fossil fuels (oil, coal and natural gas) have resulted in the enhanced greenhouse effect (where there are now increased concentrations of GHGs). Thus, this extra heat being trapped results in the rising of the earth’s temperature and contributes to global warming.

Statistical data by the National Oceanic and Atmospheric Administration (NOAA, 2019i) reveals that, since 1880, the global annual temperatures of the land and sea have increased per decade at an average of 0.13°F (0.07°C). The NOAA data also shows that 2018 marked the fourth highest recorded temperature increase of 1.42°F (0.79°C) from the average annual global temperature of land and sea (NOAA, 2019ii) while the third highest temperature increase of 1.51°F (0.84°C) was noted in 2017 (NOAA, 2019iii) and

the second highest temperature increase of 1.62°F (0.90°C) took place in 2015 (NOAA, 2019iv). The first highest temperature increase recorded to date took place in 2016 and amounted to 1.69°F (0.94°C) (NOAA, 2019i).

According to the theory of global warming conducted by Barbir et. al. (1990) more than 20 years ago, rising temperatures result in sea levels rising because of melting ice glaciers; erosion of coastlines and contamination of drinking water supplies; extreme weather patterns such as heat waves, droughts, hurricanes and floods which have all caused environmental and economic destruction, an increase in human illnesses and an unprecedented record of deaths. This is still accurate in the 21st century, with similar views on the impacts of global warming also being shared by Luber and Prudent (2009), Adams (2016), Harrould-Kolieb and Savitz (2010) and many other theorists and international organizations.

We see evidence of extreme weather conditions believed to be attributed to global warming reported in “Extreme weather around the world,” (2018) by MSN News in:

- Quebec, Canada where, in July 2018, a heatwave killed approximately 70 people with temperatures reaching 95 degrees Fahrenheit (35 degrees Celsius).
- China, where floods in Beijing and Tianjin affected 250,000 people and 32,000 hectares of crops in the province of Shandong in July 2018.
- Dominican Republic’s capital city of Santo Domingo, where flooding occurred in July 2018 during tropical storm Beryl, marking nine inches of

consistent rainfall over a 24-hour period. Many persons were left homeless and approximately 150,000 persons were without electricity.

In addition, more recent extreme weather was reported in September 2019 where Category 5 Hurricane Dorian with wind speeds of over 220 miles per hour (mph) devastated some of the islands of the Bahamas, specifically the Abacos and Grand Bahama islands (McLaughlin, Andone and Holcombe, 2019). This left 70,000 people homeless, a death toll of 43, with the expectation that this figure will rise as hundreds of people remain missing (Blackwell, Newton and Maxouris (2019).

The Union of Concerned Scientists (2019) has emphatically stated for many years that the temperature of the earth is rising and that this is attributed to GHG emissions, especially CO₂ emissions. They advise that should this warming continue, there will be further environmental and economic devastation for many communities around the globe.

This concern is further shared by the United Nations (UN) Intergovernmental Panel on Climate Change (IPCC) in its special report submitted in October 2018 titled 'Global Warming of 1.5°C'. The report mentions that the temperature of the earth is rising, and the impact of climate change is real with evidence of increased severe weather patterns occurring around the globe. An urgent global response with comprehensive cooperation from all industries and governments is required to limit the global temperature increase this century to 1.5°C above pre-industrial levels and not 2°C as was previously agreed to by the 2015 Paris Climate Change Agreement (Intergovernmental Panel on Climate Change (IPCC), 2018). [The IPCC defines the pre-industrial era as between 1850-1900, before the industrial revolution commenced, and

advises that this period is used as a baseline to represent an approximation of pre-industrial temperature levels]. Indeed, the Paris Climate Agreement involves Parties to the United Nations Framework Convention on Climate Change (UNFCCC) working towards a common goal to combat climate change in order to ensure a sustainable low carbon future. This Agreement aims to maintain the global temperature this century below 2°C above pre-industrial levels, while pursuing further efforts to limit the global temperature increase this century to 1.5°C (UNFCCC, 2019i).

The IPCC report further advises that to limit the global temperature increase this century to 1.5°C, anthropogenic CO₂ emissions will have to be reduced by 45% from 2010 levels to 2030, and reach 'net zero' by 2050. These actions must occur now in order to mitigate further catastrophic climate change events and ensure a safe and sustainable future (IPCC, 2018).

It is indeed a concern when the IPCC is drawing attention to a global temperature crisis and the statistical data presented above by the NOAA (2019i-iv) for the average global temperatures for land and ocean surfaces show evidence of a trend of recent global temperatures that are not on a trajectory to achieve the IPCC's target of 1.5°C global temperature limit for this century. In fact, according to the IPCC's report, the global temperature is currently rising by 0.2°C per decade, and on its present path, the current threshold of 1.5°C this century will be reached unfortunately by 2040 (IPCC, 2018).

Despite evidence throughout the years that our climate has changed there are still deniers. According to a news article titled 'Scientists unite to decry deniers of climate change' by Munro (2010), a U.S. senator has called 17 prominent climate

scientists criminals whereas many experts have suggested that climate scientists should commit suicide. Over 250 prominent scientists, including 11 Nobel laureates, have noted, however, that there is overwhelming evidence of a changing climate and this cannot be ignored. They urge climate change deniers to focus on evidence and desist from their political and personal attacks (Munro, 2010).

With all this evidence of our changing climate and the average global temperature increases, what is the contribution of the maritime shipping sector towards global warming and, more specifically, towards CO₂ emissions?

1.2 Maritime Shipping and its contribution to global emissions

Shipping refers to the transportation of cargo and goods by water, land or air transport (Bradley, Diesenreiter, Wild and Tromborg, 2009). For the purpose of this study, we will focus on the ocean transportation of cargo and goods carrying more than 90 percent of the global trade of goods (Basaran, 2016).

This form of transportation, also known as maritime shipping, has been in existence for thousands of years (Monios and Wilmsmeier, 2018). According to the World Shipping Council (2019) the early sea travelers – the Phoenicians, Greeks and Egyptians among others - sailed the oceans seeking new treasures and returned home to trade items (for example jewels, foods and materials). However, this was not an easy process as the loading and unloading of sacks, barrels and wooden crates filled with individual goods being manually transported on and off the vessel was extremely slow and ineffective. This process known as ‘break bulk shipping’ was the only method of

transporting goods to and from ships; it lasted until the second half of the 20th Century (World Shipping Council, 2019).

Loading and unloading cargo from ships was also extremely labor-intensive resulting in ships spending less time at sea and more time in port, highly exposing cargo to loss, accident and theft. To tackle this problem, processes to make loading and unloading more effective were developed, such as using rope to bundle timber, sacks to carry coffee beans and pallets for stacking and transporting bags. In the 18th century, the railway industry showed that the cargo shipping method being used was problematic and ineffective when transporting cargo from trains to ships and from ships to trains (World Shipping Council, 2019).

There was hope for a more effective transportation cargo process for shipping with Malcom McLean's development of the container in 1956 which revolutionized ports, transformed shipping and port operations, opening up the door for globalization (Monios and Wilmsmeier (2018). The advent of the shipping container gave merchants a more secure and efficient method to transport cargo both over land and sea and significantly reduced loss of cargo due to damage and pilferage. Ships no longer spent weeks in ports having their cargo manually loaded and unloaded. Instead, large cranes provided this service in just a few hours, allowing ships to spend more time at sea resulting in greater profitability. With this, the growth of shipping lines began, followed by mergers which resulted in the formation of large global companies (Monios and Wilmsmeier, 2018).

The shipping industry continues to grow with new technologies and strategies constantly being developed to make the movement of cargo faster and more efficient.

There has been a tremendous improvement in the design of ships which now ensures that they can accommodate effective transportation processes allowing for the simultaneous transport of finished, dry and wet bulked products. The shipping industry is focused on constant improvement of efficient processes, with a focal point of having full shiploads of cargo as well as optimizing costs (Panayides, Lambertides and Savva 2011).

Another improvement affecting shipping constitutes the multimodal transportation (MT) which reaches land and sea boundaries of all five continents (Mukherjee and Li (2013). According to The Global Facilitation Partnership for Transportation and Trade (2013) MT is referred to as a transport operation consisting of different modes of transportation organized by a single operator. MT is the most efficient method of door to door transportation at the international level. In one voyage, MT combines the best advantage each mode of transportation has to offer, road haulage flexibility, railways large capacity and the lower cost of water transportation. The efficiency in the MT process is made possible because the shipper depends on one ship operator who organizes the entire journey of the cargo from pickup to delivery (The Global Facilitation Partnership for Transportation and Trade, 2013).

As global trade increases, however, so do shipping emissions, negatively impacting air quality, climate, the environment and human health (Fuglestvedt et. al. (2009). An area of concern in shipping lies in the constant fossil fuel usage resulting in emissions of carbon dioxide (CO₂) sulfur oxide (SO_x), nitrogen oxide (NO_x) and particulate matter (PM) (Walker, 2016). The main fossil fuel type used in shipping is residual oil also known as heavy fuel (HFO) or 'bunker fuel', which is the energy source

of concern, especially for cargo ships (Gallucci 2018). While cruise ships also burn bunker fuel (Bennett 2018), cargo ships are significant users of this type of fuel (Gallucci 2018). It is to be noted that at the end of 2018, there were 53,000 merchant ships trading internationally (Statista, 2019) and 314 cruise line passenger ships (Cruise Market Watch, 2018) which proves the emphasis that must be put on the ocean transport of cargo.

Bunker fuel, which is a cheap, dirty and widely available fuel (Wang, 2014) consists of a mixture of diesel and heavy petroleum residue which remains after gasoline and lighter petroleum products have been extracted from the crude oil refining process. Its rate of decomposition is extremely slow and especially when an oil spill occurs it results in dangerous environmental problems (“IMO Bans Bunker Fuel” 2010). Other types of fuel used in shipping include: (1) LNG (Liquefied Natural Gas), which is a natural gas which, when cooled to a liquid form at temperatures of -162°C (-260°F), is made easier to transport and store (Shell, 2019ii). When used as a fuel for transportation, LNG produces less emissions than diesel and heavy fuel oil (Shell, 2019i). Over the years LNG has grown in popularity as a marine fuel (Oiltanking, 2019i). (2) MDO (Marine Diesel Oil) is a marine fuel which comprises a blend of various distillates (marine gasoil) and an extremely low heavy fuel oil content. There are various blends of MDO which allow for this fuel to be used in different engines. However, even though MDO produces less emissions than HFO, it is more expensive than HFO and this results in commercial shipping choosing to use HFO instead of MDO (Oiltanking, 2019ii). (3) Marine Gas Oil (MGO) which is the lightest fuel oil used in shipping, is a clean distillate oil used mostly in smaller ships (Fridell, 2019).

Fossil fuel consumption in maritime transport has been on the increase for many years. In 1925, approximately 66 million tonnes (Mtonne) of fuel oil was consumed (Fridell, 2019). In 2002 this amount increased to 200 Mtonne (Endresen, Sørgård, Behrens, Brett and Isaksen 2007). In 2012 there was a further increase to 300 Mtonne: of this amount: 228 Mtonne was HFO, 64 Mtonne was MDO, and 8 Mtonne was LNG (Fridell, 2019).

Every time a shipping vessel sets sail using fossil fuel as an energy source it will emit significant levels of CO₂, SO_x, NO_x, and PM (Walker, 2016). Corbett, Fischbeck and Pandis (1999) advise that 70-80% of emissions from all ships occur 400 km (248 miles) away from land. Whenever any fuel combustion occurs, NO_x is automatically formed in the atmosphere (Icopal Noxite, 2011) as well as SO₂ (Energy Education 2017) and CO₂ (Energy Education, 2018). As a result of chemical reactions of NO_x and SO₂, the formation of PM occurs, producing adverse results on human health (United States Environmental Protection Agency, 2019ii).

CO₂ is a gas which is naturally derived from plants and animals and is a vital component of the carbon cycle. However, fossil fuel burning emits anthropogenic CO₂ which contributes to global warming and ocean acidification (Energy Education, 2018). The occurrence of ocean acidification causes sea water to become acidic, prohibiting the formation of carbonate ions which are essential for the formation of coral skeletons and seashells (NOAA, 2019v). In addition to CO₂, other gases are also emitted from shipping and contribute to global warming (Fridell, 2019). These include methane (CH₄) and dinitrogen oxide (N₂O) (Styhre, Winnes, Black, Lee, and Le-Griffin 2017); along with a solid or particle known as black carbon (BC) (Harrould-Kolieb, 2008).

According to Energy Education (2017), SO_x are pollutants consisting of oxygen molecules and occur in the atmosphere from the combustion of sulfur-based fuels. The most common form of this pollutant is SO₂. SO_x form a component of acid rain which has a debilitating effect on both vegetation and humans, causing lower crop yields to farmers and respiratory diseases and death in humans (Energy Education, 2017).

NO_x comprises a mixture of gases which include oxygen and nitrogen. Two common forms of this gas include: nitrogen dioxide and nitric oxide (Agency for Toxic Substances and Disease Registry, 2011). When fuel combustion occurs, nitrogen is released which then combines with oxygen atoms creating nitric oxide. The latter then further combines with oxygen to create nitrogen dioxide (Icopal Noxite, 2011). Short exposures to nitrogen dioxide can cause respiratory symptoms such as coughing, wheezing or difficulty in breathing. Long term exposure may result in the development of asthma and increase respiratory infections (United States Environmental Protection Agency, 2019i).

According to the United States Environmental Protection Agency (2019ii) PM (particulate matter), also known as particle pollution, refers to a combination of liquid droplets and solid particles in the atmosphere. The formation of these particles is caused by pollutants emitted as a result of the burning of fossil fuel and the complex reactions of chemicals: NO_x and SO₂. Some particles are large and visible (i.e. smoke and dust) while others can only be detected with microscopic equipment. This minute matter, once inhaled, can make its way into an individual's bloodstream or even deep in the lungs resulting in serious health problems such as: aggravated asthma; irregular heartbeat; decreased lung function; premature death in people with heart or lung

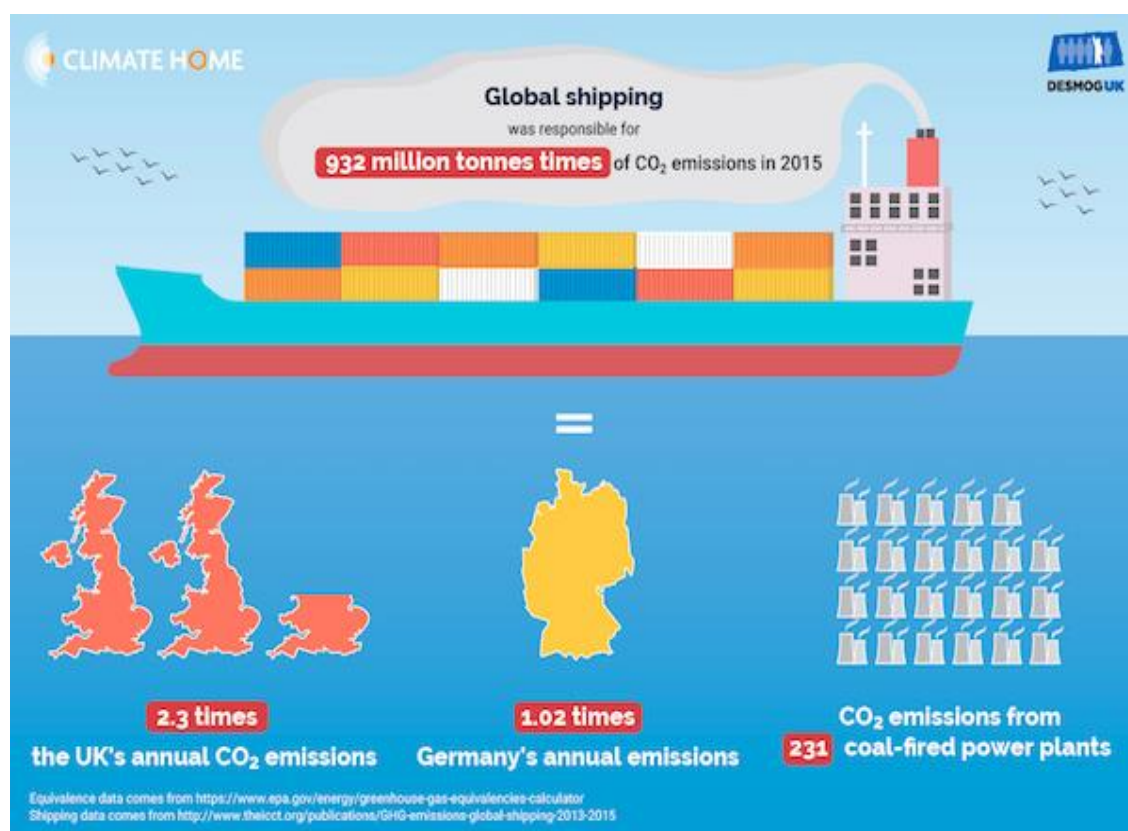
disease; irritation of airways, and difficulty in coughing or breathing (United States Environmental Protection Agency, 2019ii).

Thus, emissions from fossil fuel contribute to global warming (Walker, 2016) and the atmospheric pollutants have adverse health effects. In fact, these pollutants contribute to approximately 90,000 human deaths annually (Mims, 2010). In October 2018 Dr. Tedros Adhanom Ghebreyesus, the head of the World Health Organization (WHO), warned that air pollution is the world's 'new tobacco' and is responsible for killing 7 million people annually and causing harm to billions. He mentioned that this is a global crisis which requires urgent attention from all relevant stakeholders (Carrington and Taylor 2018). Researchers from the International Council on Clean Transportation (ICCT), The George Washington University Milken Institute School of Public Health, and the University of Colorado Boulder conducted a study assessing the premature mortality attributed to air pollution from transportation. This data was released in March 2019 and revealed that in 2015, PM and ozone non-road engines, on-road vehicles and oceangoing vessels were responsible for an estimated 385,000 premature deaths globally. Approximately 15% or 60,000 deaths resulted from air pollution from 70,000 international ships (Rutherford and Miller, 2019). It is evident from the above-mentioned information that many health and environmental risks are associated with emissions from ships as a result of fossil fuel burning.

In the 'Third IMO Greenhouse Gas Study in 2014' (we will refer to this as the 2014 IMO Study) the authors Smith et. al. (2015) advised that in 2012 the CO₂ emissions from international shipping accounted for 2.2% of the global CO₂ emissions, and this figure is projected to increase between 50% and 250% by 2050. In 2015,

global shipping was responsible for 932 million tonnes of CO₂ emissions (Olmer, Comer, Roy, Mao and Rutherford (2017i)). This amount represented 2.6% of the global CO₂ emissions from fossil fuel use and industrial processes. As seen below in Figure 1, this was equivalent to 2-3 times the UK's annual CO₂ emissions, 1.02 times Germany's annual emissions, and the CO₂ emissions from 231 coal-fired power plants (Darby 2017). In 2015, if there was a country known as international shipping (with regards to CO₂ emissions) it would rank sixth in the world (representing 2.6% of the global CO₂ emissions), just above Germany (Olivier, Janssens-Maenhout, Muntean, Peters, 2016).

Figure 1: 2015 CO₂ emissions for Global Shipping



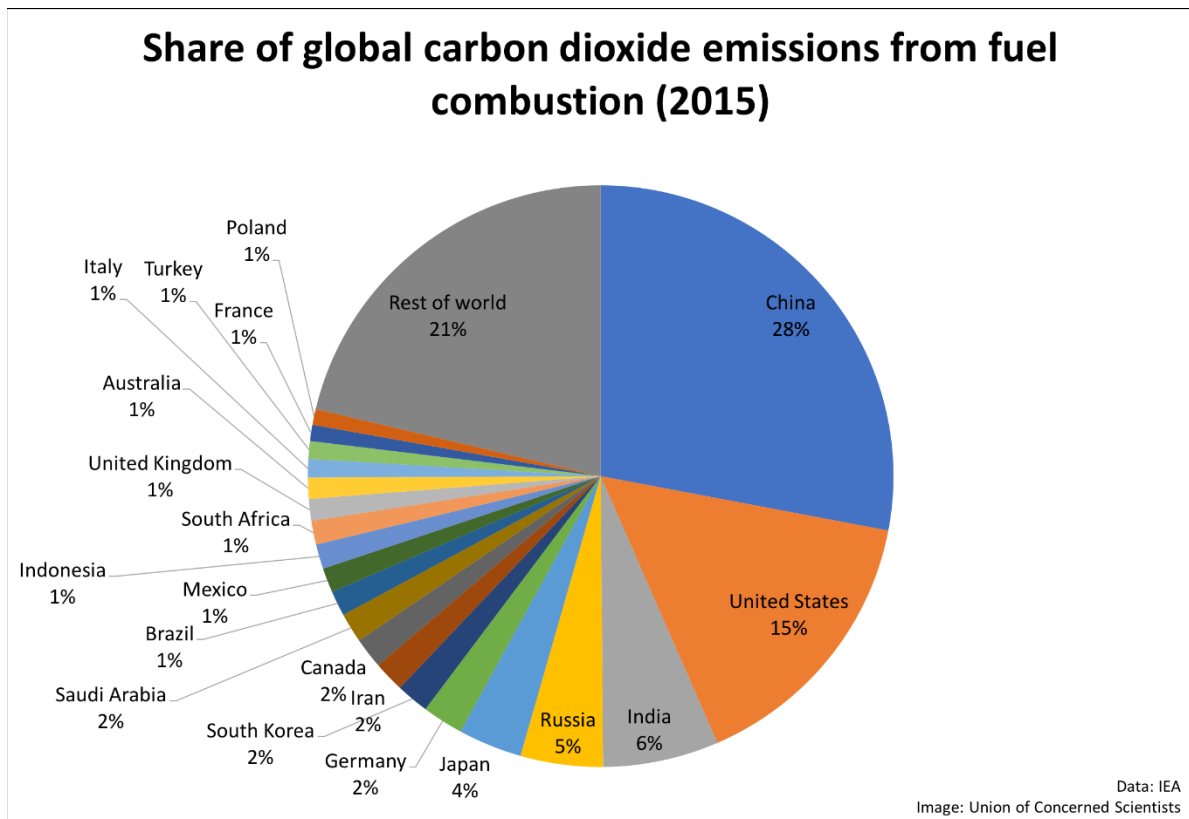
Source: (Darby 2017)

Thus, even though shipping is an efficient mode of transportation, it generates, annually, approximately one billion tonnes of CO₂ emissions which represents between

2% and 3% of the global CO₂ emissions (“Lower Emissions on the High Seas” (2017)). The shipping industry is, therefore, a major climate polluter.

To put these findings into perspective we present, in Figure 2, the 2015 global CO₂ contributions made by country based on data gathered by the International Energy Agency (IEA) (2017) and a study carried out by the Union of Concerned Scientists (2018). As is evident from the following diagram, China ranks first in global CO₂ emissions (28%) followed second by the United States (15%); third by India (6%); fourth by Russia (5%); fifth by Japan (4%) and sixth by Germany (2%), the country used as a comparison in Figure 1.

Figure 2: 2015 global CO₂ emissions by countries



Source: Union of Concerned Scientist (2018)

As global trade continues to increase, the shipping sector will be in greater demand, leading to an increase of CO₂ emissions in the future (Eide et. al., 2013). Despite the polluting nature of this sector (Olivier et. al. 2016), shipping has been excluded from the 2015 United Nations (UN) Paris Climate Agreement (United Nations Framework Convention on Climate Change (UNFCCC) (2019i). There is no reason specifically mentioned as to why this exclusion has occurred. However, what is known is that after the Paris Climate Change Agreement meetings in 2015, the International Maritime Organization (IMO) - the international regulatory body of the shipping industry - has stated its commitment to reduce GHG emissions from international shipping (IMO, 2019xii). For this reason, we fervently seek through our research to discover what action has been taken by the IMO to reduce CO₂ emissions from global shipping and to determine the progress which has been made to achieve this.

1.3 The Object of the Research Undertaken

The IMO (International Maritime Organization) is a specialized agency of the United Nations (UN) which has been tasked with the responsibility of adopting and implementing numerous regulations to govern maritime safety, maritime security, oil pollution and environmental protection (IMO, 2019i). Indeed, the IMO is the main international institution charged with the responsibility of ensuring that the shipping industry and its operations prevent further harm and damage to our global environment (Basaran, 2016).

The object of this thesis lies in examining and analyzing the role the IMO is playing in mitigating CO₂ emissions from shipping in order to determine the realistic progress

which has been made by the organization in this field. We have chosen to focus on CO₂ emissions from shipping rather than on SO_x (sulfur oxide), NO_x (nitrogen oxide), PM (particulate matter), because this gas is the number one contributing gas to global warming (Barbir et. al. 1990).

More specifically, the object of the research lies in:

- Examining the IMO's regulations which have been adopted and implemented along with the IMO's strategies, global partnerships and projects which have been established to reduce CO₂ emissions from global shipping.
- Determining the overall progress which has been made in reducing CO₂ emissions from global shipping.
- Providing recommendations on future action which could be taken by the IMO to ensure significant progress is made in reducing CO₂ emissions from global shipping.

Important questions being asked in undertaking this research are:

- What are the main regulations, strategies, global partnerships and projects adopted and implemented by the IMO in order to mitigate CO₂ emissions from global shipping?
- What enforcement measures are in place to ensure that the IMO regulations on mitigating CO₂ emissions from shipping are adhered to?
- What type of power does the IMO have to enforce its regulations?
- Is the action undertaken by the IMO relevant or enough to mitigate CO₂ emissions?

1.4 Chapter Summary

The thesis consists of four chapters:

Chapter One (Introduction) describes the objective of the thesis, the research questions, the theoretical approach, methodology and outlines the chapters' summary. Information is also provided on the evolution of the shipping industry and its contribution to CO₂ emissions.

Chapter Two focuses on examining the IMO conventions, strategies, global partnerships and projects which have been adopted only, or adopted and implemented in order to mitigate CO₂ emissions from shipping. In addition, it briefly examines the autonomous or unmanned vessel reality which is being considered by the IMO in order to mitigate air pollution from shipping.

Chapter Three comments on the CO₂ emissions from shipping before and after the implementation of the IMO's regulations in order to determine the progress made in reducing such emissions. It also comments on the extent of the IMO's power to implement regulations to achieve the successful reduction of CO₂ emissions. Finally, it identifies any impediments which may delay or inhibit progress in reducing CO₂ emissions.

Chapter Four (Conclusion and Recommendations) provides the conclusions of the research analysis regarding the effectiveness of the IMO's role in guiding the sector to successfully reduce CO₂ shipping emissions. It also provides recommendations regarding future IMO action in this area.

1.5 Methodology

Our methodological approach focuses on the qualitative method of documentary analysis related to the research. To answer the questions raised in the present thesis (Section 1.3) we will conduct extensive research on information regarding the IMO's structure, its regulations, strategies, global partnerships, and projects with the view to mitigate CO₂ emissions from global shipping, as well as on the challenges faced by the organization in achieving this.

To aid in this process extensive University of Ottawa library and internet searches are used which include looking for 'academic literature' on the IMO and the reduction of shipping emissions, using key search terms such as: "shipping emission reduction"; "international maritime organization"; "climate change and shipping emissions"; "maritime shipping"; "evolution of the international maritime organization", among other relevant terms. [This involved reviewing over 100 documents both academic and non-academic]. In addition, internet and library searches for 'non-academic literature' such as annual reports, statistics on CO₂ shipping emissions and strategies to mitigate these, governmental and stakeholder information, journal articles, government publications, conference papers, newspaper articles and any other relevant non-academic literature will be used to aid in this research.

1.6 Theoretical Framework

The theoretical framework used in the present thesis is based on Boyd's (2003) theory of Unnatural Law where he provides a comprehensive assessment of the weaknesses and strengths of Canadian environmental law. The objective of his work is to: (1) accurately assess the effectiveness of Canadian environmental laws and policies; (2) examine the reasons for Canada's progress or failure to progress in this area; and (3) provide solutions for Canada regarding changes to its policies and laws, enabling the country to become a global sustainable future leader (Boyd, 2003). Boyd's analogy is likened to events which occur during a doctor's appointment: an examination, a diagnosis and a prescription (Boyd, 2003).

In analyzing Canada's environmental record (air, land, water and biodiversity) with aid from the Organization for Economic Co-operation and Development (OECD), Boyd advises that Canada's environmental performance when compared to other industrialized nations is weak. The reason why the Canadian approach towards environmental protection is not successful is because "the root causes of environmental degradation are never addressed". "All of the effort is directed toward treating the symptoms of environmental harm, a strategy that may mask or mitigate the damage but will never prevent it. Canada, like the United States, attempts to protect the environment through an increasingly complex web of laws and regulations. These efforts focus on moderating the harmful impacts of human activities in industrial societies, without challenging the dominant paradigm of endless economic growth based on ever-increasing consumption of energy and resources" (Boyd, 2003 p. 276).

Even though Boyd's theory is based on Canada rather than the IMO, we find it useful in our undertaking. In effect, what we will extract from Boyd's (2003) theory is the need to address the 'root causes of environmental degradation' with respect to shipping emissions. Although we will not follow Boyd's reasoning (examination, diagnosis, prescription) we will use his theory as a general point of reference, as a baseline in order to assist in the examination of the IMO's progress towards reducing CO₂ emissions. In this way, we will seek and comment on any root causes which may prohibit such progress at the IMO level and address them.

Chapter 2 - The International Maritime Organization (IMO) and its role in reducing CO₂ emissions from global shipping

The present chapter focuses on examining the IMO conventions, strategies, global partnerships and projects towards mitigating CO₂ emissions from global shipping. In addition, it provides a brief description of autonomous/unmanned vessels which may have beneficial effects on reducing CO₂ emissions.

2.1 An Introduction to The International Maritime Organization (IMO)

According to the International Maritime Organization (IMO, 2019i) the IMO is a specialized agency of the United Nations (UN) which was initially established out of a growing need by many countries to effectively promote and manage maritime safety through international shipping regulations (IMO, 2019i). In 1948 in Geneva, an international conference was held resulting in the adoption of the *Convention on the Intergovernmental Maritime Consultative Organization* - its name at the time was the Inter-Governmental Maritime Consultative Organization (IMCO) - which formally established the IMO (United Nations Treaty Collection, 2019). In 1958, this convention entered into force and the first organization meeting of the IMCO took place the following year. In 1982 the name IMCO was officially changed to the International Maritime Organization (IMO, 2019i).

Today, the IMO has 174 Member States which represent most countries in the world including the main maritime powers (IMO, 2019ii). It also comprises three Association Members [Faroes (Faroe Islands), Hong Kong (China) and Macao (China)] (IMO, 2019ii, iii). Non-Governmental Organizations (NGOs) and Intergovernmental Organizations (IGOs) enter into agreements to work with the IMO in areas of common interest, only after securing approval from IMO authorities which consist of: the Assembly (IMO, 2019iii), the highest governing body of the IMO which includes all IMO Member States (IMO, 2019 xli)], the Council, which is elected by the Assembly and is known as the Executive Organization of the IMO, and five main Committees: The Maritime Safety Committee (MSC); the Marine Environment Protection Committee (MEPC); the Legal Committee; the Technical Cooperation Committee and the Facilitation Committee. In addition, there are many Sub-Committees which support the work of the main technical committees (MSC and MEPC) (IMO, 2019iii). The IMO structure also extends to include the Secretariat of the IMO (United States Coast Guard (USCG) (2018)] consisting of the Secretary-General Mr. Kitack Lim (from the Republic of Korea - appointed on January 1st, 2016 for an initial four-year term) along with 300 international personnel who are all based at the IMO's headquarters in London (IMO, 2019iv). The Secretariat is responsible for the IMO's daily administrative operations which include meeting coordination and preparation (USCG) (2018) and the Secretary-General is the chief administrative officer of the organization (1948 Convention of the International Maritime Organization, Part VIII – The Secretariat – Article 33-38 (United Nations Treaty Collection, 2019).

The main objective of the IMO is to facilitate international cooperation and develop international regulations to be adhered to by all shipping nations in order to promote and provide an efficient, safe, secure and sustainable shipping industry. This is achieved by implementing numerous rules to govern maritime safety, maritime security, oil pollution, environmental protection, implementation, compliance and cooperative legislative competence (IMO, 2019i). The IMO also plays an important role in achieving the targets presented by the United Nations (UN) Sustainable Development Goal (SDG) 14: 'Conserve and sustainably use the oceans, seas and marine resources for sustainable development' (United Nations, 2019ii). The SDGs program is an action plan for all countries to promote prosperity and protect the environment (United Nations, 2019iii). This plan was adopted in 2015 by all the Member States of the UN and aims to achieve a sustainable future for the planet and all populations by 2030. There are 17 goals in the plan which focus on developing strategies to address issues such as poverty, health, education, job opportunities, equality, climate change, the preservation of forests and the ocean (United Nations, 2019iii).

Since the establishment of the IMO, there have been over 50 international conventions and agreements and many protocols and amendments which have been adopted. The IMO's process of adoption and implementation of conventions involves discussions of Member States in the following IMO's constituent bodies: - the Assembly, the Council, the Maritime Safety Committee, the Marine Environment Protection Committee, the Legal Committee and the Facilitation Committee. These discussions focus on current and future developments in shipping and other related industries as well as the adoption of new conventions or the amendment of existing ones, all with the

goal of meeting present and future demands of the shipping industry. There is also a voting process (Part XIV - Article 62) during these discussions, with each member only being allowed to vote once. Decisions are made by majority vote. Following the adoption of a convention and its formal acceptance by individual governments – expressing their consent to the convention using methods such as signature, ratification, acceptance, approval or accession – the convention enters into force within a specific time frame (IMO, 2019v).

If amendments have to be made to existing conventions, this may take place with a faster procedure called ‘tacit acceptance’ where amendments can now enter into force between 18 to 24 months (IMO, 2019v) after an amendment has been adopted by an appropriate IMO body (Shi, 1999). “Thus, an amendment becomes effective on a specified date, determined by the body adopting the amendment, unless a certain percentage of contracting States, a blocking minority, rejects the amendment by that date” (Shi, 1999, p.306). The percentage of contracting Governments that reject the amendment must consist of more than-one third of all contracting Governments; or the contracting Governments must own no less than 50 per cent of the world’s gross merchant tonnage (IMO, 2019v). The Tacit Acceptance Procedure reduces the length of time taken between the adoption of an amendment and its entry into force (Shi, 1999). It involves a much shorter time frame than previous years where amendments were adopted by a two-third majority of Contracting States before they could enter into force (IMO, 2019v). This lengthy process was known as the explicit acceptance procedure and resulted in amendments taking five to ten years before they entered into force (Shi, 1999).

We will now turn our attention to one of the focal points of our research: identifying the IMO's Conventions which have been adopted and aim at reducing CO₂ emissions from shipping as well as the IMO's strategies, global partnerships and projects which have all been established to aid in this process.

2.2 The IMO Conventions on Mitigating Emissions from Shipping

In this section we will focus on the description of the IMO Conventions which have been adopted or adopted and implemented for the period 1973 – 2018 and which aim at reducing CO₂ emissions from shipping. Even though IMO regulations focus on reducing GHGs in general, CO₂ is a GHG (Barbir et. al.,1990). We assume, therefore, that the adoption of regulations on GHGs reduction will also lead to the reduction of CO₂ emissions.

2.2.1 The International Convention for the prevention of Pollution from Ships (MARPOL)

In analyzing the IMO Conventions on mitigating shipping emissions, we see evidence of the first sign of the IMO's contribution to reduce pollution and, therefore, CO₂ shipping emissions through an important international Convention adopted in 1973, the *International Convention for the Prevention of Pollution from Ships* (MARPOL) (IMO, 2019vi). The adoption of MARPOL came as a result of the Torrey Canyon disaster in 1967 where an accident in the English Channel resulted in the ship's entire cargo of

120,000 tons of crude oil being spilled into the sea. At that time, this was the largest oil pollution incident ever recorded (IMO, 2019 vi, vii).

Due to a series of increased tanker accidents in 1976 and 1977, MARPOL was subsequently amended by the adoption of the 1978 Protocol (National Oceanic and Atmospheric Administration (NOAA, 2019vi). Some of the tanker incidents included: (1) the Argo Merchant vessel which ran aground in 1976 near Nantucket Island, Massachusetts U.S.A. The vessel broke apart and spilled all of its cargo consisting approximately of 183,000 barrels of No. 6 fuel oil (80%) and cutter stock (20%) (NOAA, 2019vi, vii); and (2) the tanker Irene Challenger which broke apart and sank in 1977 near Midway Island in the North Pacific Ocean with 9.6 million gallons of crude oil onboard (NOAA, 2019vi). The 1978 Protocol was adopted in order to prevent and reduce pollution from ships due to the fact the 1973 MARPOL Convention had not yet entered into force. The MARPOL Protocol of 1978 ended up absorbing the parent Convention and entered into force in October 1983 (IMO, 2019vi).

There was a further amendment to MARPOL with the adoption of the 1997 Protocol which added to MARPOL its Annex VI on the Prevention of Air Pollution from Ships. The Annex entered into force in 2005 (IMO, 2019vi). Also occurring in 1997, was the 1997 Kyoto Protocol - an international agreement linked to the United Nations Framework Convention on Climate Change (UNFCCC) - which entered into force in 2005, giving the IMO the mandate to reduce GHG emissions from the shipping industry (United Nations Framework Convention on Climate Change (UNFCCC) 2019ii; UNFCCC, n.d.; IMO, 2019xxiv). In short, from its inception to the present-day MARPOL has experienced many amendments (IMO, 2019vi).

MARPOL covers accidental and operational oil pollution, air pollution, and pollution from garbage, chemicals, sewage and goods in packaged form, as represented by the six Annexes below (IMO, 2019vi):

- Annex I - Regulations for the Prevention of Pollution by Oil (entered into force in 2nd October 1983)
- Annex II - Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk (entered into force 2nd October 1983)
- Annex III - Prevention of Pollution by Harmful Substances Carried by Sea in Package Form (entered into force 1st July 1992)
- Annex IV - Prevention of Pollution by Sewage from Ships (entered into force 27 September 2003)
- Annex V - Prevention of Pollution by Garbage from Ships (entered into force 31 December 1988)
- Annex VI - Prevention of Air Pollution from Ships (entered into force 19th May 2005), (this will be examined as follows).

We will examine MARPOL Annex VI along with some other amendments to MARPOL which include the Energy Efficiency measures for ships - Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) (IMO, 2019xiv) - as follows.

2.2.2 MARPOL Annex VI - Prevention of Air Pollution from Ships

As previously mentioned, the IMO's (2019ix) MARPOL Annex VI, was adopted in 1997 and later entered into force in 2005. It places limits on sulfur oxides (SO_x) and nitrogen oxides (NO_x) emitted from the ship's exhaust. It also prohibits deliberate emissions of ozone depleting substances (ODS) and regulates shipboard incineration and the emissions of volatile organic compounds (VOC) from tankers. To further improve MARPOL Annex VI, in 2005, the MEPC agreed to revise MARPOL Annex VI (this revision entered into force 1st July 2010) to make a greater contribution towards reducing shipping emissions. This revision focused on progressively reducing global emissions of SO_x, NO_x and particulate matter (IMO, 2019ix).

There was a further amendment to MARPOL Annex VI in 1997, with the adoption of resolution 8 which invited the MEPC to investigate the environmental impact of CO₂ emissions from ships and devise strategies to mitigate these. This resolution specifically invited the IMO and the UNFCCC to conduct a study on CO₂ emissions from ships in order to determine the percentage of CO₂ emissions which are derived from ships in relation to the global inventory of CO₂ emissions (IMO, 2019xxiv).

Further, in December 2003, resolution A.963(23) on IMO Policies and practices regarding GHG emission reduction from ships, was adopted by the IMO Assembly. This resolution – which does not constitute an amendment to MARPOL Annex VI-, is complementary in substance to Annex VI as it assists in encouraging the MEPC to take steps towards developing mechanisms to reduce GHG emissions from international shipping (IMO, 2019xxiv). The resolution also urges the MEPC to give priority to the

establishment of GHG emission baselines; the evaluation of operational, technical and market-based solutions; the development of Guidelines which would allow the practical application of a GHG emissions indexing scheme; and the development of a methodology describing the GHG efficiency of a ship with regards to the GHG emissions index for that ship (IMO, 2004).

In 2011 the first ever mandatory global energy efficiency resolution for international shipping was adopted through resolution MEPC.203(62) on the *Inclusion of regulations on energy efficiency for ships* under MARPOL Annex VI. This added a new Chapter 4 to MARPOL Annex VI Regulations for the prevention of air pollution from ships which introduced mandatory energy efficiency regulations such as: The Energy Efficiency Design Index (EEDI) for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for all ships. The goal of the EEDI and SEEMP is to outfit ships with energy efficiency targeting the reduction of GHG emissions being released into the atmosphere (IMO, 2019xiv, xxxviii).

EEDI and SEEMP entered into force on 1 January 2013. The EEDI aims to equip new ships with more energy efficient engines and equipment. It allows the industry to choose the best energy efficient technologies for their specific ship design as long as the required energy efficiency level is achieved. EEDI also requires a minimum energy efficiency level per capacity mile (for instance, tonne mile) for ships of different types and sizes (IMO, 2019xiv). Mentioning specifically CO₂ emissions, the IMO has stated: “The EEDI provides a specific figure for an individual ship design, expressed in grams of carbon dioxide (CO₂) per ship’s capacity-mile (the smaller the EEDI the more energy efficient ship design) and is calculated by a formula based on the technical design

parameters for a given ship” (IMO, 2019xiv p.1). The design of all new ships must meet the reference level for their ship type (IMO, 2019xiv). A thorough explanation of the formula used to calculate the EEDI can be found in Resolution MEPC.212(63) (IMO, 2012).

According to the IMO (2019xiv), for the EEDI process, the CO₂ reduction level (grams of CO₂ per tonne mile) is currently set at 10% for new ships. This amount will be tightened every five years to ensure that it keeps abreast with new technological developments for reduction and efficiency measures. The EEDI was initially developed for the largest and more energy intensive new ships such as: bulk carriers, tankers, general cargo ships, gas carriers, container ships, refrigerated cargo carriers and combination carriers (IMO, 2019xiv). However, in 2014, MEPC adopted amendments to EEDI in order to include newer ship types such as: ro-ro cargo ships (vehicle carriers), LNG (liquefied natural gas) carriers, ro-ro passenger ships, ro-ro cargo ships and cruise passenger ships which have non-conventional propulsion. Thus, ship types which are responsible for approximately 85% of CO₂ emissions from international shipping are now included under the international regulatory regime (IMO, 2019xiv).

The SEEMP (for new and existing ships) is a management plan that allows ship operators to monitor the operational energy efficiency of their ships in a cost-effective manner. This can be done by the use of an Energy Efficiency Operational Indicator (EEOI) as a monitoring tool (IMO, 2019xiv). SEEMP also incorporates best practices for fuel efficient ship operations and it provides the voluntary use of the EEOI guidelines (IMO, 2019xiv - MEPC.1/Circ.684 (Annex, 3.4. p.4, IMO, 2019xvi). The EEOI allows operators to measure the fuel efficiency of a ship, allowing them to consider any

changes during the ship's operation which could have an effect on fuel efficiency. Operational changes which are frequently used include cleaning propellers, improved voyage planning, installing waste heat recovery systems, frequent cleaning of the underwater part of the ship and technical measures such as fitting a new propeller (IMO, 2019xiv). Some other operational measures include slow steaming, weather routing and trim optimization (Dewan, Yaakob and Suzana (2018). Slow steaming refers to a reduction in sailing speeds in order to conserve fuel, reduce operational cost and improve a company's profit margins (Cariou, 2011; Cepeda, Assis, Marujo and Caprace (2017). Weather routing is used to find the best routes in relation to weather conditions which will consume the least amount of fuel (De Wit 1990). Trim optimization refers to ships having the right trim which will provide minimal resistance through water (Reichel, Minchev and Larsen, 2014). Ships can carry a specified amount of cargo at designated speeds allowing them to consume a specified amount of fuel under a specific trim condition resulting in the optimization of the trim, and the consumption of less fuel ("Ship-board Energy Efficiency", 2015).

In October 2016, further amendments were made to MARPOL Annex VI with the adoption of resolution MEPC.278 (70) – entering into force on March 1, 2018 - which introduced the *data collection system for fuel oil consumption of ships*, making it now mandatory to record and report the type of fuel oil consumed by ships. Under this amendment, on or before December 31, 2018, ships with 5000 gross tonnage and more have to collect data on every type of fuel oil used along with information on proxies for transport work (IMO, 2019xiv).

According to the IMO (2019xv), at the end of each calendar year, the aggregated data is reported to the Flag State. The Flag State issues a Statement of Compliance to the ship after ensuring that the reported data has complied with the requirements. The Flag State must then pass this data to the IMO Ship Fuel Oil Consumption Database. The IMO then produces an annual report summarizing the data collected and passes this on to the MEPC. Member States now have access to this data through the IMO's Ship Fuel Oil Consumption Database which has recently been launched within the platform of the Global Integrated Shipping Information System (GISIS) (IMO, 2019xv). The GISIS is an information system developed by the IMO which allows the public free access to information pertaining to the maritime sector. This can include information on marine casualties and incidents, maritime security, survey and certification, ship fuel oil consumption and many other modules (IMO, 2017; Maritime Safety and Security Information Centre (2019)).

The mentioned mandatory air pollution reduction measures are forecasted to significantly reduce CO₂ emissions from the shipping industry. By 2020, both the EEDI and the SEEMP are estimated to reduce CO₂ emissions by 200 million tonnes annually. By 2030, this figure is projected to increase to 420 million tonnes of CO₂ annually. In addition, there should also be savings in fuel cost in the shipping industry: \$20 to \$80 billion by 2020 and between \$90 to \$310 billion by 2030 (IMO, 2019xiv).

Although the IMO seeks to reduce CO₂ emissions using EEDI and SEEMP (IMO, 2019xiv), the IMO's slow response to implement measures to reduce GHG emissions is under attack. According to Lister, Poulsen and Ponte (2015) emissions from shipping are unfortunately being underestimated and any emission reduction strategies currently

being undertaken are on a slow trajectory. We see that in 1997, the Kyoto Protocol gave the mandate to the IMO to reduce GHG emissions from the shipping industry (UNFCCC, 2019ii; UNFCCC, n.d.; IMO, 2019xxiv). However, it wasn't until 2011, 14 years after the adoption of the Kyoto Protocol that measures of the MEPC resulted in the adoption of the first mandatory global GHG reduction instrument for the international shipping sector (Karim, 2015). Thus, the 2011 *Inclusion of regulations on energy efficiency for ships* under MARPOL Annex VI which introduced the EEDI and the SEEMP became the first legally binding climate change treaty to reduce GHG in the shipping industry since the Kyoto Protocol (IMO, 2019xiv).

Further, they are critics as to the effectiveness of the EEDI and SEEMP measures. Karim (2015) advises that the EEDI imposes a minimum energy efficiency level per capacity mile for ships of different types and sizes (IMO, 2019xiv). However, according to Karim (2015), even though SEEMP is mandatory, the measures adopted to meet the energy efficiency targets are not specified. Thus, ship owners must make their own decisions regarding the best energy efficient measures to adopt (Karim, 2015). This could prove to be problematic because of the absence of guidance provided to the ship owners as to the implementation of the said programs resulting in the most effective energy efficiency technology for the ship not being chosen and, thus, the amount of emissions not being reduced as effectively as possible.

In this regard, Dewan et. al. (2018) also advises that one major barrier to the implementation of the IMO's energy efficiency measures is the lack of communication to the relevant stakeholders in the shipping industry regarding the energy efficiency concept and its benefits to the industry. According to Nguyen (2018), the IMO solely

issues guidelines regarding the implementation of the EEDI and SEEMP, leaving the choice of the energy efficiency technologies to the industry (Rojon and Smith, 2014). This creates a knowledge gap, as many ship owners, builders, operators, managers and designers are exposed to huge amounts of technological information regarding energy efficiency but due to their limited knowledge they cannot always make the most effective choice and adopt the most energy efficient measures (Nguyen, 2018; Dewan et. al., 2018). Ship operators or ship crew may be equipped with technical knowledge and be well versed on the ship's operation; however, due to the company's management structure they are not able to make decisions on energy efficiency measures. A collaborative effort between ship managers and ship operators is usually required to achieve optimum results regarding energy efficiency measures. If there is a lack of understanding and communication between them, the implementation of effective energy efficiency measures may not occur (Dewan et. al. (2018).

Finally, critics note that due to expected growth in world trade, emissions from ships are expected to continue to increase in spite of the EEDI and the SEEMP. Greater measures will be required if the shipping industry is to make an impact towards reducing the effects of climate change (Bazari and Longva, 2011).

As we continue our search for IMO policies focused on reducing CO₂ emissions, we embark upon the Initial IMO Strategy on the reduction of greenhouse gas (GHG) emissions from ships (IMO, 2019xii). As CO₂ is an important GHG (Barbir et. al. 1990), any strategies aimed at reducing greenhouse gases should also assist in mitigating CO₂ emissions.

This Initial Strategy is proof that the IMO is continuing its work to address GHG emissions from international shipping (IMO 2019x), It constitutes the first initiative by the IMO to develop a comprehensive plan to reduce GHG emissions from ships. In October 2016, the Initial Strategy was recognized as a solution for reducing emissions from shipping at the 70th meeting of the Marine Environmental Protection Committee (MEPC 70). This was later adopted in April 2018 at (MEPC 72) (IMO, 2019xii, xiii). Overall, the Strategy (IMO 2019x) is significant as it furnishes a framework providing Member States with a comprehensive Roadmap to achieve reductions in GHG emissions from international shipping.

The main objectives of the Strategy as advised by the IMO (2019x) are to:

- address GHG emissions from international shipping in order to participate in the global efforts to alleviate the global emission problem tackled by the Paris Agreement, the United Nations 2030 Agenda for Sustainable Development and its SDG (as mentioned in section 2.1) 13: *'Take urgent action to combat climate change and its impacts-*.
- identify appropriate actions which can be implemented by the international shipping sector to assist it in reducing shipping GHG emissions and simultaneously enhance its role in the development of global trade.
- aid in achieving the above-mentioned objectives by including research and development incentives along with a GHG emission monitoring plan for the international shipping sector.

It is believed that all of these objectives can be achieved by providing short, mid-term and long-term measures along with supporting measures [(such as technical

cooperation, capacity building and research and development (R&D)], and by overcoming any barriers which would create an obstacle in attaining these measures (IMO, 2019xii). However, these measures (IMO, 2019x) which constitute planning tools for what needs to be done within a particular time frame, still need to be finalized and agreed upon by the MEPC and other relevant IMO authorities in order for them to become adopted and enforceable IMO regulations in the future. The list of these measures is quite extensive, so we have decided to mention a few which need to be adopted by the international shipping sector within targeted timelines (IMO, 2019x): -

- short-term measures to be adopted by between 2018 and 2023 include, among others:
 - improving the existing energy efficiency framework [(by adopting, for example, Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP)] mentioned above (Section 2.2.2);
 - making further improvements to the technical cooperation and capacity-building activities under the Integrated Technical Cooperation Programme (ITCP) as explained below (Section 2.4.1);
 - adopting further national action plans to address GHG emissions from international shipping;
 - encouraging further enhancement of energy efficiency of ships by implementing activities for research and development which would address marine propulsion, alternative low-carbon and zero-carbon fuels and innovative technologies.

- mid-term measures to be adopted by between 2023 and 2030 mainly focus on:
 - market-based measures (MBMs) being used to create incentives to reduce GHG emissions;
 - developing further technical cooperation and capacity-building activities under the Integrated Technical Cooperation Programme (ITCP)
 - adopting an alternative low-carbon and zero-carbon fuels implementation programme;
 - implementing operational energy efficiency measures for new and existing ships;
 - developing a feedback mechanism to allow for greater sharing of information regarding the lessons learned from the implementation of the measures.

- long-term measures to be adopted beyond 2030 include, among others:
 - the development and provision of zero-carbon or fossil-free fuels to create an environment which would allow the shipping industry to consider decarbonization. To date, this Initial Strategy is the only IMO program which mentions moving away, in time, from fossil fuel;
 - assistance and encouragement in facilitating new or innovative emission reduction mechanisms in the future.

The measures of the IMO's Initial Strategy are major future steps towards mitigating GHG emissions in the maritime shipping sector (IMO, 2019x). According to Corsi (2018) of the Climate Institute, the IMO's Strategy is strong and ambitious and

sets out a vivid framework to reduce emissions. As we look specifically at the targets for the reduction of GHG and CO₂ emissions, we see that under the 'levels of ambition' section of the Strategy (p. 5), it is forecasted that a 50% reduction of the total annual GHG emissions should be achieved by 2050 compared to 2008 levels, with the intention of having them entirely phased out. For CO₂ emissions from international shipping it is forecasted to have a reduction of 40% by 2030, with efforts towards a further reduction of 70% by 2050, compared to 2008 (IMO, 2019x).

However, critics of this IMO Initial Strategy are not lacking. The International Council on Clean Transportation (2018) advises that once the targets for the IMO Strategy are complied with, international shipping would consume between 3.8% and 5.8% of the world's remaining carbon budget under the Paris Agreement, an increase from 2.3% in 2015. This increase could be due to the fact that as global trade increases, the shipping industry's efficient mode of transportation will be in greater demand and accompanying this will be more consumption of fuel, leading to increased shipping emissions (Cullinane and Bergqvist, 2014).

Corsi (2018), another critic, mentions that another disadvantage of the Strategy is the absence of a non-compliance procedure on quantitative emissions reduction targets. In other words, the absence of penalties in the Initial Strategy regarding non-compliance could result in an increase of CO₂ emissions from ships. He further notes that this could possibly weaken the effectiveness of the strategy. The author also advises that, in the future, MEPC meetings may implement measures which can be taken to have this rectified.

Another criticism made by the same author is that the future of market-based mechanisms, [which are aimed at creating incentives to reduce GHG emissions - some examples include providing support for research and development or creating incentives in the shipping industry to achieve improvements in energy efficiency (IMO, 2019x)], all fall under the mid-term strategy to be adopted between 2023 and 2030 (IMO, 2019x). These market-based mechanisms have been previously discussed within the IMO when Resolution A.963 (23) (IMO Policies and Practices related to the reduction of GHG emissions from ships) was approved in 2004. In effect, in this Resolution there was a requirement for the evaluation of operational, technical and market-based solutions (IMO, 2004). However, even though 14 years have passed since the Resolution, the implementation of market-based mechanisms has again been delayed as it is now part of the mid-term future strategy of the IMO's Initial Strategy [Corsi (2018)] scheduled to be adopted between 2023 and 2030 (IMO, 2019x). Finally, Corsi notes that even if the IMO Strategy is fully complied with, the target for achieving the 1.5°C reduction (Corsi, 2018), which is urgently recommended by the IPCC (2018) will not be attained due to the increase of international shipping based on the data mentioned above by the International Council on Clean Transportation (2018).

A revised Strategy is scheduled to occur in 2023. This signifies the importance of remaining current and relevant in order to continue to reduce GHG emissions (IMO, 2019x). It is hoped that, by that time, a greater assessment of the IMO's Strategy will be conducted in order to determine its effectiveness in reducing maritime emissions (Corsi, 2018). As we continue our research, we seek now to discover the IMO's global

partnerships and projects geared towards the reduction of CO₂ emissions from global shipping.

As international maritime shipping regulations are adopted and implemented by the IMO, the ultimate responsibility for their implementation resides strictly with the government of individual countries (Karim, 2015). However, due to lack of resources, some governments are sometimes unable to comply with the IMO's regulations (IMO, 2019xviii).

According to Karim (2015) a lack of political will, legal expertise, technical, and financial inability in many developing countries may pose challenges for the implementation of the IMO regulations. In effect, some technical experts of the local maritime administrations in developing countries may experience difficulty in understanding the technical terms of the IMO Conventions. In addition, integrating the IMO regulations in the local legal frameworks may constitute a challenge, as some developing countries may not have the legal expertise to effectively draft their local legislation to properly reflect the IMO Conventions. This can occur because many developing countries are independent states and find it difficult to amend their local laws to incorporate international conventions (Karim, 2015). Further, the author advises that some developed countries lack the political will and environmental responsibility to implement the IMO regulations despite their technical, legal and financial resources.

In order to ensure that challenges faced by developed and developing countries do not prevent the implementation of the IMO's regulations, in May 2013 (IMO, 2019xviii), the IMO prepared the foundation for its global capacity-building projects. This involved the adoption of resolution MEPC.229(65) which focused on the *Promotion of*

technical co-operation and transfer of technology relating to the improvement of energy efficiency of ships. The resolution was adopted to ensure that technical assistance would be provided by the IMO to Member States and especially to developing countries to ensure that they can become involved in the transfer of energy efficiency technologies through the IMO's various programs such as: the Integrated Technical Cooperation Programme (ITCP), the Global Maritime Energy Efficiency Partnership (GloMEEP) project and the Marine Technology Cooperation Centre (MTCC) network. Even though these are all different IMO programs, they are all aimed at reducing GHG emissions from the maritime shipping sector (IMO, 2019xviii).

The ITCP focuses on providing developing countries' governments with technical assistance programs in order to aid them in implementing IMO regulations (IMO, 2019xix). The GloMEEP program focuses on 10 Lead Pilot Countries inclusive of both developed and developing countries with the goal of working to assist these countries to reduce GHG emissions from their maritime sector (IMO, 2019xiii). Finally, the Global Maritime Technology Cooperation Centre (MTCC) Network (GMN) assists the developing world and, more specifically, the Least Developed Countries (LDCs) and the Small Island Developing States (SIDS) to mitigate GHG emissions from the shipping sector. This is done through the establishment of five global MTCC networks (IMO, 2019xxiii). All of these programs are further explained below.

2.2.3 Integrated Technical Cooperation Programme (ITCP)

The IMO established the ITCP in the late 1990's (IMO, 2019xix) in order to aid governments that lacked technical knowledge and resources in implementing IMO

regulations. The ITCP aims to assist governments of developing countries with technical assistance programs focusing on: (1) human resources development which would provide training for individuals assisting them in effectively managing and developing programs related to maritime safety administration, marine environmental protection, development of maritime legislation, facilitation of maritime traffic, technical port operations and the training of seafarers and shore-based personnel; (2) institutional capacity-building which involves providing government institutions with all the necessary knowledge, technical assistance and training required to be able to comply with the IMO's regulations on maritime safety and security and the control and prevention of maritime pollution; and (3) advocacy of global maritime rules and standards – ensuring that international treaty instruments are ratified, and the national legislation is implemented (IMO, 2019xix).

According to the United Nations (2019v), the IMO's ITCP focuses on ensuring that at both the country and the IMO levels the technical assistance activities contribute to the implementation of the United Nations 2030 Agenda and its Sustainable Development Goals (SDGs). Despite the fact that there is no regular budget for technical cooperation activities, reliance is placed on extra budgetary resources to complete the technical cooperation work. Therefore, the 2018-2019 budget for the ITCP is USD \$13,000,000.00.

The IMO Secretariat organizes effective partnership arrangements to provide resources (financial and/or in-kind) to support the implementation of the ITCP. These arrangements are provided by international and regional organizations, Member States and non-governmental organizations and industry (United Nations, 2019v).

The work of the ITCP is vital in assisting developing countries with the implementation of IMO instruments to ensure safe and secure shipping and enhanced environmental protection (IMO, 2019xix). However, there is a cause for concern in the IMO's capacity in fulfilling the growing need of technical assistance for developing countries and ensuring that the ITCP remains sustainable. The challenge lies in providing continuous funding for the ITCP (IMO, 2019xxi).

2.2.4 Global Maritime Energy Efficiency Partnership (GloMEEP) project

The GloMEEP (Global Maritime Energy Efficiency Partnership) (GloMEEP, 2019; IMO 2019xiii) is a GEF-UNDP (Global Environment Facility-United Nations Development Programme) IMO global partnership project implemented by the UNDP (United Nations Development Programme) – which was established in 2015 by the IMO within its Marine Environment Division - and funded by the Global Environment Facility (GEF). GloMEEP is comprised of a dedicated Project Coordination Unit which assists 10 Lead Pilot Countries (LPCs): Argentina, China, Georgia, India, Jamaica, Malaysia, Morocco, Panama, Philippines and South Africa in developing programs and policies to significantly reduce GHG emissions from international shipping (IMO, 2019xiii). It is believed that these countries were chosen due to the rapid growth of their maritime sectors, and the necessity to reduce any negative impact their emissions will have on the environment (“How the GloMEEP project is trying to nurture efficiency in shipping”, 2016).

The GloMEEP project - formally designated as '*Transforming the Global Maritime Transport Industry towards a Low Carbon Future through Improved Energy Efficiency*' - focuses on building capacity to implement technical and operational measures in developing countries where high levels of shipping occur. The promotion of a low-carbon maritime sector is the primary goal of this project. This is achieved by enabling the 10 LPCs to be leaders in their respective regions (IMO, 2019xxii). The project provides the said countries with information regarding Legal, Policy and Institutional Reform (LPIR) in addition to enhanced private-public partnerships for innovation and technology deployment and capacity building (United Nations, 2018ii). It also focuses on encouraging national government action and industry innovation to implement maritime energy efficiency measurements (GloMEEP, 2019).

More specifically, the project's three main components are (GloMEEP 2019): -

- *Legal, Policy and Institutional Reforms (LPIR)* - this component aims to support the national activities of the LPCs by providing them with vital information regarding *LPIR* for the effective implementation of IMO's energy efficiency regulations. It is hoped that the implementation of these regulations will encourage other developing countries to ratify the IMO's regulations.
- *Maritime Sector Energy Efficiency Capacity Building, Awareness Raising, Knowledge Creation and Dissemination* - this component aims to provide greater awareness and capacity of the IMO energy efficiency regulations among the LPCs. Thus, encouraging these countries to ratify, implement

and enforce the said regulations as well as participate in the further development of ship operational and design energy efficiency measures in the LPCs.

- *Public-Private Partnerships to Catalyse Maritime Sector Energy Efficiency Innovation, R&D and Technology Deployment* - this component focuses on encouraging the involvement of the private sector - involved in energy efficiency activities related to the maritime sector - in developing countries (within the region of the 10 LPC'S). This is to be achieved through the use of international forums, knowledge sharing and collaborative pilot efforts regarding technology assessment and deployment.

To assist in achieving the above-mentioned components the following activities have been organized: (1) Global Activities - LPIR templates/guidelines, training materials, global workshops, train the trainer courses, publications and dissemination. (2) Regional Activities - Regional workshops and dissemination, regional marine centers of excellence and (3) National Activities – National baseline and needs assessment, national strategies development, energy assessments, capacity building workshops, implementation of required LPIR, technology development/deployment, dissemination (GloMEEP, 2019).

To further support low-carbon shipping, the GloMEEP project aims to produce an *'innovative public-private partnership'* within the framework of the GloMEEP project through a new Global Industry Alliance (GIA) for maritime energy efficiency (IMO, 2019xxii). In 2017, GIA was launched with a main focus of bringing maritime industry

leaders together to encourage them to support an energy efficient and low carbon maritime transport system (IMO, 2019 xxxix). Leading private sector players have joined GIA and these include: - ship owners, ship operators, engine and technology builders and suppliers, classification societies, big data providers, oil companies and ports (GloMEEP, 2019).

GIA's areas of focus include: - energy efficiency technologies and operational best practices, digitalization and alternative fuels. Maritime industry leaders are brought together through activities carried out or promoted by GIA which include: research and development, industry fora to encourage a global industry dialogue; showcasing of advances in technology development and positive initiatives by the maritime sector; and the implementation of capacity-building and information exchange activities (GloMEEP, 2019).

Andrew Hudson, head of the United Nations Development Program (UNDP) Water and Ocean Governance Programme advised that the UNDP is happy that GIA was formed and this would provide an opportunity for everyone to work together and assist in removing barriers [for example technical, informational and awareness] in order to work towards the transformation of a low carbon future for the shipping industry (United Nations Development Programme, 2017). We also found that Xiaomei Tan, senior climate change specialist, and Christian Severin, a senior environmental specialist with regards to the maritime sector, have said that "The sector has untapped potential in energy savings and emissions reduction. Energy consumption and CO₂ emissions could be reduced by up to 75% by applying operational measures and

implementing existing technologies” [“How the GloMEEP project is trying to nurture efficiency in shipping” (2016 p.1)].

These specialists further advise that although the GLOMEEP project has good intentions, its reliance on the private sector and national governments creates a situation where many people are involved in the process and difficulties can arise to keep everyone happy. In addition, Tan mentions that the aim of the project is for the shipping sector (ship owners, operators and charterers) to participate in the efforts to reduce shipping pollution. However, due to a lack of awareness regarding the current energy saving potential available to the shipping industry, this may not occur [“How the GloMEEP project is trying to nurture efficiency in shipping” (2016)].

2.2.5 Global Maritime Technology Cooperation Centre (MTCC) Network (GMN)

In 2017 (IMO, 2019xxiii), the IMO officially launched the Global Maritime Technology Cooperation Centre (MTCC) Network (GMN) which is operated by the IMO and funded by the European Union. This GMN project formally titled ‘*Capacity Building for Climate Change Mitigation in the Maritime Shipping Industry*’ was established to assist the developing world and, more specifically, the Least Developed Countries (LDCs) and the Small Island Developing States (SIDS) in order to assist them with the mitigation of GHG emissions in the shipping sector (IMO, 2019xxiii) and, as a result, the reduction of CO₂ emissions from ships (Barbir,1990). This will be done through the promotion and development of new and innovative technology with the goal to improve

energy efficiency and assist the shipping sector to move towards a low-carbon future (IMO, 2019xxiii).

To aid in this GMN project five global MTCC networks have been established. They are located in Africa - hosted by Jomo Kenyatta University of Agriculture and Technology, Mombasa, Kenya; Asia - hosted by Shanghai Maritime University, China; the Caribbean - hosted by University of Trinidad and Tobago, Trinidad and Tobago; Latin America - hosted by International Maritime University of Panama, Panama; and the Pacific - hosted by Pacific Community, Suva, Fiji (IMO, 2019xxiii).

These MTCCs are expected to provide a leadership role in their regions to reduce shipping emissions by promoting energy-efficiency technologies and operations. It is expected that through outreach and collaborative activities, the MTCCs will assist countries within their regions to develop national maritime energy-efficiency policies and measures, promote low-carbon technologies and operations related to maritime transport and establish voluntary pilot data collection and reporting systems (IMO, 2019xxiii). In the Global MTCC Network (GMN) Summary Report (2018) we see evidence of MTCC programs which occurred in 2018 such as: -

- In October 2018 there was technical training for MTCC staff. This training focused on energy efficiency in ship design and operations, adaptation to climate change and port energy management. In addition, during this session, staff were exposed to presentations on harnessing wind power, electric and digital solutions, and a vision of the look of future ports.
- In July 2018 there was a MTCC-Asia Global Forum on Green Shipping. In attendance were EU and IMO representatives, maritime institutions, maritime

authorities, and shipping industries. This forum provided information on environmental protection (both atmospheric and marine) from shipping operations.

- In October 2018 there was a MTCC-Caribbean 4th National Workshop. In attendance were ship operators, shipping agents, ships owners, regulators, maritime administrators, international organizations and academics, maritime technology providers and ministry representatives. The purpose of this workshop was to facilitate capacity building in the region through coordinated works with the port authorities, maritime administrations, relevant government departments and stakeholders in order to encourage compliance with MARPOL Annex VI.

Further, in October 2019, there was the Third Annual GMN Conference in collaboration with the World Maritime University (WMU) held in Sweden where the 5 MTCCs provided reports on their individual pilot projects which focused on various measures aimed at mitigating emissions from the maritime sector (IMO, 2019 xlii). Here the success of the MTCC projects is reported as follows (IMO, 2019 xlii): -

- The MTCC-Caribbean has raised awareness in the Caribbean on reducing shipping emissions through two of their pilot projects. The projects aim to (1) establish a maritime energy efficiency baseline and cost/benefit analysis for different energy efficiency technologies and (2) collect fuel consumption data throughout the Caribbean. According to Captain Sukhjit, Deputy Director and Technical Head of MTCC-Caribbean, as a result of the pilot projects creating

- greater awareness in the Caribbean, local stakeholders consider developing alternative fuels.
- The MTCC-Asia has been developing a software tool to help ships' crews record fuel consumption and is working on ways of optimizing the angle at which ships float in the water ("trim") in order to improve their performance. It has also been conducting ship fuel oil consumption data collecting and reporting (IMO, 2019 xlii p. 1).
 - MTCC Latin America has organized numerous workshops in the region in order to assist maritime authorities and stakeholders to comply with the IMO regulations regarding energy efficiency. In addition, their pilot project focuses on the collection of fuel consumption data and it examines barriers which may prohibit the regional ship owners and operators from implementing the IMO's regulations.
 - MTCC Africa has also been collecting fuel consumption data and has developed standardized e-forms for data collection equipment (tablets), enabling ships' crews to input key parameters, such as fuel type, fuel consumed, engine rating and so on. This data is then uploaded via satellite to a web-based platform where it can be processed and analyzed. By the end of 2018, more than 1000 data sets were collected. A demonstration pilot project on port energy audits is also being implemented (IMO, 2019 xlii p. 1).
 - MTCC Pacific has been focusing on energy efficiency technologies and operations for ships, and the collection of fuel oil consumption data. For example, in the port of Honiara, Solomon Islands there has been a

considerable reduction of emissions - the exact amount was not provided- as a result of energy efficiency measures implemented.

According to Dr. Cleopatra Doumbia-Henry, WMU President, "The MTCC Network is a project that unites maritime experts from all over the world in five MTCCs in order to provide capacity building for climate mitigation in the maritime shipping industry. Its work plays an invaluable part in promoting global awareness and in developing global solutions to mitigate GHG emissions from shipping through efficient and sustainable energy use,". Dr. Doumbia-Henry further states, "Climate change is a global challenge, and it is only if we work together and share our knowledge and technologies on energy efficiency and renewable energy production that we can be successful in mitigating climate change" (IMO, 2019 xlii p.1).

2.3 The IMO and Autonomous or Unmanned Ships

As the IMO continues to find ways to make international shipping safer, more secure and energy efficient, it is considering technological advancements to aid in this process such as the operation of Maritime Autonomous Surface Ships (MASS) which can operate partially or fully independent of human intervention (IMO, 2019xxv). There are varying degrees of autonomy in MASS which include: (1) some operations on ships which are automated with seafarers onboard to operate and control shipboard functions and systems; (2) seafarers being onboard and ships being remotely controlled and operated from another location; (3) no seafarers onboard and ships being remotely

controlled and operated from another location; and (4) a fully autonomous ship which depends upon itself to make decisions and determine actions (IMO, 2019xxv).

The development of this technology has already become reality. For example, Kongsberg a Norwegian maritime technology expert and Yara, a fertilizer producer have both embarked on a project to build this world's first autonomous and zero emission container ship name 'Yara Birkeland' due to be completed by 2020 ("Video: World's First Autonomous", 2017). In 2018 there was a successful demonstration of the world's first fully autonomous ferry in the city of Turku, Finland by Rolls-Royce and Finnish state-owned ferry operator Finferries. Also occurring in 2018 in Turku Finland, was the opening of an autonomous ship research and development center by Rolls-Royce to aid in the future development of the autonomous ship ("7 Major Developments", 2018).

According to Burmeister, Bruhn, Rødseth and Porathe (2014i) the development of an autonomous ship would provide solutions to three major challenges of the maritime sector:

- Minimize operational expenses to allow for greater efficiency in international trade
- Mitigate environmental impacts and reduce GHG emissions
- Remove minor operational tasks from crew members and create greater opportunities for them to undertake more interesting and rewarding work, making their profession more attractive

Similarly, Hogg and Ghosh (2016) advise that they are safety, economic and environmental advantages to autonomous ships such as fewer crew members onboard which will result in lower labor cost and a reduction in the risk of human error which can

potentially avoid environmental disasters. Autonomous ships will also allow for a ship design which will create more space and improve energy efficiency resulting, therefore, in the efficient use of fuel (O'Brien, 2018). According to MUNIN - Maritime Unmanned Navigation through Intelligence in Network (2016i) autonomous ships can also significantly contribute to the greening of ships through the use of alternative fuels resulting in reduced shipping emissions. Some alternative fuels used in shipping include: - liquefied petroleum gas (LPG), liquefied natural gas (LNG), ethanol, biogas, nuclear fuel and biodiesel (European Maritime Safety Agency (EMSA (2019).

MUNIN (2016i) also notes that another advantage of autonomous ships is that they can create a more efficient operation as they are equipped with advanced automatic energy management systems and improved routing and navigation which will aid in reducing shipping emissions. Further advantages include: - health management systems for all ship systems, an intelligent awareness system and autonomous navigation ("Video: World's First Autonomous", 2017).

Even though unmanned vessels may have a positive effect on shipping emissions, Hogg and Ghosh (2016) advise that there are disadvantages in putting them forward such as: the high costs to initially invest in the technology and set up on-shore communication operations to monitor the ships; the loss of jobs among seafarers due to the fact that their roles will become obsolete due to automation; the risk of a cyber-attack on the ship's operation system causing a failure in its navigational ability which could result in collisions, casualties and environmental pollution (Hogg and Ghosh, 2016). The authors further advise that there is the risk of unmanned ships not being covered by insurance companies due to high safety and security concerns which may

be greater without onboard crew members. Insurance provides peace of mind to individuals and companies, and in the event of a loss or damage it prevents financial disaster (Buckley, 1994). Therefore, it is of significant importance that the initiatives of the maritime industry are covered by insurance (liability, cargo) as this protects cargo owners and shipping companies against loss or damage to cargo or vessels and third-party injury or loss (Maritime Industry Foundation, 2019). Finally, there is currently no legal framework or international regulations or conventions in place for MASS in order to operate in international waters. This creates uncertainty as to the framework within which these vessels may operate.

To remedy this drawback, in May 2018, the IMO's Maritime Safety Committee (MSC) commenced the process of developing a regulatory framework for MASS which has been divided into two parts: Step 1 - a scoping exercise which will ascertain how autonomous ships of varying degrees can be incorporated into IMO's existing regulatory instruments and used to improve international shipping; and Step 2 - an analysis to determine the best way to address the MASS operations and how technology, operational factors and the human element can be combined to effectively achieve this (IMO, 2019xxv).

During the MSC meeting held in May 2018 (IMO, 2019xxv) a Correspondence Group on MASS was established. Its responsibility was to test the methodology and the framework of the agreed regulatory scoping exercise and to report their findings at the December 2018 MSC meeting. This information (IMO, 2019xxvi) was reviewed at the December meeting and was approved by MSC. It was further agreed that during the first half of 2019 the MSC would have an initial review of the IMO's instruments that

need to be amended to adapt to MASS and this would be conducted by many volunteering Member States and would be supported by interested international organizations (IMO, 2019xxvi). This meeting (IMO, 2019xxxiii) occurred between the 5th and the 14th of June 2019 during which the MSC approved the Interim guidelines for MASS trials. These trials must be conducted with a degree of safety, security and protection of the environment. In addition, operators of MASS must be experienced and qualified to conduct MASS trials in a safe manner. Finally, during the June meeting there was the scheduling of an intersessional MSC working group for September 2019 to continue the regulatory scoping exercise – currently under way - with the expectation to have this completed in 2020 (IMO, 2019xxxiii). The list of IMO instruments which will be covered during the scoping exercise for MASS include: Collision regulations (COLREG); Safety of Life at Sea (SOLAS) convention; Tonnage measurement (Tonnage Convention); Loading and Stability (Load Lines); Search and Rescue (SAR); Safe Containers (CSC); Training of seafarers and fishers (STCW, STCW-F); and Special trade passenger ship instruments (SPACE STP, STP) (IMO, 2019xxvi).

MSC will continue to conduct further analysis into developing a better understanding of MASS and its benefits to the shipping sector. MSC will strive to determine the best ways that the IMO's instruments can be used to incorporate MASS into their regulations considering the human element, technology and operational factors, along with identified guidelines which will ensure continued maritime safety, security and environmentally sound operations (IMO, 2019xxv, xxvi).

As we conclude this chapter, we affirm the commitment of the IMO to reduce CO₂ emissions from shipping through conventions, strategies, global partnerships and

projects (IMO 2019i-xxvi, GloMEEP (2019)). One major point which we have noted is that, in their current pursuit to reduce CO₂ emissions, the IMO has strongly focused on implementing measures to mitigate fossil fuel usage such as: the EEDI for new ships, the SEEMP for all ships (IMO, 2019xiv); the IMO's Global Networks and Partnerships programs ITCP (IMO, 2019xix); GloMEEP (GloMEEP, 2019); and the MTCC (IMO, 2019xxiii). In addition, preliminary work has been conducted by the IMO on autonomous ships which focus on improving energy efficiency in ships (IMO, 2019xxv, xxvi). Finally, the IMO's Initial Strategy includes long-term measures - to be adopted beyond 2030 – with provisions for zero-carbon or fossil-free fuels, inviting, in this way, the shipping industry to consider decarbonization (IMO, 2019x). This is the only IMO initiative inclusive of measures aimed at moving away from fossil fuel usage.

We have noted, however, that critics of the IMO's initiatives undertaken stress their inadequacy or slow development in tackling shipping emissions. As global trade increases, the shipping industry's efficient mode of transportation will be in greater demand and accompanying this will be more consumption of fuel, leading to increased shipping emissions (Cullinane and Bergqvist, 2014). As we continue our research in the following chapter, we seek to discover if the IMO's initiatives have been, overall and as critics seem to suggest, inadequate to reduce CO₂ emissions from the global shipping sector.

Chapter 3 - Results and Analysis

This chapter comments on the CO₂ emissions from shipping before and after the implementation of the IMO's regulations in order to determine the progress made in reducing such emissions. It also comments on the extent of the IMO's power to implement regulations to achieve the successful reduction of CO₂ emissions. Finally, it identifies any impediments which may delay or inhibit progress in reducing CO₂ emissions.

3.1 Introduction

In our previous chapter we focused on the regulations, strategies, global partnerships, and projects of the IMO from 1973 to 2018. In this chapter, we will comment on global CO₂ emissions from maritime shipping for the period 2007-2015. This timeframe will be broken down into two segments, the first focusing on the period 2007- 2012 - before IMO regulations specifically targeting the reduction of CO₂ emissions were implemented -; and the second targeting the period 2013-2015 - after the IMO regulations specifically targeting the reduction of CO₂ emissions were implemented -. This time frame was chosen primarily because our objective is to understand what the CO₂ emission levels were before and after the implementation of the IMO regulations. This will allow us to determine if progress was made in reducing CO₂ emissions from global shipping based on the IMO regulations. In addition, this time frame was chosen due to the availability of reliable data on global shipping emission levels as information on emissions after 2015 is not available. Also, in this chapter we will provide information on future projections for global CO₂ emissions from shipping.

Finally, there will be a focus on the IMO's power to implement regulations, and a look at any impediments which may prohibit the IMO's progress in reducing CO₂ emissions.

3.2 CO₂ Emissions from global shipping for the period 2007-2015

During the period 2007 to 2012 - before the IMO regulations specifically targeting the reduction of CO₂ emissions were implemented - global CO₂ emissions were generally on the increase from 31,409 million tonnes in 2007 to 35,640 million tonnes in 2012 as affirmed by Table 1 below. The Table is based on data from the 'Third IMO Greenhouse Gas Study 2014' prepared by Smith et. al. (2015).

To establish this estimate, Smith et. al. (2015) gathered information on the global fleet activity of ships from AIS (Automatic Identification System), IHSF (IHS Fairplay) which provided data on the technical characteristics of ships and from IEA (International Energy Agency) which provided data on marine bunker sales statistics. AIS is an automated, autonomous tracking system used in the maritime world to track the location of ships. This is achieved using transponders (which transmit and receive AIS data) (Marine Traffic, 2018). IHS Fairplay is an organization which monitors the largest global maritime database, providing information on ship ownership, movement, characteristics, ports, casualties, research and news (Alex Centre for Multimedia and Libraries n.d.). IEA is an international organization which provides data, analysis and solutions on all fuels and all technologies (International Energy Agency, 2019).

Table 1: A comparison of global CO₂ shipping emissions with total shipping and international shipping CO₂ emissions (values in millions tonnes CO₂)

| Year | Global CO ₂ | Third IMO GHG Study 2014 CO ₂ | | | |
|----------------|------------------------|--|-------------|------------------------|-------------|
| | | Total shipping | % of global | International shipping | % of global |
| 2007 | 31,409 | 1,100 | 3.5% | 885 | 2.8% |
| 2008 | 32,204 | 1,135 | 3.5% | 921 | 2.9% |
| 2009 | 32,047 | 978 | 3.1% | 855 | 2.7% |
| 2010 | 33,612 | 915 | 2.7% | 771 | 2.3% |
| 2011 | 34,723 | 1,022 | 2.9% | 850 | 2.4% |
| 2012 | 35,640 | 938 | 2.6% | 796 | 2.2% |
| Average | 33,273 | 1,015 | 3.1% | 846 | 2.6% |

Source: Smith et. al. (2015)

The data in Table 1 uses the bottom-up method to provide a comparison of global CO₂ shipping emissions with total shipping and international shipping CO₂ emissions (Smith et. al. (2015)). In a bottom-up approach, data is collected at all levels

of an organization in order to identify the existing operational risks (Elliott, 2013). The IMO uses the bottom-up method to estimate emission levels from ship activity (international, domestic and fishing vessels), with calculations being based on fuel consumption (per engine), activity and emissions (per GHG and pollutant substance). This is done for every in-service ship for every hour of the years 2007-2012. The totals are then calculated for each fleet, and then for the global shipping activity (international, domestic and fishing). Global fleet technical data from IHSF and fleet activity data from AIS are used for this method (Smith et. al. 2015).

Based on the data in Table 1, the year 2007 commenced with 3.5% of global CO₂ emissions (the highest percentage for this period), followed by the same figure for the following year. However, in 2009 we see a reduction of global CO₂ emissions to 3.1% with a further decline in 2010 to 2.7%. Then, in 2011 we see an increase of global CO₂ emissions to 2.9%, followed by a further reduction in 2012 to 2.6%. As Smith et. al. (2015) explain, between 2007- 2012 the total fuel consumption of all ships in the study were between approximately 247-325 million tonnes. This resulted in total shipping % of global CO₂ emissions fluctuating from 1100 million tonnes (3.5% of global CO₂ emissions in 2007) to 938 million tonnes (2.6% of global CO₂ emissions in 2012). International shipping (i.e. shipping between ports of different countries with the exclusion of fishing and military vessels) is the lead fuel consumer and CO₂ emitter. Also, three (3) ship types (container ships, oil tankers and bulk carriers) dominate the total fuel consumption of international shipping.

Smith et. al. (2015) further advise that during 2007-2012 the fuel type being used by the marine sector (international shipping, domestic navigation and fishing) was fossil

fuel. They note that international shipping took the lead in CO₂ emissions with the dominant fuel of choice being HFO (heavy fuel oil) followed by MDO (marine diesel oil), and LNG (liquefied natural gas) respectively. The domestic navigation sector - this refers to vessels of all flags navigating between ports of the same country, except for fishing and military vessels and those vessels involved in international navigation - comes in second place in CO₂ emissions. In this sector, more MDO than HFO is being consumed and there is no consumption of LNG. In final position is the fishing sector - this refers to inland, coastal and deep-sea fishing - whose fuel of choice is similar to that of the domestic navigation.

During this pre-IMO implementation regulation period, Smith et. al. (2015) further advise that any increase in fleet activity (resulting in increased fuel consumption and CO₂ emissions) was due to an increase in trade activity and any reduction of fuel and CO₂ emissions was a result of low trading activity - along with the introduction of slow steaming possibly to cut the ship owners operating costs.

One cannot but wonder whether the presence of the IMO regulations would have contributed to a reduction of CO₂ emissions. To answer this question, we look at Table 2 below [Olmer, Comer, Roy, Mao and Rutherford (2017i) in their report on 'Greenhouse Gas Emissions from Global Shipping 2013-2015'] on CO₂ emissions related to shipping from 2007-2015, before and after the IMO implemented regulations. [As we look at the comparative data for the period 2007-2012 we see there is somewhat of a difference in numbers between Table 1 and 2. This is due to the fact that in Table 1 the estimated global CO₂ data represents CO₂ emissions from fossil fuel consumption and cement production (Smith et. al., 2015) while in Table 2 the estimated global CO₂

data represents CO₂ emissions from fossil fuel use and industrial processes [Olmer et. al. (2017i); Emissions Database for Global Atmospheric Research (EDGAR (2017))]. Even though the figures during this period differ, a general comparison between the two Tables provides a similar trend of a reduction and increase for the same years during the period 2007-2012].

Table 2: Comparison of Global CO₂ emissions for shipping from 2007-2015

| | Third IMO GHG Study (million tonnes) | | | | | | ICCT (million tonnes) | | |
|--|--------------------------------------|---------------|---------------|---------------|---------------|---------------|-----------------------|---------------|---------------|
| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Global CO₂ Emissions | 31,959 | 32,133 | 31,822 | 33,661 | 34,726 | 34,968 | 35,672 | 36,084 | 36,062 |
| International Shipping | 881 | 916 | 858 | 773 | 853 | 805 | 801 | 813 | 812 |
| Domestic Shipping | 133 | 139 | 75 | 83 | 110 | 87 | 73 | 78 | 78 |
| Fishing | 86 | 80 | 44 | 58 | 58 | 51 | 36 | 39 | 42 |
| Total Shipping | 1,100 | 1,135 | 977 | 914 | 1,021 | 942 | 910 | 930 | 932 |
| % of global | 3.5% | 3.5% | 3.1% | 2.7% | 2.9% | 2.6% | 2.5% | 2.6% | 2.6% |

Source: Greenhouse Gas Emissions from Global Shipping 2013-2015 (Olmer et. al. (2017i))

A general glance at the comparative information for the period 2007-2015 in Table 2 would suggest to us that there has been a general CO₂ emission reduction throughout this period. For example, we see that the total shipping % of global CO₂ emissions in 2007 was 3.5%, and in 2015 it was reduced to 2.6%. There is especially a reduction during the period 2013-2015 (compared to previous years) when the IMO

regulations to reduce CO₂ emissions from shipping were implemented. This gives the impression that the IMO regulations could be responsible for this reduction of CO₂ emissions from shipping. However, on closer examination we learn that this reduction is not credited to the IMO regulations. Instead, as authors note, the reduction is due to the fact that global trade activity was reduced during that period as compared to previous years [(Olmer et. al. (2017i)].

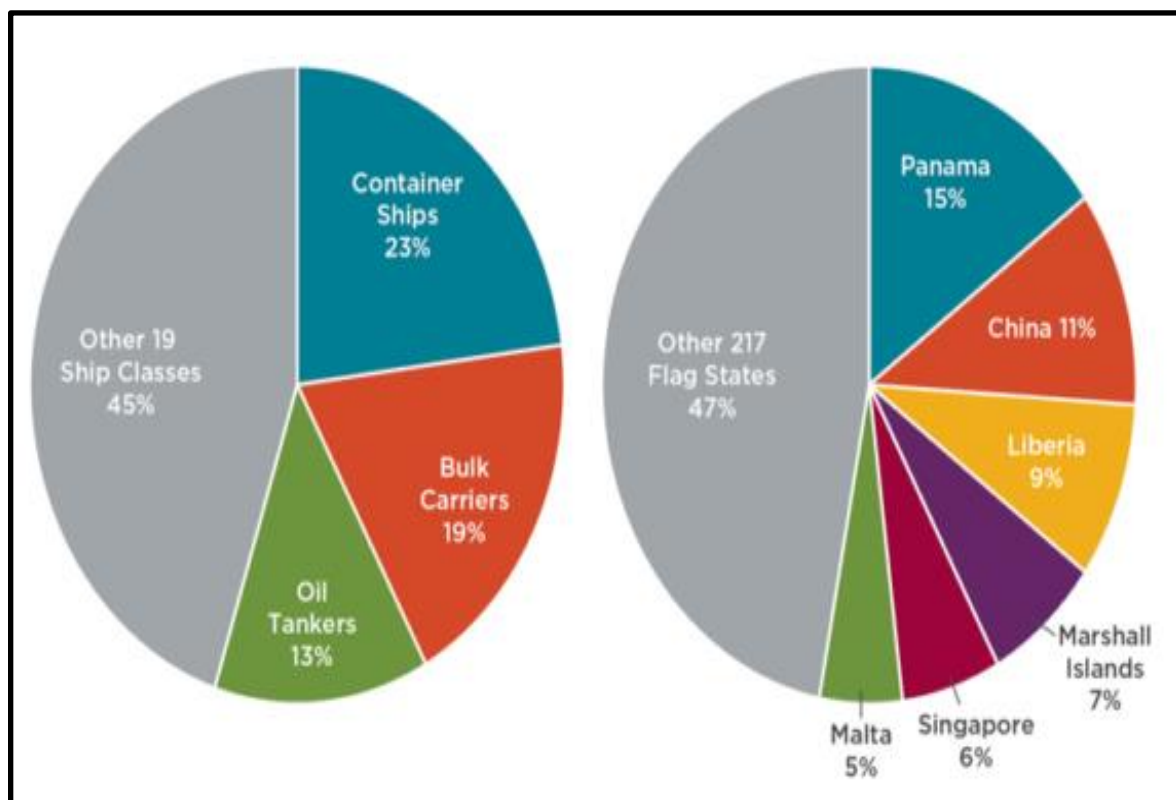
As we further examine the statistical data of CO₂ emissions from shipping for the period 2013-2015 – period post IMO shipping emissions regulations - (IMO, 2019xiv) we see that, during this period and despite the fact that IMO regulations were implemented, the total shipping % of global CO₂ emissions were on a steady increase. Olmer et. al. (2017i) advise that during the said period (2013-2015) the total shipping fuel consumption increased from 291 million tonnes to 298 million tonnes. This resulted in an increase of the total shipping CO₂ emissions from 910 million tonnes to 932 million tonnes (+2.4%). According to Olmer et. al. (2017i), during 2013-2015, there was a 1.4% increase in international shipping emissions, a 6.8% increase in domestic shipping emissions, and a 17% increase in fishing emissions; with total shipping representing on average 2.5% of the global CO₂ emissions (from fossil fuel use and industrial processes).

According to Olmer et. al (2017i), even though there have been improvements in the operational efficiency of ships during this period (2013-2015) due, for example, to IMO regulations (EEDI and SEEMP), there have also been increases in fuel consumption and GHG emissions during this period. Their study revealed that major ship classes (for example container ships, bulk carriers, oil tankers etc.) have become

more efficient and have decreased their intensity of their CO₂ emissions. However, despite that fact that there was an overall reduction in trade activity for the period 2007-2015, there was an increase in the total CO₂ emissions (during 2013-2015) believed to be due to an increase in global trade activity within that period, which resulted in an increase in travel/transport. More specifically, it was discovered that the CO₂ intensity of general cargo ships decreased by 5%, but there was an increase in CO₂ emissions by 9% in this ship class due to an increase in trade and shipping during this period.

Further, Olmer et. al. (2017ii) analyzed various classes of ships (international, domestic and fishing vessels) examining their fuel consumption, operational efficiency, CO₂ and GHGs contributions, operating hours, installed power, distance travelled, cargo carrying capacity, operating speed, energy use, and shipping routes. From the global fleet that Olmer et. al. (2017i) studied, the ship class with the largest CO₂ emissions is the container ship with 23% followed by bulk carriers (19%), and oil tankers (13%) (Figure 3 (chart on the left)). The combined total of these three classes corresponds to 55% of CO₂ emissions which is a representation of more than half of the approximately 1 billion tonnes of CO₂ emissions emitted between 2013 - 2015. The other 19 ship classes (for example cruise liners, general cargo, chemical tankers, liquefied gas tanker, refrigerated bulk carriers among others) accounted for 45% of the average percent share of CO₂ emissions by ship class. In addition, out of 223 flag states, the ships flying six flags were responsible for most of the CO₂ emissions (Figure 3 (chart on the right)) (Olmer et. Al. 2017i).

Figure 3: 2013-2015 Average percent share of CO₂ emissions by ship class (left) and flag state (right)



Source: Greenhouse Gas Emissions from Global Shipping 2013-2015 (Olmer et. al., 2017i).

Olmer et. al (2017i) also advise that during this period (2013-2015) the international shipping sector became the dominant CO₂ emissions contributor representing approximately 87% of the total CO₂ emissions from ships annually. The authors mention that the reason CO₂ emissions for international shipping were on the increase during this period (2013-2015) was due to several factors such as an increase:-

- In the international fleet - ships being used for international trade increased by 1.5%. This fleet consisted of cruise ships, fishing vessels, chemical tankers, general cargo ships and liquefied gas tankers.

- In activity from the largest ships - there was an increase in transportation of the international fleet by 7%, with general cargo ships and chemical tankers activity increasing by 15% followed by an 11% increase in cruise ships and a 9% increase for container ships. In addition, there was also an increase in operating hours for general cargo ships (+12%), cruise ships (+8%), chemical tankers (+7%), but no increase for container ships or bulk carriers.
- In the main engine power of many classes of ships - chemical tankers (+10%), followed by cruise ships (+7%), general cargo ships (+6%) and container ships (+6%). There was no change in the main engine power in oil tankers and bulk carriers.
- In the speed of the largest container ships and the largest oil tankers. The largest oil tankers sped up by almost 4%, along with the container ships which sped up in excess of 11%. Increased speeds allow these ships to reach many destinations in a shorter time frame, while consuming more fuel and emitting more CO₂.

A point of grave concern to us lies in the fact that Smith et. al. (2015) have forecasted that maritime CO₂ emissions are to significantly increase in the coming decades. The authors advise that the main drivers predicted to be responsible for this would be the increased consumption of fossil fuel usage by the maritime sector and the increase in the demand for maritime transport. This could become a reality, as cargo ships are significant users of HFO or bunker fuel (Gallucci, 2018). Thus, as global trade

increases the shipping industry will be in greater demand and accompanying this will be more consumption of fuel, leading to increased shipping emissions (Cullinane and Bergqvist, 2014).

In their study, Smith et. al. (2015) used 16 emission scenarios to determine the future projection of CO₂ emissions from international shipping. These emission scenarios are used to depict various ways in which emissions could develop, taking into consideration energy, policy and socioeconomic factors. In all the scenarios, combinations of ship efficiency, trade and emissions can be found. The general conclusion of this study projected a future increase in CO₂ emissions. It forecasted an average increase of 29% of CO₂ emissions by 2030, and an average increase of 95% of CO₂ emissions by 2050 (Smith et. al. 2015).

The future projection of increased CO₂ emissions along with the increase of CO₂ emissions from shipping during the period 2013-2015 (post IMO regulations to reduce CO₂ emissions), suggest to us that the IMO's current regulations and future strategies and projects focusing on fossil fuel mitigation [EEDI and SEEMP (IMO, 2019xiv); ITCP (IMO, 2019xix); GloMEEP (GloMEEP, 2019); MTCC (IMO, 2019xxiii); and autonomous ships (IMO, 2019xxv, xxvi)] are counterproductive. This conclusion aligns with the criticisms of the IMO measures analyzed in Chapter 2 stating that IMO actions regarding CO₂ shipping emissions are on a slow trajectory.

3.3 The players involved in the IMO's law-making process

As we attempt to comprehend the reason why the IMO measures are not achieving a reduction of CO₂ emissions from global shipping, we look at the IMO law-making process. According to Karim (2015), a point of concern lies in the fact that international non-governmental organizations (INGOs) are involved in the IMO's law-making process, even though they have no voting rights in the IMO. In fact, the 1948 IMO Convention gives the IMO the power to consult and cooperate with non-governmental international organizations on matters within the scope of the IMO (IMO, 2019viii). In 1961, the IMO Assembly adopted the *Rules for Consultative Status of Non-Governmental International Organizations with the International Maritime Organization*, with Guidelines being developed in 1978. Throughout the years several amendments have been made to these Rules and Guidelines (IMO, 2013). These rules allow consultative status to be granted by the IMO's Council - with the Assembly's approval - to INGOs who can make a substantial contribution to the work of the IMO (IMO, 2019iii).

The representation of INGOs include: - cargo owners and charters, ship-owners and operators, environmental organizations, seafarers and other labor organizations, large oil companies, research organizations, classification societies, training organizations, organizations representing marine-related industries, protection and indemnity insurance clubs, other marine insurers and environmental NGOs. From this list the most powerful group appears to be the ship owners and operators as they have the power to influence the Member States who have vested shipping interests (Karim, 2015).

By awarding this power to INGOs, the following concern is raised: it is possible that INGOs, especially the ones with vested shipping interests, could be there to be lobbyists for shipowners, oil companies and other parties with shipping interests. According to Karim (2015, p. 20 -21) “*Non-governmental organizations do not just influence the law-making process merely by their submissions and participation in the meetings of MEPC and other IMO organs. Their main influence comes via IMO Member States who also share similar interests.*”. Although Karim’s (2015) concern of the INGO’s involvement in the IMO’s law making process cannot be substantiated, we can only wonder if a contributing factor to the present IMO regulatory reality regarding the reduction of CO₂ emissions from shipping constitutes the INGO’s power in the IMO rule-making process.

In addition, when we look at the IMO as an international organization, we see that the leaders (the IMO Members States) through their voting rights (IMO 2019v) determine which regulations will be adopted and implemented; thus setting the tone for the future in the maritime sector. On closer inspection with regards to the composition of the IMO Member States, data from 1965 - 2019 shows the world’s largest oil producers consist of the IMO Member States (BP p.l.c., 2019; Perry, 2019; United States Energy Information Administration (2019iii)). Making us wonder if the slow speed towards the adoption and implementation of GHG (CO₂) regulations, in addition to the delay pertaining to decarbonization, could be attributed to the fact that the Member States have a vested interest in oil, which could influence their voting decisions.

3.4 The IMO's authority to enforce their regulations

According to Karim (2015) the IMO is a significant and successful organization which develops international law to protect and preserve the marine environment from pollution. However, one of the major challenges for the IMO is its lack of authority to enforce its marine environmental regulations on shipping vessels. In effect, the authority to enforce such regulations lies with the Flag States. In this section, we seek to establish if a contributing factor to increased CO₂ emissions from shipping constitutes the lack of the IMO's authority to enforce its own regulations.

The term Flag state refers to a country where the vessel is registered (USLegal.com, 2019). There is a distinction to be made between Flag states, port states and coastal states. As Molenaar (2016) advises port states are ports which are responsible for granting persons or goods access to their states through the control processes of immigration, customs, sanitation, and matters of national security. In addition, port states ensure that foreign ships visiting their ports comply with national or international standards. Coastal States are States with a sea-coastline who have jurisdiction over their own maritime zones. This area can include fresh-water lakes and salt-water lakes or seas which are disconnected from another sea or ocean.

Under MARPOL, the definition of "Administration", the role and responsibilities of the Flag state appear as follows (Lloyd's Register (2005): -

- Article 2 - Definitions (p. 5) – (5). "Administration" means the Government of the State under whose authority the ship is operating. With respect to a ship entitled to fly a flag of any State, the Administration is the Government of that State."

- Article 4 - Violation (p.7) - (1). “Any violation of the requirements of the present Convention shall be prohibited and sanctions shall be established therefor under the law of the Administration of the ship concerned wherever the violation occurs. If the Administration is informed of such a violation and is satisfied that sufficient evidence is available to enable proceedings to be brought in respect of the alleged violation, it shall cause such proceedings to be taken as soon as possible, in accordance with its law”.

Further clarification of the role of the Flag State can be found in the United Nations Convention on the Law of the Sea (UNCLOS) (United Nations, 2018i). In 1982, UNCLOS was adopted, signed, and entered into force later, in 1994. This international treaty is responsible for establishing law and order in the world’s seas and oceans by implementing rules which govern all the uses of the oceans and their resources. The ocean is viewed as an interconnected body of water and any problem encountered could eventually affect the entire ocean. UNCLOS comprises 320 articles and 9 annexes which govern all aspects of the ocean space including: marine scientific research, environmental control, economic and commercial activities, delimitation, the transfer of knowledge and settlement disputes pertaining to ocean matters (United Nations, 2018i).

Under UNCLOS, the IMO is recognized as the global legislative entity on maritime issues and is mandated to continue its regulatory responsibilities under its provisions. The IMO is mentioned by UNCLOS in many provisions as a ‘competent international organization’ with reference to international shipping rules and standards

on maritime safety, efficiency of navigation and prevention and control of marine pollution from vessels and by dumping (IMO, 2019xxviii).

The IMO is specifically mentioned by UNCLOS, in Annex VIII - *Special Arbitration* - Article 2 - *'List of experts'* as follows: "The lists of experts shall be drawn up and maintained, in the field of fisheries by the Food and Agriculture Organization of the United Nations, in the field of protection and preservation of the marine environment by the United Nations Environment Programme, in the field of marine scientific research by the Intergovernmental Oceanographic Commission, in the field of navigation, including pollution from vessels and by dumping, by the International Maritime Organization, or in each case by the appropriate subsidiary body concerned to which such organization, programme or commission has delegated this function" (UNCLOS n.d. p.190).

Under UNCLOS (n.d): -

- Flag States are responsible for managing all ships flying their flag *Part VII - High Seas - Section 1 General Provisions - Article 94 - Duties of the Flag States.*
- Flag States are responsible for the enforcement of shipping standards - *Section 6 - Enforcement - Article 217 - Enforcement by Flag States.*
- Flag States are responsible for enforcing measures with respect to pollution from or through the atmosphere - *Section 6 - Enforcement - Article 222 - States shall ensure that within their air space or the vessels flying their flag that pollution is prevented, reduced or controlled.*

All Flag States must comply with UNCLOS and ensure that the applicable international rules and standards of the IMO are followed (United Nations, 2018i & IMO, 2019xxviii). Therefore, the enforcement of IMO's marine environmental protection falls under the applicable provisions of UNCLOS (Karim, 2015) resulting in both IMO and UNCLOS being dependent on Flag states to fulfill their jurisdictional and enforcement power (United Nations, 2018i & IMO, 2019xxviii).

In our view, the enforcement of IMO regulations can only be successful if the Flag States are serious about reducing air pollution, or specifically CO₂ emission levels from shipping. It is true that Flag States have the power to fine vessels for MARPOL violations (Lloyds Register, 2005). However, one issue which we have found not to be addressed by UNCLOS (n.d.), IMO (2019xxviii) and MARPOL Conventions (Lloyd's Register, 2005) is that there does not appear to be evidence of any operational procedures in place to impose fines or penalties on Flag States themselves if they fail to fulfill their jurisdictional and environmental responsibility regarding the IMO's regulations. This lack of accountability and fines or penalties imposed could result in Flag States not performing at their optimum level and achieving the desired results of reducing air pollution or specifically CO₂ emissions from ships.

According to Karim (2015), the sole reliance on the Flag States to use their jurisdictional powers regarding international marine environmental conventions has proven in many cases to be unsatisfactory. Karim (2015) notes, for instance, that Flag of convenience countries (FOC) "find no incentive to prescribe stringent national regulation or proper implementation of international instruments" (Karim, 2015 p. 33) including, therefore, environmental conventions. Flag of Convenience refers to ships

which are registered under a foreign flag, instead of being registered under the country of the ship's owners. This is done in order to, among other things, avoid paying high taxes (Cambridge Dictionary Online, 2019). According to Boczek (1962 p.2) the term FOC refers to the "flag of any country allowing the registration of foreign-owned and foreign-controlled vessels under conditions which, for whatever the reasons, are convenient and opportune for the persons who are registering the vessels".

Under international law all ships are required to sail under the flag of a sovereign state in order to gain government protection while they are at sea. This law also pertains to governments ensuring that the vessels registered under their flags are safe and follow all applicable regulations (Richardson, 2002). According to Toh and Phang (1993) FOC's have been in existence since the 1950's and have been a source of convenience for many ship owners. The authors note that under this arrangement: (1) fewer regulatory restrictions are placed on flag states (for example issues pertaining to the vessel's age, safety, construction, manning repairs and scheduling). (2) FOC countries charge a nominal initial registration and annual tonnage fees to vessels flying their flag; and they do not impose taxes on corporate profits, or crew income derived from the flag ship's operation. (3) Ships registered in FOC countries allow ship owners to employ cheap labor of any nationality which is often accompanied with low benefits (Thuong, 1987). In addition, according to Thuong (1987) FOC's provide political advantages for ship owners, especially where situations of political conflict arise at sea. For example, flying the FOC allows them to go undetected and not be associated with their original country's flag which may be involved in political conflict.

In the 2018 United Nations Conference on Trade and Development Review of Maritime Transport Report (UNCTAD, 2018i) it is noted that, in that year, Panama, the Marshall Islands and Liberia were, respectively, the top three leading flags of registration despite the fact that they were not major shipowners. In fourth place was Hong Kong SAR, followed by Singapore. In fact, 76% of the global registrations in terms of tonnage for commercial ships were being registered under a foreign flag for that same year, as opposed to the flag related to the country of the ship owner. There are many instances where ships from Flag of Convenience (FOC) countries never visit the country of the shipowner.

Toh and Phang (1993) mention that despite the advantages pertaining to FOC's, they are also many disadvantages which are related to: pollution, safety concerns and the exploitation of cheap non-unionized labor. "Flags of convenience countries are notorious for not having or not strictly enforcing manning, maintenance, and safety standards. Even if they made an honest attempt to enforce these regulations, many of these so-called pirate ships never or seldom call upon the port of registry, a problem compounded by the fact that many ships are registered using bearer shares where ownership cannot be traced" (Toh and Phang, 1993, p.3).

According to a 2015 study on CO₂ emissions by flag state conducted by Johansson, Jalkanen, and Kukkonen (2017), the global shipping contribution to CO₂ emissions by flag state vessel is too high. Panama, China, Liberia and the Marshall Islands have four of the largest fleets, carrying in total 57% of the global seaborne cargo, and are responsible for 48.4% of the total CO₂ emissions in 2015 (832 million tons). The fifth to eighth largest fleets are Singapore, the United Kingdom, Malta and

The Bahamas, and they are responsible for 20% of the CO₂ emissions (Johansson et. al. (2017). It must be noted that these flag states are Member States of the IMO (2019ii). As Johansson et. al. (2017, p. 407) state: “The IMO-registered marine traffic is responsible for most of the emissions for all the considered pollutants, e.g., for approximately 91% and 93% of the CO₂ and PM2.5 emissions, respectively.”

The focus of FOCS appears to be on financial gains with less emphasis being put on enforcing MARPOL regulations [Hamad (2016)]. In addition, Hamad adds that FOCS are not penalized for not enforcing these regulations. This situation can, thus, result in delinquent attitudes among the ship owners and operators compromising environmental protection. We can, therefore, conclude that a contributing factor to the increase CO₂ emissions from ships is not only the increase in trade activity for ships using fossil fuel, but also that the IMO does not have the authority to enforce its regulations. Rather, flag states do.

It is indeed disheartening to be faced with information not only on high CO₂ emissions resulting from shipping for 2013-2015 (Olmer et. al., 2017i) but also on a high contribution rate of CO₂ emissions from ships of Member States of the IMO (Johansson et. al., 2017; Olmer et. al., 2017i) for the same period. It is even worse to think that CO₂ emissions from shipping are projected to increase in the future (Smith et. al. 2015). As previously stated, one issue which we have found not to be addressed by UNCLOS (n.d.), the IMO (2019xxviii) and MARPOL (Lloyd’s Register, 2005) is that there does not appear to be evidence of any operational procedures in place to impose fines or penalties on Flag States themselves if they fail to fulfil their jurisdictional and

environmental responsibility regarding the IMO's regulations. These factors lead us to conclude that an increase of CO₂ emissions from ships in the future will naturally ensue.

Recognizing that its regulations were not being effectively implemented and complied with by the Flag States (Basaran, 2016), in 1992, the IMO established a special Sub-Committee on Flag State Implementation (FSI) in order to improve the performance of governments (IMO, 2019xxx). In 2013, the FSI Sub-Committee was renamed the Sub-Committee on Implementation of IMO Instruments (III). This Sub-Committee receives instructions from the Maritime Safety Committee and the Marine Environmental Protection Committee. It focuses on ensuring that the IMO instruments pertaining to maritime security, safety and marine environment protection are implemented and enforced (IMO, 2019xxx). This is done by analyzing data on port, flag and coastal states pertaining to their implementation practices of IMO instruments, as well as by identifying any challenges they face in implementing these instruments and provide them with solutions (IMO) (2019xxx, xxxii). The Sub-Committee is also involved in analyzing audit reports from the mandatory IMO Member State Audit Scheme (which is mentioned below); conducting casualty analysis on marine incidents and providing recommendations to prevent marine incidents; analyzing port State control data; and providing guidelines for surveys and certification (IMO) (2019xxx, xxxii).

In addition, the IMO adopted a Voluntary Member State Audit Scheme (IMO, 2019xxix, xxxi) which is an audit to promote maritime safety and environmental protection. It consists of a comprehensive and objective assessment of a Member State, in order to determine how effective, it is at implementing the IMO regulations covered by the Scheme. In April 2014, the MEPC adopted amendments to MARPOL Annex I to VI

to include the IMO Audit Scheme. Due to these amendments from 2016 onwards the auditing of Member States became mandatory (IMO, 2019xxix, xxxi).

Even though both regulations (The Sub-Committee on Implementation of IMO Instruments (III) and the Voluntary Member State Audit Scheme) provide a measure of accountability for port, flag, coastal states, and Member States (IMO, 2019xxix, xxx, xxxi), we have found no evidence to indicate that the IMO imposed any fines or penalties for non-compliance with environmental standards. This, in turn, places the power of any decision to implement penalties for non-compliance in the hands of the Flag States, as they fulfill their jurisdictional and enforcement power of IMO instruments under UNCLOS (United Nations, 2018i; IMO, 2019xxviii).

As we conclude this chapter, we believe that our strategic plan of examining data of: CO₂ emissions from global shipping from 2007-2012 (before IMO regulations to reduce CO₂ emissions were implemented), 2013-2015 (after IMO regulations to reduce CO₂ emissions were implemented), future projections for global CO₂ emissions; the authority IMO has to implement their regulations, as well as the players involved in the IMO's law-making process and the impediments which may prohibit the IMO's progress in reducing CO₂ emissions, have all placed us in a position to effectively reach a decision on the IMO's progress in reducing CO₂ emissions from shipping. The IMO's actions in this area are on a slow trajectory. More must be done by the IMO to reverse the trend of environmental degradation due to CO₂ emissions from shipping. As we enter our concluding chapter, we aim to provide information which may be warranted for the IMO to follow based on the findings of our research.

Chapter 4 – The Way Forward

The present chapter provides the conclusions of the research analysis regarding the effectiveness of the IMO's role in guiding the sector to successfully reduce CO₂ shipping emissions. It also provides recommendations regarding future IMO action in this area.

On the basis of our detailed analysis of the IMO's regulations and data regarding CO₂ shipping emissions, it is obvious that the progress - a term defined as "the process of gradually improving or getting nearer to achieving or completing something", (Collins Dictionary Online, 2019 p.1) - made by the IMO regarding the regulation of shipping emissions is on a slow trajectory. The IMO is not getting closer to reducing CO₂ emissions from global shipping. On the contrary, shipping emissions are increasing with time and future projections in this regard are not encouraging. Indeed, as global trade increases the shipping industry's efficient mode of transportation will be in greater demand and accompanying this will be more consumption of fuel, leading to increased shipping emissions (Cullinane and Bergqvist, 2014). The mentioned alarming projected increase in CO₂ emissions from 50% to 250% by 2050 (Smith et. al. (2015), fueled by an increase in global trade, cannot be overlooked.

This slow trajectory is affirmed by the fact that it wasn't until 2011, 14 years after the adoption of the 1997 Kyoto Protocol [which gave the mandate to the IMO to reduce GHG emissions from the shipping industry (UNFCCC, 2019ii; UNFCCC, n.d.; IMO 2019 xxiv)], that measures of the MEPC resulted in the adoption of the first mandatory global GHG reduction instrument for the international shipping sector (Karim, 2015) - the EEDI and SEEMP (IMO,2019xiv) –.

Further, as already mentioned in the previous chapter, the IMO has no authority to enforce its marine environmental regulations. It is the Flag States (Karim, 2015) that have the power to fine vessels for MARPOL violations (Lloyds Register, 2005). If the Flag States fail to do so, they are not accountable for failing to fulfil their jurisdictional and environmental responsibility regarding enforcement of the IMO's regulations. This lack of accountability may result in the poor implementation of international conventions by Flag States leading to increased CO₂ emissions from ships. Finally, the presence of FOCs - in 2018, 76% of the global registration of commercial ships is under FOCs (UNCTAD, 2018i) - whose main focus appears to be on financial gains rather than on environmental protection, further distances the shipping sector from achieving the reduction of CO₂ emissions from ships.

By noting this slow progress, it is not our intention to discredit the important work done by the IMO, the main organization worldwide that regulates the shipping industry (IMO, 2019i). Indeed, there is no disputing that the IMO plays a significant role in protecting and preserving the marine environment with its many international regulations (Basaran, 2016) and initiatives. The IMO has achieved and implemented energy efficiency measures (the EEDI and SEEMP (IMO, 2019xiv) which aid in counteracting the CO₂ emissions problem. Further, the IMO's Global Networks and Partnerships programs ITCP (IMO, 2019xix), GloMEEP (GloMEEP, 2019) and MTCC (IMO, 2019xxiii) were established to ensure that any challenges faced by developing countries do not prohibit them from implementing the IMO energy efficiency technologies (IMO, 2019xviii). There is also preliminary work being conducted by the IMO into autonomous ships which will focus on improving the energy efficiency of ships

(IMO, 2019xxv, xxvi). These are important measures aimed at counteracting shipping emissions. Finally, any future action on the reduction of CO₂ shipping emissions will probably be approved and implemented by the IMO. In this way, this international organization is the key to present and future action in this field.

However, given the increase in CO₂ emissions despite the adoption of IMO measures, we suggest that the IMO's approach be amended in order to achieve significant progress towards reducing CO₂ emissions from global shipping. In our opinion, there is no one solution to reducing CO₂ emissions from global shipping. As demonstrated in the previous chapter, the energy efficiency concept alone is not enough to achieve this goal. Indeed, as we have affirmed, between 2013-2015 [the period IMO's energy efficiency measures (EEDI and SEEMP) were implemented] there was an increase in CO₂ emissions. This was believed to be attributed to an increase in fuel consumption and an increase in trade activity in shipping despite the presence of the IMO's energy efficiency measures. Hence, energy efficiency measures alone are not adequate to tackle CO₂ emissions from shipping.

We, therefore, suggest that the IMO should not just adopt and implement energy efficiency measures. It should take urgent action now, not in later years, [not in 2030 as is suggested by the IMO Initial Strategy – long term measures which will focus on the development of zero-carbon fuels to decarbonize the sector (IMO, 2019x)]. But more emphasis should be placed now on incorporating regulations on the use of energy sources (such as renewable energy sources for example, wind, solar, biomass, hydropower) in order to produce zero emissions. Even though the IMO's Initial Strategy does not make a specific mention of the term renewable energy sources, we hope this

energy source is on their agenda regarding the long-term measures to be adopted beyond 2030 (decarbonization). We say this because the concept of zero carbon fuels includes both the use of renewable energy sources which emit zero emissions (U.S. Energy Information Administration, 2019) and the use of, for example, hydrogen which, according to Psaraftis (2019), is an energy source currently used in shipping, which when burnt doesn't emit CO₂ or SO_x, but it emits small amounts of NO_x. However, as the author notes, the problem with hydrogen arises during its production, which comprises the use of fossil fuel in the form of natural gas and which leads to the release of CO₂ along with other gases emitted. Therefore, the use of hydrogen defeats the purpose of a zero-carbon fuel environment. Only if renewable energy sources (for example wind, solar, biomass, hydropower) are used to generate electricity for hydrogen, can the latter be considered carbon-free (Psaraftis, 2019). Thus, the use of renewable energy sources by the IMO's Initial Strategy would allow the shipping industry to consider decarbonization. Fortunately, these measures are all aimed at moving away from fossil fuel usage, but regrettably are staged to occur in later years, rather than right now.

According to Boyd (2003) in order to see an improvement in the environment, environmental laws must shift their focus from treating the symptoms of a problem and address the root cause of environmental degradation. For instance, he states that "Laws intended to limit air pollution rely on expensive technological solutions but ignore the unsustainable rate of fossil fuel use that causes air pollution" (Boyd, 2003 p. 277). When we look at the IMO with regards to the 'root causes of environmental degradation' (Boyd, 2003) more specifically related to CO₂ emissions from shipping, we are of the

view that the 'root causes' (Boyd, 2003) of the problem of increased CO₂ emissions stem from: (1) the increased fossil fuel usage – from an increase in global trade resulting in shipping being in greater demand, therefore producing increased CO₂ emissions (Eide et. al., 2013) and (2) the absence of the adoption and implementation of regulations by the IMO pertaining to the decarbonization of the maritime sector, which would focus on tackling the cause of the problem, the 'root cause' (fossil fuel). This can only materialise by the IMO Members States through their voting rights (IMO 2019v). As previously mentioned, we wonder if this delay could be attributed to the fact that the Member States have a vested interest in oil, which could influence their voting decisions.

The current IMO regulations, strategies, global partnerships and projects we have examined throughout this paper [with the exception of the IMO Initial Strategy – long term measures on the development of zero-carbon fuels to decarbonize the sector (IMO, 2019x)] all focus on treating the symptoms (the CO₂ emissions problem) with energy efficiency measures only. How about dealing with the total eradication of the problem of fossil fuel instead of treating the symptoms? Now, rather than later, waiting for the IMO Initial Strategy to be implemented.

It is understandable that the shipping industry would significantly focus on current measures to mitigate their industry's fuel of choice, instead of total eradication. However, on the basis of the foregoing analysis, we believe that more emphasis should be placed on providing immediate regulations that would encourage or guide the shipping sector to move towards achieving zero emissions from ships through the use of renewable sources of energy. Indeed, we find it surprising that there is a delay in the

IMO Initial Strategy as we must wait until 2030 to create an environment which would allow the shipping industry to consider decarbonization (IMO, 2019x). Further, it is also striking that the IMO hasn't implemented a regulatory framework for renewable energy sources, like it has for MASS (IMO, 2019 xxv) - conducting MASS trials (IMO, 2019xxxiii), testing methodology (for example using theoretical analysis to investigate the possibility of how this renewable energy source could work) and reporting findings (IMO, 2019 xxv).

As we look at renewable energy as an energy source for shipping, we see that it refers to energy from natural sources, for example wind, solar, biomass, hydropower (U.S. Energy Information Administration, 2019). There are many benefits to renewable energy sources according to the United States Environmental Protection Agency (2017) such as: - (1) producing zero emissions and assisting in reducing air pollution; (2) creating more options for energy usage and reducing the dependence on imported fuels; and (3) creating economic development and employment in manufacturing and installation -among other jobs present in the renewable energy sector.

Some of the disadvantages as mentioned by Capareda (2019) are: (1) there is sometimes a lack of consistent availability for most renewable energy sources and this may pose a problem for production and usage and; (2) the equipment/materials required for some renewables is expensive (for example solar photovoltaic (PV cells). As Pérez-Navarro et. al. (2016) notes, the general problem with renewable energy is its feasibility, particularly when one renewable energy source is solely used. Capareda (2019) adds that a problem with renewable energy is that it may not be readily available in the quantities desired. This may lead to situations where the total energy capacity

required for ships to sail around the globe is not achieved. According to Sailors for the Sea (2019), before ship owners decide what renewable energy their ships will need, they must first establish whether the renewable energy resources are enough to power the vessel.

Despite the disadvantages, there are companies that are not waiting on the IMO to implement regulations pertaining to renewable energy. Rather, they have chosen to pay closer attention to their own environmental responsibility and have decided to act on it. Some, we believe, may have chosen to commit to decarbonization based on the 2018 IMO's Initial Strategy which aims to reduce total annual GHG emissions by 50% by 2050 compared to 2008 levels (IMO, 2019x). For example, in May 2019, the Eco Marine Power (EMP) announced that its renewable energy technology Aquarius Management and Automation System (MAS) +Solar Solution, had been installed on the MV Panamana (a large general cargo ship owned by Masterbulk Pte. Ltd in Singapore). This installation has been a major milestone for EMP as MV Panamana was the focus of a ship renewable energy study for the past few years. The equipment installed (which aims to promote solar power, save fuel and reduce emissions) includes a class-approved hybrid battery pack, battery charging equipment, flexible marine-grade photovoltaic (PV) panels with special mounting frames and a computer automation and management system. It was also recently announced that this solar power equipment will be integrated with EMP's Aquarius (MAS) and put into service in the future ("Ship Solar Power System Installed on Large General Cargo Ship MV Panamana", 2019).

Pérez-Navarro et. al. (2016) further suggest that the solution to the availability of the renewable energy sources is the use of a hybrid system where a combination of

several renewable energy sources are used to generate the necessary power for ships sailing the seas. Although this is the ideal solution to achieve zero emissions, our research has revealed that there is no general consensus on its implementation by the shipping sector. Instead, the hybrid system being used by the shipping sector constitutes the combination of renewable energy and fossil fuel to power vessels. Some examples constitute the following:

- The Maersk Pelican, an oil tanker, is one of the world's largest cargo ships, [owned by A.P Moller and flies the flag of Singapore (Vesselfinder.com (2019)]. The vessel is powered not only by fossil fuel, but also using wind propulsion. Two 30-meter rotor sails were installed on this ship and it sailed on its first voyage with its new sails to Saudi Arabia on the 29th September 2018 ("Wind-powered ships are making a comeback", 2018). Future testing of this vessel is still required to test its viability ("Rotor Sails Fitted on board Maersk's Tanker in a World's 1st ",2018).
- The Vindskip designed by Lade AS from Norway, will use its tall and thin structure to be its sail using wind power to generate a forward motion, in addition to using natural gas. It is hoped that when the vessel sets sail in the future it will reduce its fuel usage by 60% (Spross, 2019).
- Since 2012, Nissan's *Nichioh Maru* ship, which has a solar energy power generated system, has been transporting automobiles. This vessel is operated by the Nito Kaiun company, a Japanese company, and operates internally in Japan. The ship's engineering system allows for a reduction of almost 1,400 tonnes of exhaust discharges, resulting in an overall annual reduction of 4000 tonnes of

carbon dioxide discharges. The ship has over 28 solar panels and is outfitted with LED-based lighting systems, and an electronically controlled diesel engine (“Nichioh Maru – The First Car Carrier with Solar Power System”, 2016).

Even though a hybrid system as in the above-mentioned examples is not our desired solution in order to decarbonize the shipping sector, it is an encouraging step in reducing emissions from shipping.

As we search to find data on the current percentage of renewable energy being used by the shipping sector, we are not finding a concrete figure being given. We are aware that the sector is dominated by fossil fuel and renewable energy is slowly growing (IRENA, 2015). According to data from Olmer et. al. (2017i), in 2015 the total fuel consumption for the shipping sector (international, domestic and fishing vessels) was 72% for residual, 26% distillate and 2% LNG (the cleanest burning fossil fuel). Thus, we envision the percentage for the use of renewables by the shipping industry to be extremely low considering these percentages.

Considering the above, how feasible is using renewable energy sources more extensively in shipping? Psaraftis (2019) advises that there is a growing interest for the use of this energy source in the shipping sector, especially regarding wind and solar power. Pérez-Navarro et. al. (2016) further notes that renewable energy sources have now reached a mature level of technical development, making it possible to be used as a future substitute to fossil fuels. According to the International Renewable Energy Agency (IRENA, 2015) the global shipping fleet can be transformed at all levels (international and domestic) by renewable energy. IRENA (2015) further notes that even

though fossil fuel remains the dominant energy source of the shipping sector, the concept of renewable energy is slowly being embraced by the shipping sector and will not only reduce their fuel bill but will also reduce their emissions. It is possible for renewable energy sources to be used on ships, either by providing retrofits to existing fleet or by incorporating the clean technology into new shipbuilding and design (IRENA, 2015). According to IRENA's Director-General Francesco La Camera who spoke in October 2019 in Singapore at the launch of the Global Maritime Forum's Annual Summit, (IRENA, 2019): "decarbonising transport is critical to a sustainable future. Shipping is a major contributor to transport emissions and it is encouraging that the industry has shown a clear willingness to engage the energy sector to exchange ideas on low-carbon pathways. As the cost of renewables falls, the decarbonisation options available become increasingly competitive". He continues to state: "by 2030 alternative low-carbon fuels could reach parity with heavy fuel oil, so it is vitally important that the ship industry prepares itself for a low-carbon future" (IRENA, 2019 p.1).

The extended use of renewable energy sources in shipping seems, therefore, promising. In our view, if Maersk, the world's largest shipping company undertakes initiatives on the use of renewable energy sources to fuel its vessels to reduce emissions and decarbonize its fleet (Wilcox, 2019). The possibility of the use of renewable energy in shipping is a very real one. One cannot but remain very hopeful regarding its use by this sector.

Could more attention be paid to research and development and finding ways to make renewable energy sources more used by the shipping sector? We see evidence

of research and development focusing on the future decarbonization for ships in the following cases: -

- Maersk, the world's largest shipping company is aiming to be carbon neutral by 2050 [This is the same date set under the Initial IMO's Strategy, which has forecasted that 50% of total annual GHG emissions should be achieved by that date (IMO, 2019x)]. In demonstrating its commitment towards this end, in March 2019, the company collaborated with Shell and other members of the Dutch Sustainable Growth Coalition and tested a biofuel-powered vessel. This vessel used 20 percent biofuels which were produced from waste cooking oil on one of their largest vessels. The 25,000 nautical-mile journey from Rotterdam to Shanghai is reported to save 1500 metric tonnes of CO₂ emissions (Wilcox, 2019).
- Neoline, - a European French start-up shipping line (Wolfrom, 2019 -] has chosen Neopolia, a French shipbuilder, to build its first two sail-powered roll-on-roll-off (ro-ro) cargo vessels. They will both be equipped with a 4000-kW diesel-electric propulsion system and batteries along with four foldable sails based on yacht technology. These vessels should save 80% to 90% in fuel consumption and reduce emissions. Both vessels will be 136m-long with the first ship to be completed by the end of 2019 and delivered by the end of 2021 ("Neopolia to build two sail-powered ro-ro cargo ships for Neoline", 2019).
- In September 2019, we see another commitment to decarbonize the maritime sector, called: 'Getting to Zero Coalition' (a partnership between

the Global Maritime Forum, the Friends of Ocean Action, and the World Economic Forum) [Saul (2019)]. Following this initiative, leading oil and shipping companies, banks and ports worldwide [Sixty commercial groups are committed to this initiative, among them: - (1) banks – Societe Generale, Citigroup, ABN AMRO (2) Commodity players – Cargill, COFCO International, Trafigura (3) Mining group – Anglo American and (4) Shipping company – A.P. Moeller Maersk (owner of the largest global container shipping line) (Saul, 2019)], are all working to achieve zero carbon emissions in the maritime sector by 2030. Saul advises that the goal is to have vessels, fuels and supported infrastructure ready by 2030 to make zero emissions a reality in the maritime sector. According to Ben van Beurden, chief executive of Royal Dutch Shell which has also joined the initiative, “Decarbonizing maritime shipping is a huge task with no simple answer, but it has to be done” (Saul, 2019 p.1).

Thus, with further research and development, the possibility exists for renewable energy to be used on a larger scale in the near future. In turn, this should encourage the IMO to seriously consider regulations regarding renewable energy in shipping. Unfortunately, as can be seen in the above examples, the action of decarbonization is being demonstrated by the private sector, but not by the IMO. Although the private sector may be reacting to what maybe a future IMO regulation (zero-carbon or fossil free fuels for ships, (IMO, 2019x) the IMO’s current actions suggest to us that decarbonizing the shipping sector sooner rather than later is not a priority. This

demonstrates, once more, the slow process of the IMO regarding the decarbonization of the shipping sector, which can aid in reducing CO₂ emissions in global shipping. As mentioned above, more in this area can be achieved.

The IMO plays a significant role in protecting and preserving the marine environment with its many international regulations (Basaran, 2016). Our research has taught us that the institution has the power to reach millions in the maritime sector and encourage them to take steps to adopt IMO regulations and become more environmentally responsible. However, its actions, so far, towards decarbonizing the shipping sector are, as affirmed, on a slow trajectory.

In order to improve this situation, the IMO must speed up the implementation of its measures towards decarbonizing the sector, there is no other way. Society's reluctance to move away from fossil fuel use as an energy source according to Adams (2016) is causing this world to be headed on a trajectory of rapid destruction - for example global warming and the negative effects associated with it-. It appears that this reliance has also gripped the shipping industry, as fossil fuel remains the dominant energy source of the industry (Smith et. al. 2015).

The IMO cannot successfully achieve the reduction of CO₂ emissions from the maritime sector alone. This is a global problem which requires a global solution and must include maritime and non-maritime stakeholders. As such there must be a greater collaboration between the IMO and the following: -

- The shipping sector - these two entities must have frequent dialogues to determine if challenges exist in implementing the IMO's regulations and what strategies can be put in place to assist the sector. Yes, we see

evidence of the shipping sector being involved in the IMO's law-making process through their consultative power (IMO 2019 iii, viii; Karim 2015). However, what we seek to stress here is that there must be a dialogue between the IMO and the shipping sector on what immediate measures can be taken by the shipping sector (sooner rather than later) for them to efficiently reach zero emissions.

- Governments – As Flag States are largely responsible for enforcing the IMO's regulations (United Nations 2018i, IMO 2019xxviii), there needs to be an Educational Awareness Campaign regarding the negative environmental effects which are caused by CO₂ emissions from global shipping. This should include frequent dialogue with Government officials, but especially with the employees of the Flag, Port and Coastal States to ensure that they are aware of the important role they play when they enforce IMO regulations. Other methods to communicate this message could be adopted in the form of posters, television and radio announcements as well as the use of social networks.
- Financial institutions - these can provide the necessary financing to the shipping sector to allow them to be equipped or make changes to their vessels regarding compliance with IMO regulations. For example, creating financial incentives which would encourage the shipping sector to invest in renewable energy sources which will result in zero emissions. In this regard, we see evidence of banks such as Citi, DNB, Société Générale, ABN Amro, Crédit Agricole CIB, Danish Ship Finance, Danske Bank, DVB,

ING and Nordea collaborating and considering providing loans to ship owners whose objective is to decarbonize their shipping process (Parker and Christensen, 2019).

- Insurance companies – Insurance coverage is omni-present in the maritime industry in protecting against loss or damage (Maritime Industry Foundation, 2019). The IMO should encourage insurance companies to provide incentives (for example, cheaper premiums) to their insureds for them to comply with IMO regulations and work towards implementing measures to decarbonize their shipping process.

All the above-mentioned recommendations will not work in the IMO's current system which focuses on energy efficiency measures. In our opinion, our recommendations are feasible, but they can only work when the IMO adopts and implements regulations focused on the decarbonization of the sector (renewable energy sources). We do believe the current system is imperfect, and there will be challenges for the maritime sector to accept renewable energy sources. Nonetheless, if Maersk, (the world's largest shipping company) undertakes initiatives to use renewable energy sources to fuel its vessels in order to reduce emissions and decarbonize its fleet (Wilcox, 2019)], it is feasible for the IMO to do the same. We must try to inject new action into the system to tackle the 'root cause' (Boyd, 2003) of the problem (fossil fuel). Until such time has come, the problem of the CO₂ emissions from shipping will continue and the treatment of the 'symptoms' by using energy efficiency measures based on

future predictions will look grim (increase in CO₂ emissions from 50% to 250% in 2050 (Smith et. al. (2015).

Should the IMO agree to implement sooner rather than later regulations regarding the use of renewable energy sources in shipping and to cooperate with the industry stakeholders on this ground, the decarbonization of the sector and the reduction of CO₂ emissions from shipping would start becoming a reality. There is such great urgency to have this done now since shipping is a constant fossil fuel user and CO₂ is a great contributor to climate change (Walker, 2016). We cannot but hope that the IMO will take corresponding action in the future.

Conclusion

The present thesis focused on examining and analyzing the role the IMO is playing in mitigating CO₂ emissions from global shipping. This research has taken us on a journey where we have determined that there is slow progress made by the IMO in mitigating CO₂ emissions. This is indeed troubling because, as global trade increases, there will be a greater demand for the shipping sector which will lead to an increase in fuel consumption and shipping emissions (Cullinane and Bergqvist, 2014). In addition, the alarming projected increase in CO₂ emissions from 50% to 250% in 2050 (Smith et. al. (2015) fueled by an increase in global trade cannot be ignored.

The IMO is globally respected and has the potential to reach millions in the maritime sector by providing them with information on how they can be environmentally responsible. To combat the CO₂ emissions problem, urgent action must be taken now rather than later (and not in 2030), to implement regulations which can transform the

sector into becoming one where zero-carbon or fossil free fuels (preferably renewable energy) becomes a reality. The IMO Member States have the power through their voting rights to adopt and implement regulatory decisions [decisions are made by majority votes] (IMO, 2019v). For this change to occur the IMO Members must exhibit the political will to vote for regulatory measures which do not include fossil fuel used in shipping. Only then will any significant progress be made towards the reduction of CO₂ emissions from global shipping.

Bibliography

Abrahamson D.E. (1989). Global warming: The issue, impacts, responses. In: Abrahamson DE (ed) *The challenge of global warming*. Washington, DC: Island Press, Washington, D.C., 3-34.

Adams K. (2016). The Psychohistory of Climate Change: A Clear and Present Danger. *The Journal of Psychohistory* 44 (2), 114-136

Retrieved from

<https://web.a.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=1&sid=06e45b03-505f-462f-8e01-9b4d11626967%40sdc-v-sessmgr03>

Agency for Toxic Substances and Disease Registry (2011). Toxic Substances Portal. Nitrogen Oxides. USA.gov Government.

Retrieved from

<https://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=69>

Air Pollution and Climate Secretariat (2018, June). IMO adopts greenhouse gas strategy for Shipping. *Acid News*. No. 2

Retrieved from

<http://airclim.org/acidnews/imo-adopts-greenhouse-gas-strategy-shipping>

Alex Centre for Multimedia and Libraries (n.d.) About IHS Fairplay.

Retrieved from

<http://www.acml-egypt.com/Fairplay.html>

Australian Government Department of the Environment and Energy (n.d). Greenhouse Effect.

Retrieved from

<https://www.environment.gov.au/climate-change/climate-science-data/climate-science/greenhouse-effect>

Banawan, A., El Gohary, M., & Sadek, I. (2010). Environmental and economical benefits of changing from marine diesel oil to natural-gas fuel for short-voyage high-power passenger ships. *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment*, 224(2), 103-113.

Retrieved from

<https://journals.sagepub.com/doi/pdf/10.1243/14750902JEME181>

Barbir, F., Veziroğlu, T., & Plass, H. (1990). Environmental damage due to fossil fuels use. *International Journal of Hydrogen Energy*, 15(10), 739-749.

Retrieved from

https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/03603199/v15i0010/739_eddtffu.xml

Barling J. (2014). *Organizational Leadership. The Science of Leadership. Lessons from Research for Organizational Leaders*. Oxford University Press

Retrieved from

<https://books-scholarsportal-info.proxy.bib.uottawa.ca/en/xml/chapter?id=/ebooks/ebooks3/oso/2014-04-04/1/9780199757015-Barling&chapterId=acprof-9780199757015-chapter-1>

Basaran I. (2016). The Evolution of the International Maritime Organization's Role in Shipping. *Journal of Maritime Law and Commerce*, 47 (1), 101 - 117

Retrieved from

<https://search.proquest.com/docview/1779935486?accountid=14701>

Bazari Z. and Longva T. (2011). Project Final Report. Assessment of IMO mandated energy efficiency measures for international shipping. Estimated CO₂ Emissions Reduction from Introduction of Mandatory Technical and Operational Energy Efficiency Measures for Ships. Lloyd's Register, London UK, DNV, Oslo, Norway.

Retrieved from

<http://www.imo.org/en/MediaCentre/HotTopics/GHG/Documents/REPORT%20ASSESSMENT%20OF%20IMO%20MANDATED%20ENERGY%20EFFICIENCY%20MEASURE%20FOR%20INTERNATIONAL%20SHIPPING.pdf>

Beckman R. and Sun Z. (2017). The Relationship between UNCLOS and the IMO Instruments. *Asia-Pacific Journal of Ocean Law and Policy* 2(2), 201-246.

Retrieved from

https://brill.com/view/journals/apoc/2/2/article-p201_201.xml

Bennett L. (2018, January 14). Call for national ban on cruise ships burning bunker fuel. *The Advocate News*.

Retrieved from

<https://www.theadvocate.com.au/story/5166524/call-for-national-ban-on-cruise-ships-burning-bunker-fuel/>

Blackwell V., Newton P., and Maxouris D. (2019, September 7). The Bahamas' death toll is rising as 70,000 residents left homeless by Hurricane Dorian seek food and shelter. *CNN*

Retrieved from

<https://www.cnn.com/2019/09/07/us/hurricane-dorian-bahamas-saturday-wxc/index.html>

Boczek BA (1962) *Flags of convenience: an international legal study*. Harvard University Press, Cambridge, MA

Boyd, David R. (2003). *Unnatural Law: Rethinking Canadian Environmental Law and Policy*. University of British Columbia Press

BP p.l.c. (2019). BP Statistical Review of World Energy 2019, 68th Edition.

Retrieved from

<https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf>

Braden D. (2015, December 10). Shipping Industry Calls IMO to regulate shipping emissions. *Journal of Commerce*

Retrieved from

https://search-proquest-com.proxy.bib.uottawa.ca/docview/1747759575?rfr_id=info%3Axi%2Fsid%3Aprimo

Bradley, D., Diesenreiter F., Wild M., Tromborg E. (2009). World Biofuel Maritime Shipping Study: Canadian Bioenergy Association, 2009. Canadian Electronic Library/desLibris
Retrieved from
<https://www.deslibris.ca/ID/242418>

Brown L. (2019, May 3). Climate Change: What is a climate emergency? *BBC News*.
Retrieved from
<https://www.bbc.com/news/newsbeat-47570654>

Buckley M. (1994). *The Structure of Business*. Third Edition. Pitman Publishing.

Burmeister, H., Bruhn, W., Rødseth Ø., & Porathe, T. (2014i). Autonomous Unmanned Merchant Vessel and its Contribution towards the e-Navigation Implementation: The MUNIN Perspective. *International Journal of E-Navigation and Maritime Economy*, 1(C), 1-13.

Retrieved from
https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/24055352/v1icomplete/1_aumvaieitmp1.xml

Burmeister, H., Bruhn, W., Rødseth, Ø., & Porathe, T. (2014ii) Can Unmanned Ships Improve Navigational Safety? *Transport Research Arena 2014 Paris*

Retrieved from
<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.846.5385&rep=rep1&type=pdf>

Cambridge Dictionary Online (2019). Flag of Convenience. Cambridge University Press

Retrieved from
<https://dictionary.cambridge.org/us/dictionary/english/flag-of-convenience>

Canadian Encyclopedic Digest (CED) (2017i). Environmental Law III.6. (c) (Ontario), Environmental Law (Ontario) III – Shipping 6 – Regulations (c) Air. Prepared by Joan E. Dunlop, B.A., LL.B.: September 2008 updated by the legal editorial staff of Thomson Reuters Canada: December 2017. Environmental Law (Ontario), 4th edition Ontario, Volume 23, Title 59

Retrieved from
<https://nextcanada-westlaw-com.proxy.bib.uottawa.ca>

Canadian Encyclopedic Digest (CED) (2017ii). Environmental Law IV.1. (b) (Ontario), Environmental Law (Ontario) IV – Air Pollution 1 – Federal Legislation (b) – Regulation of Specific Sources. Prepared by Joan E. Dunlop, B.A., LL.B.: September 2008 updated by the legal editorial staff of Thomson Reuters Canada: December 2017. Environmental Law (Ontario), 4th edition Ontario, Volume 23, Title 59

Retrieved from

<https://nextcanada-westlaw-com.proxy.bib.uottawa.ca>

Canadian Encyclopedic Digest (CED) (2018). Environmental Law IV.1. (b) (Western), Environmental Law (Western) IV – Air Pollution 1 – Federal Legislation (b) – Regulation of Specific Sources. Prepared by H. Peter Eccles, B.A., LL.B. of the Ontario Bar: November 2005 updated by the legal editorial staff of Thomson Reuters Canada: January 2018. Environmental Law (Western), 4th edition Western, Volume 25, Title 58

Retrieved from

<https://nextcanada-westlaw-com.proxy.bib.uottawa.ca>

Canadian Maritime Law (2016). Canadian Maritime Law 2016 Second Edition. 9781552214053. Toronto: Irwin Law, 2016. Edited by Aldo Chircop, William Moreira, Hugh Kindred, Edgar Gold. Canadian Electronic Library/desLibris. Absolute Page 5. Downloaded 08-07-2019. Copyright © 2016. Irwin Law All rights reserved.

Retrieved from

<https://www-deslibris-ca.proxy.bib.uottawa.ca/ID/476366>

Capareda S.C. (2019). Introduction to Renewable Energy Conversions. Milton: CRC Press LLC. pp 1- 457

Retrieved from

<https://www-taylorfrancis-com.proxy.bib.uottawa.ca/books/9780429199103>

Cariou, P. (2011). Is Slow Steaming a Sustainable Means of Reducing CO₂ Emissions from Container Shipping? *Transportation Research Part D* 16 (3), 260–264.

Retrieved from

<https://doi.org/10.1016/j.trd.2010.12.005>.

Carrington D. (2019, June 20). UK citizens' assembly on climate emergency announced. *The Guardian*.

Retrieved from

<https://www.theguardian.com/environment/2019/jun/20/uk-citizens-assembly-on-climate-emergency-announced>

Carrington D. and Taylor M. (2018, October 27). Air pollution is the 'new tobacco', warns WHO head. *Guardian News and Media Limited*.

Retrieved from

<https://www.theguardian.com/environment/2018/oct/27/air-pollution-is-the-new-tobacco-warns-who-head>

Cepeda, M., Assis L., Marujo L., and Caprace J. (2017). Effects of Slow Steaming Strategies on a Ship Fleet. *Marine Systems & Ocean Technology* 12(3), 178–186.

Retrieved from

<https://doi.org/10.1007/s40868-017-0033-3>

Chircop A., Doelle M. and Gauvin R. (2018). Shipping and Climate Change. International Law and Policy Considerations Special Report. Centre for International Governance Innovation.

Retrieved from

https://www.cigionline.org/sites/default/files/documents/Shipping%27s%20contribution%20to%20climate%20change%202018web_0.pdf

Chougle T. (2019, September 6). 7 Ways for Ships to Meet MARPOL NOx Tier III Regulation. *Marine Technology Marine Insight* Last updated 6 September 2019.

Retrieved from

<https://www.marineinsight.com/tech/different-ways-meet-nox-tier-iii-standards/>

Clean Energy Fuels (2019). Liquefied Natural Gas (LNG).

Retrieved from

<https://www.cleanenergyfuels.com/fuels/liquefied-natural-gas-lng/>

Climate emergency declarations in 822 jurisdictions and local governments cover 145 million citizens (2019, July 18) *Climate Emergency Declaration*

Retrieved from

<https://climateemergencydeclaration.org/climate-emergency-declarations-cover-15-million-citizens/>

Cole G.A. (2004). *Management Theory and Practice*, Sixth Edition. Thomson

Collins Dictionary Online (2019). Definition of Progress.

Retrieved from

<https://www.collinsdictionary.com/us/dictionary/english/progress>

Comer B., Olmer N. and Mao X. (2016). Heavy fuel oil use in Arctic shipping in 2015. Dated 21 October 2016. The International Council on Clean Transportation (ICCT).

Retrieved from

https://www.theicct.org/sites/default/files/publications/HFO%20Arctic%20Shipping_working-paper_vF_21102016.pdf

Comer B., Olmer N., Mao X., Roy B., Rutherford D. (2017). Prevalence of heavy fuel oil and black carbon in Arctic Shipping, 2015 to 2025. The International Council on Clean Transportation (ICCT).

Retrieved from

https://www.theicct.org/sites/default/files/publications/HFO-Arctic_ICCT_Report_01052017_vF.pdf

Connolly A. (2019, June 18). Reality check: Declaring a climate emergency sends a message but does little else. *Global News*.

Retrieved from

<https://globalnews.ca/news/5403185/canada-climate-emergency-vote/>

Corbett J. J. and Fischbeck P. (1997). Emissions from ships. (pollution and policy implications). *Science*, 278 (5339), 823-824

Retrieved from

<https://science-sciencemag-org.proxy.bib.uottawa.ca/content/278/5339/823>

Corbett, J., Fischbeck P. and Pandis S. (1999). Global Nitrogen and Sulfur Emissions Inventories for Oceangoing Ships. *Journal of Geophysical Research: Atmosphere*, 104 (D3), 3457-3470.

Retrieved from

<https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/1998JD100040>

Corbett J. and Farrell A. (2002). Mitigating air pollution impacts of passenger ferries. *Transportation Research Part D*, 7 (3), 197-211

Retrieved from

https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/13619209/v07i0003/197_mapiopf.xml

Corbett J., Winebrake J., Green E., Kasibhatla P., Eyring V., and Lauer A. (2007). Mortality from Ship Emissions: A global assessment. *Environmental Science and Technology* 41 (24), 8512-8518.

Retrieved from

<https://pubs-acscs-org.proxy.bib.uottawa.ca/doi/pdf/10.1021/es071686z>

Corsi G. (2018). The IMO's GHG Strategy: A Step Toward Meeting the 2 degree Target? Dated May 2018. A Climate Institute Publication

Retrieved from

<http://climate.org/wp-content/uploads/2018/06/The-IMO%E2%80%99s-GHG-strategy-A-Step-Toward-Meeting-the-2-Target.pdf>

Cruise Market Watch (2018). 2018 Worldwide Cruise Line Passenger Capacity.

Retrieved from

<https://cruisemarketwatch.com/capacity/>

Cullinane K. and Bergqvist R. (2014). Emission Control Areas and their impact on Maritime Transport. *Transport Research Part D*, 28 (May), 1-5

Retrieved from

https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/13619209/v28icomplete/1_eaatiomt.xml

Darby M. (2017, October 23). UN Shipping climate talks 'captured' by industry lobbyists. *Climate Home News Ltd.*

Retrieved from

<https://www.climatechangenews.com/2017/10/23/un-shipping-climate-talks-captured-industry/>

De Wit, C. (1990). Proposal for Low Cost Ocean Weather Routeing. *Journal of Navigation* 43(3), 428–439.

Retrieved from

<https://www-cambridge-org.proxy.bib.uottawa.ca/core/journals/journal-of-navigation/article/proposal-for-low-cost-ocean-weather-routeing/6C41584ABAC335C83521E447A68A0582>

Dewan M., Yaakob O., and Suzana A. (2018). Barriers for Adoption of Energy Efficiency Operational Measures in Shipping Industry. *WMU Journal of Maritime Affairs*, 17 (2), 169–193.

Retrieved from

<https://link-springer-com.proxy.bib.uottawa.ca/content/pdf/10.1007%2Fs13437-018-0138-3.pdf>

Easterby-Smith M., Thorpe, R. & Jackson P. (2012). *Management Research*, 4th Edition London: SAGE Publications

Ebi, K.L. et al. (2013). A new scenario framework for climate change research: background, process, and future directions, *Climate Change*, Volume 122, Issue 3, pp 363-372.

Eco Marine Power (2019). *Green Shipping with Wind and Solar Power; Harnessing Solar and Wind Power for Cleaner Shipping.*

Retrieved from

<http://www.ecomarinepower.com/green-shipping>

Eide M., Dalsøren S., Endresen Ø., Samset B., Myhre G., Fuglestad J. and Berntsen T. (2013). Reducing CO₂ from shipping - Do non-CO₂ effects matter? *Atmospheric Chemistry and Physics* 13 (8), 4183-4201.

Retrieved from

<https://www.atmos-chem-phys.net/13/4183/2013/acp-13-4183-2013.pdf>

Elliott M.W. (2013). Enterprise Risk Management 1st Edition, American Institute For Chartered Property Casualty Underwriters, Edited by Michael W. Elliott.

Ellsmoor J. (2019, July 20). Climate Emergency Declarations: How Cities Are Leading The Charge. *Forbes Media LLC*.

Retrieved from

<https://www.forbes.com/sites/jamesellsmoor/2019/07/20/climate-emergency-declarations-how-cities-are-leading-the-charge/#55d10b54f149>

Emissions Database for Global Atmospheric Research (EDGAR) (2017). CO₂ time series 1990-2015 per region/country. European Commission.

Retrieved from <http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts1990-2015>

Endresen, Ø., Sørgård, E., Behrens, H., Brett, P., Isaksen, I., (2007). A historical reconstruction of ships' fuel consumption and emissions. *Journal of Geophysical Research: Atmospheres*, 112 (D12)

Retrieved from

[https://agupubs-onlinelibrary-wiley-com.proxy.bib.uottawa.ca/doi/epdf/10.1029/2006JD007630](https://agupubs.onlinelibrary-wiley-com.proxy.bib.uottawa.ca/doi/epdf/10.1029/2006JD007630)

Energy Education (2016). Carbon Cycle. University of Calgary

Retrieved from

https://energyeducation.ca/encyclopedia/Carbon_cycle

Energy Education (2017). Sulfur Oxides. University of Calgary.

Retrieved from

https://energyeducation.ca/encyclopedia/Sulfur_oxides

Energy Education (2018). Carbon Dioxide. University of Calgary.
Retrieved from
https://energyeducation.ca/encyclopedia/Carbon_dioxide

ESL Shipping Welcomes LNG-Fueled Bulker into Its Fleet (2018, August 21) *World Maritime News*
Retrieved from
<https://worldmaritimeneeds.com/archives/259162/esl-shipping-welcomes-lng-fueled-bulker-into-its-fleet/>

European Maritime Safety Agency (EMSA) (2019). Alternative Fuels.
Retrieved from
<http://www.emsa.europa.eu/main/air-pollution/alternative-fuels.html>

exactEarth (2019). exactEarth.
Retrieved from
<https://www.exactearth.com/>

Extreme weather around the world (2018, August 1) *MSN News*.
Retrieved from
<https://www.msn.com/en-us/news/weather/extreme-weather-around-the-world/ss-BBL4LBJ#image=22>

Eyring V, Köhler H., Van Aardenne J., Lauer A. (2005). Emissions from international shipping: 1. The Last 50 years. *Journal of Geophysical Research: Atmospheres*, 110 (D17)
Retrieved from
<https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2004JD005619>

Freda F. and Zhixi Z. (2017, April 20). China is cracking down on air pollution from shipping. *Chinadialogue*
Retrieved from
<https://www.chinadialogue.net/article/show/single/en/9739-China-is-cracking-down-on-air-pollution-from-shipping>

Fridell E. (2019). Emissions and Fuel Use in the Shipping Sector. In Bergqvist R. & Monios J. (Eds.), *Green Ports Inland and Seaside Sustainable Transport Strategies* (pp. 19-33). Elsevier Inc.

Retrieved from

<https://doi.org/10.1016/B978-0-12-814054-3.00002-5>.

Fuglestvedt J., Berntsen T., Eyring V., Isaksen I., Lee D.S, Sausen R. (2009). Shipping Emissions: From Cooling to Warming of Climate-and Reducing Impacts on Health. *Environmental Science and Technology*, 43(24), 9057-9062.

Retrieved from

<https://pubs-acscs-org.proxy.bib.uottawa.ca/doi/pdf/10.1021/es901944r?rand=91uuwcpb>

Funding Agreed for Global Maritime Energy Efficiency Partnerships Project (GloMEEP) (2015, July 27). *States News Service*,

Retrieved from

<https://go.galegroup.com.proxy.bib.uottawa.ca>

Gabbatiss J. (2018, April 13) Carbon emissions from global shipping to be halved by 2050, says IMO. *Independent*.

Retrieved from

<https://www.independent.co.uk/environment/ships-emissions-carbon-dioxide-pollution-shipping-imo-climate-change-a8303161.html>

Gallucci M. (2018, June 28). At Last, the Shipping Industry Begins Cleaning Up Its Dirty Fuels. *Yale Environment 360*. Published at the Yale School of Forestry and Environmental Studies.

Retrieved from

<https://e360.yale.edu/features/at-last-the-shipping-industry-begins-cleaning-up-its-dirty-fuels>

Ghosh S. and Rubly C. (2015). The emergence of Arctic shipping: issues, threats, costs, and risk-mitigating strategies of the Polar Code. *Australian Journal of Maritime and Ocean Affairs*, 7(3), 171-182.

Retrieved from

https://journals.scholarsportal.info/pdf/18366503/v07i0003/171_teasirsotpc.xml

Global Fishing Watch (2019). Global Fishing Watch. What we do.
Retrieved from
<https://globalfishingwatch.org>

Global Maritime Energy Efficiency Partnership (GloMEEP) (2019). About GloMEEP.
About the project. The Issue. Global Industry Alliance Overview.
Retrieved from
<https://glomeep.imo.org>

Global Maritime Technology Cooperation Centre Network Officially Launched (2017,
December 4) *Marine Insight*
Retrieved from
<https://www.marineinsight.com/shipping-news/global-maritime-technology-cooperation-centre-network-officially-launched/>

Hamad H. (2016). Flag of Convenience Practice: A Threat to Maritime Safety and Security. *IJRDO Journal of Social Science and Humanities Research*. Volume 1, Issue 8, August 2016, Paper 12
Retrieved from
https://www.researchgate.net/publication/308308749_Flag_of_Convenience_Practice_A_Threat_to_Maritime_Safety_and_Security/stats

Harrould-Kolieb E. (2008). Shipping Impacts on Climate: A Source of Solutions. *Oceana - Protecting the World's Oceans*. July 2008.
Retrieved from
https://oceana.org/sites/default/files/reports/Oceana_Shipping_Report1.pdf

Harrould-Kolieb E. and Savitz J. (2010). Shipping Solutions: Technological and Operational Methods Available to Reduce CO2. *Oceana - Protecting the World's Oceans*. October 2010.
Retrieved from
<https://oceana.org/reports/shipping-solutions-technological-and-operational-methods-available-reduce-co2>

Head G.L. and Horn II S. (1997). *Essentials of Risk Management ARM 54 Third Edition Volume 1*, The Insurance Institute of America

Hicks R. (2019, April 16). 'Rebel or sink': Rallies against government inaction on climate change go global. *Eco-Business*.

Retrieved from

<https://www.eco-business.com/news/rebel-or-sink-rallies-against-government-inaction-on-climate-change-go-global/>

Hogg, T., and Ghosh, S. (2016). Autonomous merchant vessels: Examination of factors that impact the effective implementation of unmanned ships. *Australian Journal of Maritime & Ocean Affairs*, 8(3), 206-222.

Retrieved from

https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/18366503/v08i0003/206_amveofteious.xml

How the GloMEEP project is trying to nurture efficiency in shipping (2016, October 11). *Ship Technology*

Retrieved from

<https://www.ship-technology.com/features/featurehow-the-glomeep-project-is-trying-to-nurture-efficiency-in-shipping-5023407/>

Hui W. (2011). *Marine Oil Pollution Damage: A Comparative and Economic Study of the International US and Chinese Compensation Regime*. Alphen: Kluwer Law International.

Icopal Noxite (2011). Nitrogen Oxide (NOx) Pollution.

Retrieved from

<http://www.icopal-noxite.co.uk/nox-problem/nox-pollution.aspx>

IMO Agrees to CO2 Emissions Target (2018, April 13). *The Maritime Executive*

Retrieved from

<https://www.maritime-executive.com/article/imo-agrees-to-co2-emissions-target>

IMO bans bunker fuel in antarctic waters (2010). *Oil Spill Intelligence Report*, 33(27), 4.
Retrieved from

<https://search-proquest-com.proxy.bib.uottawa.ca/docview/612883722?accountid=1471>

In Depth: Unmanned Ships - Are we there yet? (2018, March 14) *World Maritime News*
Retrieved from

<https://worldmaritimeneews.com/archives/247204/interview-unmanned-ships-are-we-there-yet/>

Intergovernmental Panel on Climate Change (IPCC) (2007). Expert Meeting Report (2007) Towards New Scenarios for Analysis of Emissions, Climate Change, Impacts, and Response Strategies

Retrieved from

http://www.ipcc.ch/scoping_meeting_ar5/expert-meeting-report-scenarios.pdf
<https://archive.ipcc.ch/pdf/supporting-material/expert-meeting-report-scenarios.pdf>

Intergovernmental Panel on Climate Change (IPCC) (2013). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Retrieved from

<https://www.ipcc.ch/report/ar5/wg1/>
https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_all_final.pdf

Intergovernmental Panel on Climate Change (IPCC) (2018). IPCC Press Release. Dated 8 October 2018 - Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C approved by governments. Special Report Global Warming of 1.5°C.

Retrieved from

https://www.ipcc.ch/pdf/session48/pr_181008_P48_spm_en.pdf
<https://www.ipcc.ch/sr15/>

Intergovernmental Panel on Climate Change (IPCC) (2019). Special Report on the Ocean and Cryosphere in a Changing Climate. This Summary for Policymakers was formally approved at the Second Joint Session of Working Groups I and II of the IPCC and accepted by the 51th Session of the IPCC, Principality of Monaco, 24th September 2019 Summary for Policymakers.

Retrieved from

https://report.ipcc.ch/srocc/pdf/SROCC_FinalDraft_FullReport.pdf

International Chamber of Shipping (2017). Shipping and World Trade.

Retrieved from

<http://www.ics-shipping.org/shipping-facts/shipping-and-world-trade>

International Energy Agency (IEA) (2017). CO2 Emissions from Fuel Combustion IEA 2017. Annual Historical Series (1971-2015). CO2 Emissions from fuel combustion - Total. Region/Country/Economy.

Retrieved from

<https://www.iea.org/media/statistics/CO2Highlights.XLS>

International Energy Agency (IEA) (2018). International Shipping. Tracking Clean Energy Progress.

Retrieved from

<https://www.iea.org/tcep/transport/shipping/>

International Energy Agency (IEA) (2019). The global authority on energy.

Retrieved from

<https://www.iea.org/>

International Maritime Organization (IMO) (2004). Resolution A.963(23) Adopted on 5 December 2003 (Agenda item 19), IMO Policies and Practices related to the reduction of Greenhouse Gas Emissions from Ships

Retrieved from

[http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Assembly/Documents/A.963\(23\).pdf](http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Assembly/Documents/A.963(23).pdf)

International Maritime Organization (IMO) (2012). Annex 8 Resolution MEPC.212(63), 2012 Guidelines On The Method Of Calculation Of The Attained Energy Efficiency Design Index (EEDI) For New Ships

Retrieved from

<http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Marine-Environment-Protection-Committee-%28MEPC%29/Documents/MEPC.212%2863%29.pdf>

International Maritime Organization (IMO) (2013). Rules and Guidelines for Consultative Status of Non-Governmental International Organizations with the International Maritime Organization.

Retrieved from

<http://www.imo.org/en/About/Membership/Documents/RULES%20AND%20GUIDELINE%20FOR%20CONSULTATIVE%20STATUS.pdf>

International Maritime Organization (IMO) (2016). Introduction To The Application Of The Strategic Plan And The High-Level Action Plan (Resolution A.1099(29)).

Retrieved from

<http://www.imo.org/en/About/strategy/Documents/Introduction%20to%20application%20of%20SP%20and%20HLAP.pdf#search=secretariat%20tasks>

International Maritime Organization (IMO) (2017). Global Integrated Shipping Information System. Welcome to the Public Area.

Retrieved from

<https://gisis.imo.org/Public/Default.aspx>

International Maritime Organization (IMO) (2019i). Brief History of IMO.

Retrieved from

<http://www.imo.org/en/About/HistoryOfIMO/Pages/Default.aspx>

International Maritime Organization (IMO) (2019ii). Member States.

Retrieved from

<http://www.imo.org/en/About/Membership/Pages/MemberStates.aspx>

International Maritime Organization (IMO) (2019iii). Member States, IGOs and NGOs.
Retrieved from
<http://www.imo.org/en/About/Membership/Pages/Default.aspx>

International Maritime Organization (IMO) (2019iv). Structure of IMO.
Retrieved from
<http://www.imo.org/en/About/Pages/Structure.aspx>

International Maritime Organization (IMO) (2019v). Adopting a convention, Entry into Force, Accession, Amendment, Enforcement, Tacit acceptance procedure. Convention on the International Maritime Organization.
Retrieved from
<http://www.imo.org/en/About/Conventions/Pages/Home.aspx>
<http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/Convention-on-the-International-Maritime-Organization.aspx>

International Maritime Organization (IMO) (2019vi). International Convention for the Prevention of Pollution from Ships (MARPOL).
Retrieved from
[http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-\(MARPOL\).aspx](http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx)

International Maritime Organization (IMO) (2019vii). Background
Retrieved from
<http://www.imo.org/en/OurWork/Environment/PollutionPrevention/OilPollution/Pages/Background.aspx>

International Maritime Organization (IMO) (2019viii). Convention on the International Maritime Organization.
Retrieved from
<http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/Convention-on-the-International-Maritime-Organization.aspx>

International Maritime Organization (IMO) (2019ix). Prevention of Air Pollution From Ships.

Retrieved from

<http://www.imo.org/en/ourwork/environment/pollutionprevention/airpollution/pages/air-pollution.aspx>

International Maritime Organization (2019x). Annex 11. Resolution MEPC.304(72). Initial IMO Strategy on Reduction of GHG Emissions from Ships.

Retrieved from

<http://www.imo.org/en/OurWork/Documents/Resolution%20MEPC.304%2872%29%20on%20Initial%20IMO%20Strategy%20on%20reduction%20of%20GHG%20emissions%20from%20ships.pdf>

International Maritime Organization (IMO) (2019xi). Annex 10, Resolution (Marine Environmental Protection Committee) MEPC 189 (60), Adopted on 26th March 2010, Amendments to the Annex of the Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships, 1973).

Retrieved from

[http://www.imo.org/blast/blastDataHelper.asp?data_id=28814&filename=189\(60\).pdf](http://www.imo.org/blast/blastDataHelper.asp?data_id=28814&filename=189(60).pdf)

International Maritime Organization (IMO) (2019xii). UN Body adopts climate change strategy for shipping.

Retrieved from

<http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx>

International Maritime Organization (IMO) (2019xiii). Low carbon shipping and air pollution control.

Retrieved from

<http://www.imo.org/en/MediaCentre/HotTopics/GHG/Pages/default.aspx>

International Maritime Organization (IMO) (2019xiv). Energy Efficiency Measures

Retrieved from

<http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Technical-and-Operational-Measures.aspx>

International Maritime Organization (IMO) (2019xv). Data collection system for fuel oil consumption of ships.

Retrieved from

<http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Data-Collection-System.aspx>

International Maritime Organization (IMO) (2019xvi). Guidelines For Voluntary Use Of The Ship Energy Efficiency Operational Indicator (EEOI).

Retrieved from

http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Technical%20and%20Operational%20Measures/MEPC.1_Circ.684_Guidelines%20for%20Voluntary%20use%20of%20EEOI.pdf

International Maritime Organization (IMO) (2019xvii). Marine Environment Protection Committee 71st Session, Agenda Item 7, MEPC 71/7/4 April 2017. Reduction of GHG Emissions from Ships. A proposal to consider in developing the IMO GHG Strategy Submitted by BIMCO, IPTA and WSC

Retrieved from

http://www.worldshipping.org/public-statements/regulatory-comments/MEPC_71-7-4_-_A_proposal_to_consider_in_developing_the_IMO_GHG_strategy_-_BIMCO_IPTA_and_WSC-.pdf

International Maritime Organization (IMO) (2019xviii). Technical Co-operation (TC).

Retrieved from

<http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Technical-Co-operation.aspx>

International Maritime Organization (IMO) (2019xix). Integrated Technical Cooperation Programme (ITCP).

Retrieved from

<http://www.imo.org/en/OurWork/TechnicalCooperation/ITCP/Pages/Default.aspx>

International Maritime Organization (IMO) (2019xx). Technical Cooperation.

Retrieved from

<http://www.imo.org/en/OurWork/TechnicalCooperation/Pages/Default.aspx>

International Maritime Organization (IMO) (2019xxi). Challenges.

Retrieved from

<http://www.imo.org/en/OurWork/TechnicalCooperation/ITCP/Pages/Challenges.aspx>

International Maritime Organization (IMO) (2019xxii). Funding agreed for Global Maritime Energy Efficiency Partnerships Project (GloMEEP). Briefing: 35 27/07/2015

Retrieved from

<http://www.imo.org/en/MediaCentre/PressBriefings/Pages/35-glomeep-signing.aspx>

International Maritime Organization (IMO) (2019xxiii). Global Maritime technology cooperation centre network officially launched dated 04/12/2017

Retrieved from

<http://www.imo.org/en/MediaCentre/PressBriefings/Pages/36-MTCCMOU.aspx>

International Maritime Organization (IMO) (2019xxiv). Historic Background. IMO and the UNFCCC policy framework.

Retrieved from

<http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Historic%20Background%20GHG.aspx>

International Maritime Organization (IMO) (2019xxv). IMO takes first steps to address autonomous ships.

Retrieved from

<http://www.imo.org/en/MediaCentre/PressBriefings/Pages/08-MSC-99-MASS-scoping.aspx>

International Maritime Organization (IMO) (2019xxvi). Maritime Safety Committee (MSC), 100th session, 3-7 December 2018.

Retrieved from

<http://www.imo.org/en/MediaCentre/MeetingSummaries/MSC/Pages/MSC-100th-session.aspx>

<http://www.ifsma.org/resources/MSC-100-REPORT.pdf>

International Maritime Organization (IMO) (2019xxvii). Titles of Conventions.

Retrieved from

<http://www.imo.org/en/About/Conventions/ListOfConventions/Documents/Convention%20titles%202016.pdf>

International Maritime Organization (IMO) (2019xxviii). The United Nations Convention on the Law of the Sea (UNCLOS) and the International Maritime Organization.

Retrieved from

<http://www.imo.org/en/MediaCentre/SecretaryGeneral/SpeechesByTheSecretaryGeneral/Pages/itlos.aspx>

International Maritime Organization (IMO) (2019xxix). IMO Member State Audit Scheme.

Retrieved from

<http://www.imo.org/en/OurWork/MSAS/Pages/AuditScheme.aspx>

International Maritime Organization (IMO) (2019xxx). Implementation of IMO Instruments.

Retrieved from

<http://www.imo.org/en/OurWork/Safety/Implementation/Pages/ImplementationOfIMOInstruments.aspx>

International Maritime Organization (IMO) (2019xxxi). Flag State Implementation.

Retrieved from

<http://www.imo.org/en/OurWork/Safety/Implementation/Pages/FlagStateImplementation.aspx>

International Maritime Organization (IMO) (2019xxxii). Sub-Committee on Implementation of IMO Instruments (III).

Retrieved from

<http://www.imo.org/en/MediaCentre/MeetingSummaries/III/Pages/Default.aspx>

International Maritime Organization (IMO) (2019xxxiii). Maritime Safety Committee (MSC), 101 Session 5-14 June 2019.

Retrieved from

<http://www.imo.org/en/MediaCentre/MeetingSummaries/MSC/Pages/MSC-101st-session.aspx>

International Maritime Organization (IMO) (2019xxxiv). Marine Environment.

Retrieved from

<http://www.imo.org/en/OurWork/Environment/Pages/Default.aspx>

International Maritime Organization (IMO) (2019xxxv). E- Navigation.

Retrieved from

<http://www.imo.org/en/OurWork/Safety/Navigation/Pages/eNavigation.aspx>

International Maritime Organization (IMO) (2019xxxvi). IMO and Sustainable Development. Sustainable Development Goals.

Retrieved from

<http://www.imo.org/en/MediaCentre/HotTopics/Documents/IMO%20SDG%20Brochure.pdf>

International Maritime Organization (IMO) (2019xxxvii). Our Voyage Together. How IMO's technical cooperation supports sustainable development.

Retrieved from

<http://www.imo.org/en/OurWork/TechnicalCooperation/Documents/Brochure/Our%20Voyage%20Together.pdf>

International Maritime Organization (IMO) (2019xxxviii). Historic Background. IMO and the UNFCCC policy framework.

Retrieved from

<http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Historic%20Background%20GHG.aspx>

International Maritime Organization (IMO) (2019xxxix). Global Industry Alliance launched to support low carbon shipping

Retrieved from

<http://www.imo.org/en/MediaCentre/PressBriefings/Pages/17-GIA-GloMeep-launch.aspx>

International Maritime Organization (IMO) (2019xli). Sulphur oxides (SOx) and Particulate Matter (PM) - Regulation 14

Retrieved from

[http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-\(SOx\)-%E2%80%93-Regulation-14.aspx](http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-(SOx)-%E2%80%93-Regulation-14.aspx)

International Maritime Organization (IMO) (2019 xli). IMO Assembly

Retrieved from

<http://www.imo.org/en/MediaCentre/MeetingSummaries/Assembly/Pages/Default.aspx>

International Maritime Organization (IMO) (2019xlii). EU/IMO global project drives energy efficiency in the maritime sector.

Retrieved from

<http://www.imo.org/en/MediaCentre/PressBriefings/Pages/23-GMN-overview-.aspx>

International Renewable Energy Agency (IRENA) (2015). Renewable Energy Options for Shipping. Technology Brief

Retrieved from

https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_Tech_Brief_RE_for_Shipping_2015.pdf

International Renewable Energy Agency (IRENA) (2019). New Report Identifies Clean Energy Options for Global Shipping Industry. Dated 31/10/2019

Retrieved from

<https://www.irena.org/newsroom/articles/2019/Oct/New-Report-Identifies-Clean-Energy-Options-for-Global-Shipping-Industry>

International Transport Workers' Federation (2019). Flags of Convenience.
Retrieved from
<https://www.itfglobal.org/en/sector/seafarers/flags-of-convenience>

Johansson L., Jalkanen J.; Kukkonen J. (2017). Global assessment of shipping emissions in 2015 on a high spatial and temporal resolution. *Atmospheric Environment* 167, 403-415.
Retrieved from
https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/13522310/v167icomplete/403_gaoseiahsatr.xml
<https://www.sciencedirect.com/science/article/pii/S1352231017305563#fig4>

Johnson H. and Andersson K. (2016). Barriers to energy efficiency in shipping. *WMU Journal of Maritime Affairs*, 15(1), 79-96
Retrieved from
<https://link.springer.com/content/pdf/10.1007%2Fs13437-014-0071-z.pdf>

Joseph R. (2019, May 16). What is a climate emergency? Liberals, NDP table duelling motions on climate change. *Global News*.
Retrieved from
<https://globalnews.ca/news/5280082/what-is-a-climate-emergency-canada/>

Karim Md. S. (2015). Prevention of Pollution of the Marine Environment from Vessels. The Potential and Limits of the International Maritime Organization. Springer.
Retrieved from
<https://link-springer-com.proxy.bib.uottawa.ca/content/pdf/10.1007%2F978-3-319-10608-3.pdf>

Katsivela, Marel (2018). The Effect of Unmanned Vessels on Canadian Law: Some Basic Legal Concepts (October 12, 2018). *Maritime Safety and Law Journal* 4/2018; Ottawa Faculty of Law Working Paper No. 2019-22.. Available at SSRN.
Retrieved from
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3267996

Kendall P. (2013, July 30). The Biggest Ship in the World. *Telegraph Media Group Ltd.*
Retrieved from
<https://www.telegraph.co.uk/finance/newsbysector/industry/10203784/The-biggest-ship-in-the-world.html>

Kooij C., Cooling A. and Benson C. (2018). When will Autonomous Ships Arrive? A Technology Forecasting Perspectives (June 6, 2018). INEC Conference 2018. Available at SSRN
Retrieved from
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3191736

Kwai I. (2019, June 21). Sydney to Declare a Climate Emergency in Face of National Inaction. *The New York Times*.
Retrieved from
<https://www.nytimes.com/2019/06/21/world/australia/sydney-climate-emergency.html>

10 Largest Container Shipping Companies in the World (2019, July 31). By *Marine Insight News Network*
Retrieved from
<https://www.marineinsight.com/know-more/10-largest-container-shipping-companies-in-the-world/>

L'Esperance P. (2018). Regulating GHG Emissions from International Shipping. With assistance from Dan Vanclieaf. Environmental Education for Court Practitioners. A Symposium on Environment in the Courtroom: Enforcing Canadian GHG Emissions Laws October 25 and 26, 2018 Université Laval
Retrieved from
<https://ciril.ca/files/ciril/lesperance-regulating-ghg-emissions.pdf>

Leary K. (2018, January 26). New Ship with Rigid Solar Sails Harnesses the Power of Sun and Wind at the Same Time. Set to sail in 2019, the ship's success could encourage other companies to power their fleets with renewable energy. *Futurism.com*.
Retrieved from
<https://futurism.com/new-ship-rigid-solar-sails-harnesses-power-sun-wind-same-time>

Let's Go Solar (2018). Solar Powered Cars and Planes; Solar-Powered Cars: Still a Concept.

Retrieved from

<https://www.letsgosolar.com/consumer-education/solar-powered-cars-planes/>

Lister J., Poulsen R., Ponte S. (2015). Orchestrating transnational environmental governance in maritime shipping. *Global Environmental Change* 34, 185

Retrieved from

https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/09593780/v34icomplete/185_oteqims.xml

Lloyd's Register (2005). MARPOL - International Convention for the Prevention of Pollution from Ships Amended by Resolution MEPC.111(50) Amended by Resolution MEPC.115(51) Amended by Resolution MEPC.116(51). Articles of the International Convention for the Prevention of Pollution from Ships, 1973. Lloyd's Register Rulefinder 2005 - Version 9.4

Retrieved from

<http://www.mar.ist.utl.pt/mventura/Projecto-Navios-I/IMO-Conventions%20%28copies%29/MARPOL.pdf>

Loh C., Booth V. (2012). The Fair Winds Charter – A model PPP in Hong Kong. *European Procurement and Public Private Partnership Law Review*. 2012, Vol. 7. (2), 129-137.

Retrieved from

<https://web-b-ebsohost-com.proxy.bib.uottawa.ca/ehost/pdfviewer/pdfviewer?vid=5&sid=f9a88f8e-c84a-486e-a118-d7fdf20ff9c3%40pdc-v-sessmgr01>

Lower Emissions on the High Seas (2017, October 31). *Nature* 551(7678), 5-6

Retrieved from

<http://www.nature.com.proxy.bib.uottawa.ca/news/lower-emissions-on-the-high-seas-1.22916>

Luber G. and Prudent N. (2009). Climate Change and Human Health. *Transactions of the American Clinical and Climatological Association*, 2009; 120: 113-117. National Center for Biotechnology Information, U.S. National Library of Medicine.

Retrieved from

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2744549/>

Lucas A., Yearsley J. (2012). The Constitutionality of Federal Climate Change Legislation. *Journal of Environmental Law and Practice*, 23, 171-202.
Retrieved from
https://search-proquest-com.proxy.bib.uottawa.ca/docview/1365170770?rfr_id=info%3Axri%2Fsid%3Aprimo

Lun Y., Lai, Kee-hung, Wong Christina. W.Y, and Cheng T.C.E. (2016). Green Shipping Management (Shipping and Transport Logistics)
Retrieved from
<https://link-springer-com.proxy.bib.uottawa.ca/content/pdf/10.1007%2F978-3-319-26482-0.pdf>

7 Major Developments in Autonomous Shipping in 2018 (2018, December 27). MI News Network. *Marine Insight*.
Retrieved
<https://www.marineinsight.com/know-more/7-major-developments-in-autonomous-shipping-in-2018/>

Maragkogianni A.; Papaefthimiou S.; Zopounidis C. (2016). Mitigating shipping emissions in European ports: Social and environmental benefits. (SpringerBriefs in applied sciences and technology).
Retrieved from
<https://link-springer-com.proxy.bib.uottawa.ca/content/pdf/10.1007%2F978-3-319-40150-8.pdf>

Maritime Industry Foundation (2019). Marine Insurance. The Maritime Industry Knowledge Centre.
Retrieved from
<https://www.maritimeinfo.org/en/Maritime-Directory/marine-insurance>

Marine Traffic (2018). What is the Automatic Identification System (AIS)?
Retrieved from
<https://help.marinetraffic.com/hc/en-us/articles/204581828-What-is-the-Automatic-Identification-System-AIS->

Maritime Safety and Security Information Centre (2019). Global Integrated Shipping Information System.

Retrieved from

<https://mssic.id/global-integrated-shipping-information-system/>

Maritime Unmanned Navigation through Intelligence in Network (MUNIN) (2016i). Research in Maritime Autonomous Systems Project Results and Technology Potentials.

Retrieved from

<http://www.unmanned-ship.org/munin/wp-content/uploads/2016/02/MUNIN-final-brochure.pdf>

Maritime Unmanned Navigation through Intelligence in Network (MUNIN) (2016ii). Maritime Unmanned Navigation through Intelligence in Networks. Munin's Rationale.

Retrieved from

<http://www.unmanned-ship.org/munin/about/munins-rational/>

MARPOL Annex VI (2008). MARPOL Annex VI NOx Technical Code and Sox explained.

Retrieved from

<https://www.marpol-annex-vi.com/marpol-annex-vi/>

McLaughlin E., Andone D. and Holcombe M. (2019, September 2). Dorian ponds Bahamas as hurricane warnings are issued for Florida coast. *CNN*

Retrieved from

<https://www.cnn.com/2019/09/01/us/hurricane-dorian-sunday-wxc/index.html>

Mead R. & Andrews T.G. (2009). International Management Fourth Edition. West Sussex England, Wiley.

Merk O. (2014). Shipping Emissions in Ports. *International Transport Forum Discussion Papers*, No. 2014-20. Organization for Economic Cooperation and Development (OECD) Publishing Paris

Retrieved from

<https://www.oecd-ilibrary.org/docserver/5jrw1kctc83r1-en.pdf?expires=1562697405&id=id&accname=guest&checksum=40CA89B1DDD1EABF430D7CAE5A487C60>

Metzger D. (2016). Private Governance Can Increase Shipping's Efficiency and Reduce Its Impacts. *Vanderbilt Journal of Transnational Law*, 49 (4), 1143.

Retrieved from

<https://web-b-ebSCOhost-com.proxy.bib.uottawa.ca/ehost/pdfviewer/pdfviewer?vid=2&sid=57dde43b-6bcb-4b3e-afb0-ddb26d1b5098%40sessionmgr101>

Mims C. (2010). Bunker Fuel: Exhaust from Ships Kills 90,000 People Every Year. September 2010, Vol. 303, Issue 3, p.72. *Scientific American*.

Retrieved from

<https://web-a-ebSCOhost-com.proxy.bib.uottawa.ca/ehost/detail/detail?vid=2&sid=570acf2d-2b45-47e5-a565-880975ca8f91%40sdc-v-sessmgr01&bdata=JnNpdGU9ZWwhvc3QtbGl2ZQ%3d%3d#AN=52888727&db=a9h>

Molenaar E. (2016). Port and Coastal States. *The Oxford Handbook of the Law of the Sea*. Edited by Donald Rothwell, Alex Oude Elferink, Karen Scott and Tim Stephens

Retrieved from

<https://www.oxfordhandbooks.com/view/10.1093/law/9780198715481.001.0001/oxfordhb-9780198715481-e-13?print=pdf>

Monios J. & Wilmsmeier G. (2018). Maritime Mobilities. (First ed., Routledge studies in transport analysis)

Retrieved from

<https://www-taylorfrancis-com.proxy.bib.uottawa.ca/books/e/9781315311371>

Mukherjee P. and Li Y. (2013). Multimodality, Short Sea Shipping and the Rotterdam Rules in the Chinese Context: Selected Law and Policy Issues in Perspective. *Journal of Transportation Law, Logistics and Policy* 79 (3), 223-244.

Retrieved from

<https://web-b-ebSCOhost-com.proxy.bib.uottawa.ca/ehost/pdfviewer/pdfviewer?vid=1&sid=8acc4632-e932-4832-b469-89a06539fff4%40pdc-v-sessmgr06>

Munro, M. (2010, June). Scientists unite to decry deniers of climate change. *Canadian Centre for Policy Alternatives (CCPA) Monitor*, Vol. 17, 3.
Retrieved from
<https://search-proquest-com.proxy.bib.uottawa.ca/docview/577402470/fulltextPDF/8DB3A157EACA486APQ/1?accountid=14701>

Nast T. (2013). The Response of the International Shipping Industry to Global Climate Change. *Journal of Maritime Law and Commerce*, 44. (1), 29-45.
Retrieved from
<https://web-a-ebSCOhost-com.proxy.bib.uottawa.ca/ehost/pdfviewer/pdfviewer?vid=1&sid=62d8f6f2-d65c-4bfd-a468-1e4368ecf971%40sdc-v-sessmgr05>

National Oceanic and Atmospheric Administration (NOAA) (2019i). Global Climate Report Annual 2016. National Centres for Environmental Information.
Retrieved from
<https://www.ncdc.noaa.gov/sotc/global/201613>

National Oceanic and Atmospheric Administration (NOAA) (2019ii). Assessing the Global Climate in 2018. National Centres for Environmental Information. U.S. Department of Commerce. Ocean and Coasts Education Resources.
Retrieved from
<https://www.ncei.noaa.gov/news/global-climate-201812>

National Oceanic and Atmospheric Administration (NOAA) (2019iii). Assessing the Global Climate in 2017. National Centres for Environmental Information.
Retrieved from
<https://www.ncei.noaa.gov/news/global-climate-201712>

National Oceanic and Atmospheric Administration (NOAA) (2019iv). Global summary information - December 2015. National Centres for Environmental Information.
Retrieved from
<https://www.ncdc.noaa.gov/sotc/summary-info/global/201512>

National Oceanic and Atmospheric Administration (NOAA) (2019v). Ocean Acidification. National Centres for Environmental Information
Retrieved from
<https://www.noaa.gov/resource-collections/ocean-acidification>

National Oceanic and Atmospheric Administration (NOAA) (2019vi). 1976: A Winter of Ship Accidents. Office of Response and Restoration.
Retrieved from
<https://response.restoration.noaa.gov/oil-and-chemical-spills/significant-incidents/argo-merchant-oil-spill/1976-winter-ship-accidents.htm>

National Oceanic and Atmospheric Administration (NOAA) (2019vii). Argo Merchant. Emergency Response Division Office of Response and Restoration, National Ocean Service. *Incident News*
Retrieved from
<https://incidentnews.noaa.gov/incident/6231>

Neopolia to build two sail-powered ro-ro cargo ships for Neoline (2019, July 4). *Ship Technology*.
Retrieved from
<https://www.ship-technology.com/news/neoline-neopolia-ro-ro-cargo-ships/>

Nichioh Maru - The First Car Carrier with Solar Power System (2016, July 11) *Marine Insight*
Retrieved from
<https://www.marineinsight.com/types-of-ships/nichioh-maru-the-first-car-carrier-with-solar-power-system/>

Nunes, R., Alvim-Ferraz, M., Martins, F. & Sousa S. (2017). Assessment of Shipping Emissions on Four Ports of Portugal. *Environmental Pollution*, 231 (Pt 2), 1370-1379.
Retrieved from
https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/02697491/v231ipart_2/1370aoseofpop.xml

Nguyen, S. (2018). Development of an MCDM Framework to Facilitate Low Carbon Shipping Technology Application. *Asian Journal of Shipping and Logistics* 34 (4), 317–327.

Retrieved from

<https://doi.org/10.1016/j.ajsl.2018.12.005>

O'Brien C. (2018, September 21). Key advantages and disadvantages of ship Autonomy. *Safety4Sea*

Retrieved from

<https://safety4sea.com/key-advantages-and-disadvantages-of-ship-autonomy/>

Oiltanking (2019i). LNG (Liquified Natural Gas).

Retrieved from

<https://www.oiltanking.com/en/news-info/glossary/details/term/lng-liquefied-natural-gas.html>

Oiltanking (2019ii). Marine Diesel Oil (MDO) and Intermediate Fuel Oil (IFO).

Retrieved from

<https://www.oiltanking.com/en/news-info/glossary/details/term/marine-diesel-oil-mdo.html>

Oiltanking (2019iii) WAS (2019). Heavy Fuel Oil (HFO).

Retrieved from

<https://www.oiltanking.com/en/news-info/glossary/details/term/heavy-fuel-oil-hfo.html>

Olivier, J., Janssens-Maenhout, G., Muntean, M., & Peters, J. (2016). Trends in global CO2 emissions: 2016 Report. European Commission, Joint Research Centre (JRC), Directorate C - Energy, Transport and Climate; PBL Netherlands Environmental Assessment Agency, The Hague.

Retrieved from

https://edgar.jrc.ec.europa.eu/news_docs/jrc-2016-trends-in-global-co2-emissions-2016-report-103425.pdf

Olmer N., Comer B., Roy B., Mao X., and Rutherford D. (2017i). Greenhouse Gas Emissions from Global Shipping, 2013-2015 dated 17/10/2017. Study: Global Shipping emissions rise as IMO meets to discuss climate action. The International Council on Clean Transportation (ICCT).

Retrieved from

<https://www.theicct.org/publications/GHG-emissions-global-shipping-2013-2015>

<https://www.theicct.org/news/study-global-shipping-emissions-rise>

Olmer N., Comer B., Roy B., Mao X., and Rutherford D. (2017ii). Greenhouse gas emissions from global shipping, 2013-2015, Detailed Methodology - dated October 2017. The International Council on Clean Transportation (ICCT).

Retrieved from

[https://www.theicct.org/sites/default/files/Global-shipping-GHG-emissions-2013-](https://www.theicct.org/sites/default/files/Global-shipping-GHG-emissions-2013-2015_Methodology_17102017_vF.pdf)

[2015 Methodology 17102017 vF.pdf](https://www.theicct.org/sites/default/files/Global-shipping-GHG-emissions-2013-2015_Methodology_17102017_vF.pdf)

Panayides P., Lambertides N., Savva C. (2011). The relative efficiency of shipping companies. *Transportation Research Part E* 47(5), 681-694.

Retrieved from

[https://journals-scholarsportal-](https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/13665545/v47i0005/681_treosc.xml)

[info.proxy.bib.uottawa.ca/pdf/13665545/v47i0005/681_treosc.xml](https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/13665545/v47i0005/681_treosc.xml)

Parker M. and Christensen J. (2019 June 18). Banks Launch green charter to help shipping reduce its carbon footprint. *World Economic Forum*

Retrieved from

[https://www.weforum.org/agenda/2019/06/how-banks-are-leading-shippings-green-](https://www.weforum.org/agenda/2019/06/how-banks-are-leading-shippings-green-transition/)

[transition/](https://www.weforum.org/agenda/2019/06/how-banks-are-leading-shippings-green-transition/)

Paxian A., Eyring V., Beer W., Sausen R., and Wright C. (2010). Present-Day and Future Global Bottom-Up Ship Emission Inventories Including Polar Routes.

Environmental Science and Technology, 44 (4), 1333-1339.

Retrieved from

<https://pubs-acrs-org.proxy.bib.uottawa.ca/doi/pdf/10.1021/es9022859>

Pearce F. (2016, May 19). After Paris, A Move to Reign in Emissions by Ships and Planes. Dated 19th May 2016. *Yale Environment 360*. Published at the Yale School of Forestry and Environmental Studies.

Retrieved from

https://e360.yale.edu/features/reduce_co2_emissions_shipping_aviation_regulation_paris

Pérez-Navarro, A.; Alfonso D.; Ariza H.E.; Cárcel J.; Correcher A.; Escrivá-Escrivá, G.; Hurtado E.; Ibanez F.; Penalvo E.; Roig R.; Roldan C.; Sanchez C.; Segura I.; Vargas C. (2016). Experimental verification of hybrid renewable systems as feasible energy sources. *Renewable Energy*, 86(C), 384-391.

Retrieved from

https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/09601481/v86icomplete/384_evohrsafes.xml

Perry, M. (2019, June 11). Chart of the day: World's Top Ten Oil Producing Countries 1965 to 2018. [Blog Post] *American Enterprise Institute*

Retrieved from

<https://www.aei.org/carpe-diem/chart-worlds-top-ten-oil-producing-countries-1965-to-2018/>

Piesing M. (2018, January 4). Cargo Ships are the world's worst polluters, so how can they be made to go green? *iNews The Essential Daily*

Retrieved from

<https://inews.co.uk/news/long-reads/cargo-container-shipping-carbon-pollution/>

Psaraftis, H. (2019). *Sustainable shipping: A cross-disciplinary view*. Springer

Retrieved from

<https://link-springer-com.proxy.bib.uottawa.ca/content/pdf/10.1007%2F978-3-030-04330-8.pdf>

Purdy C. (2018, December 6). The globe's biggest maritime shipping company is abandoning fossil fuels. Shipping Solutions. *Quartz*.

Retrieved from

<https://qz.com/1486377/global-shipper-maersk-says-it-will-eliminate-fossil-fuels-by-2050/>

Putin, Niinisto want HFO-Free Arctic (2018, August 24). *World Maritime News*
Retrieved from
<https://worldmaritimenews.com/archives/259413/putin-niinisto-want-hfo-free-arctic/>

Rauhala E. (2019, June 18). On Monday Canada declared a 'climate emergency.' On Tuesday, it approved a pipeline expansion. *The Washington Post*.
Retrieved from
https://www.washingtonpost.com/world/on-monday-canada-declared-a-climate-emergency-on-tuesday-it-approved-a-pipeline-expansion/2019/06/18/242faca6-9137-11e9-956a-88c291ab5c38_story.html?utm_term=.07bdc8749954

Rehkopf L. (2003). Greenhouse Effect. *Environmental Encyclopedia* Edited by Marci Bortman, Peter Brimblecombe, Mary Ann Cunningham. Vol. 1 3rd ed. Detroit, MI: Gale, 2003 p 671-674.
Retrieved from
<http://go.galegroup.com.proxy.bib.uottawa.ca/ps/i.do?p=GURL&u=otta77973&v=2.1&it=r&id=GALE%7CCX3404800708&inPS=true&linkSource=interlink&sid=AONE>

Rehmatulla N. and Smith T. (2015). Barriers to energy efficiency in shipping: A triangulated approach to investigate the principal agent problem. *Energy Policy* 84(C), 44-57.
Retrieved from
https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/03014215/v84icomplete/44_bteeistitpap.xml

Reichel M., Minchev A., Larsen N. (2014) Trim optimisation - Theory and Practice. *TransNav, International Journal and Marine Navigation and Safety of Sea Transportation* Volume 8, # 3, September 2014 p. 387–392.
Retrieved from
<https://doi.org/10.12716/1001.08.03.09>

Richardson B. (2004). [Review of Unnatural Law: Rethinking Canadian Environmental Law and Policy. (Book Review)]." *Journal of Environmental Law and Practice*, 13 (2)
Retrieved from
<https://search-proquest-com.proxy.bib.uottawa.ca/>

Richardson, M. (2002). Crimes under flags of convenience – in a depressed shipping market, poor nations sell flags for criminal venture. *Maritime Studies*, 2002(127), 22-24.
Retrieved from
https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/07266472/v2002i0127/22_cufocinsffcv.xml

Rødseth, Ø. and Burmeister, H. (2012). Developments toward the unmanned ship, Proceedings of International Symposium Information on Ships – ISIS 2012, Hamburg, Germany, August 30-31, 2012
Retrieved from
<https://pdfs.semanticscholar.org/6a8a/771d52e210f36d48cd345a13aab294d83780.pdf>

Rojon, I., & Smith, T., (2014). On the attitudes and opportunities of fuel consumption monitoring and measurement within the shipping industry and the identification and validation of energy efficiency and performance interventions. UCL Energy Institute, London, UK
Retrieved from
<http://discovery.ucl.ac.uk/1472842/1/on%20the%20attitudes%20and%20opportunities%20of%20monitoring.pdf>

Rotor Sails Fitted on board Maersk's Tanker in a World's 1st (2018, August 30). *World Maritime News*
Retrieved from
<https://worldmaritimenews.com/archives/259777/rotor-sails-fitted-on-board-maersk-tanker-in-a-worlds-1st/>

Rowell A. (2017, October 24). How the shipping industry bought a global pass on emissions. *Ecowatch*.
Retrieved from
<https://www.ecowatch.com/paris-agreement-shipping-industry-2500715626.html>

Royal Academy of Engineering (2013). Future Ship Powering Options. Exploring alternative methods of ships propulsion. July 2013
Retrieved from
http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Air%20pollution/Future_ship_powering_options_report.pdf

Rutherford D. and Miller J. (2019, March 22). Silent but deadly: The case of shipping emissions. [Blog post] *The International Council on Clean Transportation*. Retrieved from <https://www.theicct.org/blog/staff/silent-deadly-case-shipping-emissions>

Sailors for the Sea (2019). Renewable Energy. Retrieved from <https://www.sailorsforthesea.org/programs/green-boating-guide/renewable-energy>

Saul J. (2019, September 23). Shipping sector sets course, for zero carbon vessels, fueled by 2030. *Reuters*. Retrieved from <https://www.reuters.com/article/us-climate-change-un-shipping/shipping-sector-sets-course-for-zero-carbon-vessels-fuel-by-2030-idUSKBN1W81B8>

Sea\ng: LNG to Play Central Role in IMO's Sulphur Cap (2018 April 20). *World Maritime News*. Retrieved from <https://worldmaritimenews.com/archives/250316/sea\ng-lng-to-play-central-role-in-imos-sulphur-cap/>

Seck S. (2018). Climate Change, Corporate Social Responsibility, and the Extractive Industries. *Journal of Environmental Law and Practice*, 31(3), 271-292. Retrieved from https://search-proquest-com.proxy.bib.uottawa.ca/docview/2082583765?rfr_id=info%3Axri%2Fsid%3Aprimo

Shell (2019i). Natural Gas And Its Advantages. Retrieved from <https://www.shell.com/energy-and-innovation/natural-gas/natural-gas-and-its-advantages.html>

Shell (2019ii). Liquefied Natural Gas (LNG).

Retrieved from

<https://www.shell.com/energy-and-innovation/natural-gas/liquefied-natural-gas-lng.html>

Shi L. (1999). Successful Use of the Tacit Acceptance Procedure to Effectuate Progress in International Maritime Law. University of San Francisco *Maritime Law Journal*, 11(2), 299-332. Heinonline.

Retrieved from

https://heinonline-org.proxy.bib.uottawa.ca/HOL/Page?collection=journals&handle=hein.journals/usfm11&id=314&men_tab=srchresults

Shi X. (2015). Making Ends Meet: Using a Market-Based Approach To Incentivize Foreign Vessels To Comply With The Air Emission Standards Of Marpol Annex VI. *Penn State Journal of Law and International Affairs*. Volume 4 No. 1. pp 556-601.

Retrieved from

<https://elibrary.law.psu.edu/cgi/viewcontent.cgi?article=1124&context=jlia>

Ship-board Energy Efficiency Measures - Various considerations (2015). *Ships Business.com*.

Retrieved from

<http://shipsbusiness.com/energy-efficiency-measures-trim-optimization.html>

Ship Solar Power System Installed on Large General Cargo Ship MV Panamana (2019 May 25). *Hellenic Shipping News*.

Retrieved from

<https://www.hellenicshippingnews.com/ship-solar-power-system-installed-on-large-general-cargo-ship-mv-panamana/>

Smith, T.; Jalkanen, J.; Anderson, B.; Corbett, J.; Faber, J.; Hanayama, S.; O’Keeffe, E.; Parker, S.; Johansson, L.; Aldous, L.; Raucci, C.; Traut, M.; Ettinger, S.; Nelissen, D.; Lee, D.; Ng, S.; Agrawal, A.; Winebrake, J.; Hoen, M.; Chesworth, S.; Pandey, A. (2015). Third IMO GHG Study 2014; International Maritime Organization (IMO) London, UK, April 2015.

Retrieved from

<http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Third%20Greenhouse%20Gas%20Study/GHG3%20Executive%20Summary%20and%20Report.pdf>

Spross J. (2019, February 26). Why cargo ships might (literally) sail the high seas again. *The Week*

Retrieved from

<https://theweek.com/articles/825647/why-cargo-ships-might-literally-sail-high-seas-again>

Statista (2019). Number of Ships in the world merchant fleet as of January 1, 2018, by type. The Statistics Portal.

Retrieved from

<https://www.statista.com/statistics/264024/number-of-merchant-ships-worldwide-by-type>

Stefanini S. (2018, April 9). Arctic countries call for regional heavy fuel oil ban at UN shipping talks. *Climate Home News*

Retrieved from

<https://www.climatechangenews.com/2018/04/09/arctic-countries-call-regional-heavy-fuel-oil-ban-un-shipping-talks/>

Stevenson F. (2017). The Duty to Consult the Inuit in Canada’s Black Carbon Policy Inaction. *Journal of Environmental Law and Practice*, 30(2), 139-199.

Retrieved from

https://search-proquest-com.proxy.bib.uottawa.ca/docview/1900794580?rfr_id=info%3Axri%2Fsid%3Aprim

Styhre L., Winnes H., Black J., Lee J., Le-Griffin H. (2017). Greenhouse gas emissions from ships in ports - Case Studies in four continents. *Transportation Research Part D*, 54, 212-224.

Retrieved from

<https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/13619209/v54:complete/212ggesipcsifc.xml>

Taylor A. (2019, April 25). Photos: Climate-Change Protests Around the World. *The Atlantic*

Retrieved from

<https://www.theatlantic.com/photo/2019/04/photos-climate-change-protests-around-world/588016/>

The Canadian Legal Information Institute - CanLII (2014). British Columbia Workers' Compensation Appeal Tribunal — British Columbia. 2014 CanLII 45740 (BC WCAT) — 2014-01-16.

Retrieved from

<https://www.canlii.org/en/bc/bcwcaw/doc/2014/2014canlii45740/2014canlii45740.html?searchUrlHash=AAAAQAUIInNoaXBwaW5nIGVtaXNzaW9ucyIAAAAAAQ&resultIndex=1>

The Global Facilitation Partnership for Transportation and Trade (2013). Multimodal Transport.

Retrieved from

<https://gfptt.org/node/70>

The Global MTCC Network (GMN) (2018). GMN Summary Report, Issue 4, July - December 2018. International Maritime Organization. Project funded by the European Union.

Retrieved from

<http://www.mtccasia.org/wp-content/uploads/2019/03/GMN-Summary-report-FINAL.pdf>

The International Council on Clean Transportation (ICCT) (2018) - The International Maritime Organization's Initial Greenhouse Gas Strategy. April 2018.

Retrieved from

https://www.theicct.org/sites/default/files/publications/IMO_GHG_StrategyFinalPolicyUpdate042318.pdf

Thuong L. (1987). From Flags of Convenience to Captive Ship Registries.

Transportation Journal (American Society of Transportation & Logistics Inc.), 27(2), 22

Retrieved from

<https://web-b-ebSCOhost.com.proxy.bib.uottawa.ca/ehost/pdfviewer/pdfviewer?vid=1&sid=54a502c9-ad41-4386-b9b7-afccce8fac15%40sessionmgr103>

Toh, R., & Phang, S. (1993). Quasi-flag of convenience shipping: The wave of the future. *Transportation Journal*, 33 (2), 31-39

Retrieved from

<https://search-proquest.com.proxy.bib.uottawa.ca/docview/204588540?accountid=14701>

TransportPolicy.net (2018). International: Marine: Emissions.

Retrieved from

<https://www.transportpolicy.net/standard/international-marine-emissions/>

Tucker W. (2012). Deceitful Tongues: Is Climate Change Denial a Crime? *Ecology Law Quarterly*, 39 (3), 831-894.

Retrieved from

<https://web.a.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=1&sid=5b5c88c9-fcb6-4ade-b147-1350dbd3abbf%40sessionmgr4006>

Tutton M. (2019, May 1). UK Parliament declares 'climate emergency'. *Cable News Network (CNN)*.

Retrieved from

<https://www.cnn.com/2019/05/01/europe/uk-climate-emergency-scn-intl/index.html>

Union of Concerned Scientists (2018). Each Country's Share of CO2 Emissions.

Retrieved from

<https://www.ucsusa.org/global-warming/science-and-impacts/science/each-countrys-share-of-co2.html>

Union of Concerned Scientists (2019) Global Warming Science. The science is clear. Global warming is happening. We are the primary cause.

Retrieved from

<https://www.ucsusa.org/our-work/global-warming/science-and-impacts/global-warming-science#.W-obwThKiUk>

United Nations (1998). Kyoto Protocol to the United Nations Framework Convention on Climate Change. United Nations Framework Convention on Climate Change (UNFCCC)

Retrieved from

<https://unfccc.int/sites/default/files/kpeng.pdf>

United Nations (2018i). United Nations Conventions on the Law of the Sea of 10 December 1982. Overview and full text dated 28th March 2018. United Nations Oceans and Law of the Sea. Division for Ocean Affairs and the Law of the Sea.

Retrieved from

https://www.un.org/depts/los/convention_agreements/convention_overview_convention.

United Nations (2018ii). Global Maritime Energy Efficiency Partnerships (GloMEEP) Project by International Maritime Organization (United Nations entity). The Ocean Conference.

Retrieved from

<https://oceanconference.un.org/commitments/?id=15605>

United Nations (2019i). Climate Change.

Retrieved

<http://www.un.org/en/sections/issues-depth/climate-change/>

United Nations (2019ii). Sustainable Development Goal 14 - Conserve and sustainably use the oceans, seas and marine resources for sustainable development. Sustainable Development Goals Knowledge Platform.

Retrieved from

<https://sustainabledevelopment.un.org/sdg14>

United Nations (2019iii). Helping governments and stakeholders make the SDGs a reality. Sustainable Development Goals.

Retrieved from

<https://sustainabledevelopment.un.org/>

United Nations (2019iv). Oceans and Law of the Sea.

Retrieved from

<https://www.un.org/en/sections/issues-depth/oceans-and-law-sea/>

United Nations (2019v). The International Maritime Organization (IMO). 1 IMO's Technical Cooperation Programme fosters human and institutional capacity building in the maritime administrations of Member States, thereby augmenting the level of implementation and compliance.

Retrieved from

<https://www.un.org/regularprocess/content/international-maritime-organization-imo-1-imo%E2%80%99s-technical-cooperation-programme-fosters>

United Nations Conference on Trade and Development (UNCTAD) (2018i). 2018 e-Handbook of Statistics. Merchant Fleet.

Retrieved from

<https://stats.unctad.org/handbook/MaritimeTransport/MerchantFleet.html>

United Nations Conference on Trade and Development (UNCTAD) (2018ii). Review of Maritime Transport (2018). United Nations New York and Geneva 2018.

Retrieved from

https://unctad.org/en/PublicationsLibrary/rmt2018_en.pdf

United Nations Convention on the Law of the Sea (UNCLOS) (n.d). United Nations Convention on the Law of the Sea. UNCLOS+Annexes+RES+Agreement
Retrieved from
https://www.un.org/Depts/los/convention_agreements/texts/unclos/unclos_e.pdf

United Nations Development Programme (2017). Global Industry Alliance launched to support low carbon shipping. Dated 29/06/2017.
Retrieved from
<https://www.undp.org/content/undp/en/home/presscenter/articles/2017/06/29/global-industry-alliance-launched-to-support-low-carbon-shipping.html>

United Nations Environment Programme (UNEP) (2011). Bridging the Emissions Gap. A UNEP Synthesis Report
Retrieved from
<http://wedocs.unep.org/bitstream/handle/20.500.11822/7996/-Bridging%20the%20Emissions%20Gap%20%20%20A%20UNEP%20Synthesis%20Report-20111075.pdf?sequence=3&isAllowed=y>

United Nations Framework Convention on Climate Change (UNFCCC) (n.d.). Kyoto Protocol To The United Nations Framework Convention on Climate Change.
Retrieved from
<https://unfccc.int/resource/docs/convkp/kpeng.html>

United Nations Framework Convention on Climate Change (UNFCCC) (2019i). What is the Paris Agreement. The Paris Agreement.
Retrieved from
<https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement>
<https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement>

United Nations Framework Convention on Climate Change (UNFCCC) (2019ii). United Nations Climate Change. What is the Kyoto Protocol?
Retrieved from
<https://unfccc.int/process-and-meetings/the-kyoto-protocol/what-is-the-kyoto-protocol/what-is-the-kyoto-protocol>

United Nations Framework Convention on Climate Change (UNFCCC) (2019iii). History of the Convention.

Retrieved from

<https://unfccc.int/process/the-convention/history-of-the-convention#eq-1>

United Nations Framework Convention on Climate Change (UNFCCC) (2019iv).

Emissions from fuels used for international aviation and maritime transport.

Retrieved from

<https://unfccc.int/topics/mitigation/workstreams/emissions-from-international-transport-bunker-fuels>

United Nations Treaty Collection (2019). Navigation. Convention on the International Maritime Organization. Convention on the Intergovernmental Maritime Consultative Organization.

Retrieved from

https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XII-1&chapter=12&clang=en

https://treaties.un.org/doc/Treaties/1958/03/19580317%2005-05%20PM/Ch_XII_1p.pdf

United States Coast Guard (USCG) (2018). USCG IMO Homepage. U.S. Department of Homeland Security.

Retrieved from

<https://www.dco.uscg.mil/IMO/International-Maritime-Organization-Sub-committees-HWT/>

United States Energy Information Administration (2019i). Residual Fuel Oil.

Retrieved from

<https://www.eia.gov/tools/glossary/index.php?id=residual%20fuel%20oil>

United States Energy Information Administration (2019ii). Distillate Fuel Oil.

Retrieved from

<https://www.eia.gov/tools/glossary/index.php?id=distillate%20fuel%20oil>

United States Energy Information Administration (2019iii). What countries are the top producers and consumers of oil?

Retrieved from

<https://www.eia.gov/tools/faqs/faq.php?id=709&t=6>

United States Environmental Protection Agency (2017). Local Renewable Energy Benefits and Resources. Benefits of Renewable Energy.

Retrieved from

<https://www.epa.gov/statelocalenergy/local-renewable-energy-benefits-and-resources>

United States Environmental Protection Agency (2019i). Nitrogen Dioxide (NO₂) Pollution Basic Information about NO₂.

Retrieved from

<https://www.epa.gov/no2-pollution/basic-information-about-no2#Effects>

United States Environmental Protection Agency (2019ii). Particulate Matter (PM) Pollution. Particulate Matter (PM) Basics.

Retrieved from

<https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM>

United States Environmental Protection Agency (2019iii). Global Greenhouse Gas Emissions Data. Overview of Greenhouse Gases.

Retrieved from

<https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data>

<https://www.epa.gov/ghgemissions/overview-greenhouse-gases>

United States Environmental Protection Agency (2019iv). Residual Fuel Oil.

Retrieved from

<https://www.eia.gov/tools/glossary/index.php?id=residual%20fuel%20oil>

United States Environmental Protection Agency (2019v). Distillate Fuel Oil.

Retrieved from

<https://www.eia.gov/tools/glossary/index.php?id=Distillate%20fuel%20oil>

United States Environmental Protection Agency (2019vi). The Act to prevent pollution from ships (APPS) Enforcement Case Resolutions.

Retrieved from

<https://www.epa.gov/enforcement/act-prevent-pollution-ships-apps-enforcement-case-resolutions>

United States Environmental Protection Agency (2019vii). Black Carbon Research.

Retrieved from

<https://www.epa.gov/air-research/black-carbon-research>

Upgrading from automated to autonomous shipping (2019, January 9). *Safety4Sea*

Retrieved from

<https://safety4sea.com/upgrading-from-automated-to-autonomous-shipping/>

U.S. Department of Energy (2018). U.S. Energy Information Administration, Biomass explained. Biomass - renewable energy from plants and animals.

Retrieved from

https://www.eia.gov/energyexplained/?page=biomass_home

U.S. Energy Information Administration (2019). Renewable Energy Explained.

Retrieved from

https://www.eia.gov/energyexplained/?page=renewable_home

USLegal.com (2019). Flag State Law and Legal Definition.

Retrieved from

<https://definitions.uslegal.com/f/flag-state/>

Vermeire M.B. (2012). Everything You Need to Know About Marine Fuels. Ghent, Belgium. Published by Chevron Global Marine Products June 2012

Retrieved from

https://www.chevronmarineproducts.com/content/dam/chevron-marine/Brochures/Chevron_EverythingYouNeedToKnowAboutFuels_v3_1a_DESKTOP.pdf

Vesselfinder.com (2019). Maersk Pelican – Crude Oil Tanker

Retrieved from

<https://www.vesselfinder.com/vessels/MAERSK-PELICAN-IMO-9319686-MMSI-565686000>

Video: World's First Autonomous Zero Emissions Ship to be Ready by 2020 (2017, May 9) *World Maritime News*.

Retrieved from

<https://worldmaritimeneews.com/archives/219669/video-worlds-first-autonomous-zero-emissions-ship-to-be-ready-by-2020/>

Walker T. (2016). Green Marine: An environmental program to establish sustainability in marine transportation. *Marine Pollution Bulletin* 105 (1), 199 -207.

Retrieved from

https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/0025326x/v105i0001/199_gmaeptesimt.xml

Wang H. (2014, July 9). The end of the era of heavy fuel oil in maritime shipping. [Blog post] *The International Council on Clean Transportation*.

Retrieved from

<https://theicct.org/blogs/staff/end-era-heavy-fuel-oil-maritime-shipping>

Watts R. (2007). *Global Warming And The Future Of The Earth. Synthesis Lectures On Energy And The Environment: Technology, Science And Society #1*. San Rafael, Calif. (1537 Fourth Street, San Rafael, CA 94901 USA): Morgan & Claypool.

Retrieved from

<https://www-morganclaypool-com.proxy.bib.uottawa.ca/doi/pdf/10.2200/S00098ED1V01Y200709EGY001>

WestlawNext.Canada (2009). British Columbia Maritime Employers Association and International Longshore and Warehouse Union-Canada (ILWU), Re: CarswellNat 6839; 99 C.L.A.S. 3Canada Arbitration Federal July 27, 2009Docket: C-016/09Subject: Labour; Public.

Retrieved from

<https://nextcanada-westlaw-com.proxy.bib.uottawa.ca>
[https://nextcanada.westlaw.com/Link/Document/Blob/1e48d159847f35b56e0440021280d7cce.pdf?targetType=inline&originationContext=document&transitionType=DocumentImage&uniqueId=556ab0bb-ccc8-493d-8186-7cc0cf7830a5&contextData=\(sc.Search\)](https://nextcanada.westlaw.com/Link/Document/Blob/1e48d159847f35b56e0440021280d7cce.pdf?targetType=inline&originationContext=document&transitionType=DocumentImage&uniqueId=556ab0bb-ccc8-493d-8186-7cc0cf7830a5&contextData=(sc.Search))

Wilcox M. (2019, April 22). Maersk charts course toward sustainable shipping. *GreenBiz Group Inc.*

Retrieved from

<https://www.greenbiz.com/article/maersk-charts-course-toward-sustainable-shipping>

Wind-powered ships are making a comeback (2018, October 4). *The Economist*.

Retrieved from

<https://www.economist.com/business/2018/10/04/wind-powered-ships-are-making-a-comeback>

Wolfrom M. (2019, October 21). Shipping firms look to sail into the future. *Phys.org News*

Retrieved from

<https://phys.org/news/2019-10-shipping-firms-future.html>

World Health Organization (2018). How Air Pollution Is Destroying Our Health.

Retrieved from

<http://www.who.int/air-pollution/news-and-events/how-air-pollution-is-destroying-our-health>

World Population Review (2019). Landlocked Countries 2019.

Retrieved from

<http://worldpopulationreview.com/countries/landlocked-countries/>

World Shipping Council (2019). Partners in Trade; About the Industry; Before Container Shipping

Retrieved from

<http://www.worldshipping.org/about-the-industry/history-of-containerization/before-container-shipping>

Wright D. (2018). Tsleil-Waututh Nation v. Canada (Attorney General): A case of easier said than done. The University of Calgary Faculty of Law blog. Ablawg.ca

Retrieved from

http://ablawg.ca/wp-content/uploads/2018/09/Blog_DVW_TMX_Sept2018.pdf

Zhong W. and Haigh J. (2013). The greenhouse effect and carbon dioxide. *Weather*, 68(4), 100-105.

Retrieved from

https://journals-scholarsportal-info.proxy.bib.uottawa.ca/pdf/00431656/v68i0004/100_tgeacd.xml