THE IMPORTANCE OF SUSTAINABILTY FOR INNOVATIVE SOLUTIONS AIMED AT SOLVING THE POLLUTION OF THE OCEANS

A. Sortino a, S. Vacante b, A. Andò a, M. Mauro c, V. Dagostino a, G. De Leo d, F.G. Beltrame Quattrocchi a,e1[32]

ABSTRACT

A wide range of pollutions affects our oceans. Greenhouse gas emissions, plastic waste, maritime traffic and noise from deep sea mining are example of pollutants. Innovative solutions in different areas from technology, to policy, strategy system innovation and process innovation have been scientifically researched and developed. However, the concept of sustainable innovative solutions is fundamental. For example, a new technological innovation, resulting from scientific research activity, must be sustainable in itself in order to benefit the society and the environment. In this paper, we highlight three innovative and sustainable solutions capable of addressing the rapidly worsening pollution of the oceans. The first solution is a combined process and technological innovation with the goal of reducing marine pollution from plastic waste. The second is a technological innovation for the reduction of pollutants in maritime traffic and the third is a policy innovation aimed at drafting guidelines for the acoustic impact of extraction activities related to Deep Sea Mining.

Keywords: sustainability, innovation, environmental impact, pollution, deep sea mining, hydrogen, marine litter.

LIST OF ACRONYMS

BC- Blue Carbon

BE- Blue Economy

CCS- Carbon Capture and Storage

ECA- Emission Control Area

FC- Fuel Cell

GG- Greenhouse Gas

IMO- International Maritime Organization

ISA- International Seabed Authority

MH- Metal Hybrids

MIT- Ministry of Infrastructure and Transport

PEM-Polymer Electrolyte Membrane

SCR-Selective Catalytic Reduction

SMS- Seafloor Massive Sulfide

SOI- Sustainability Oriented Innovation

WCED- World Commission on Environment and Development.

[32] a ENR - Ente Nazionale di Ricerca per la promozione e standardizzazione, Via F. Crispi, 248 - 90139, Palermo, Italy. Contacts: +39 0917439545, info@enrstandards.org.

b Centro per gli studi di Tecnica Navale CETENA S.p.A., Via I. D'Aste, 5 – 16121, Genova, Italy. Contacts: +39 0105995460, info@cetena.it.

c Dipartimento di Scienze e Tecnologie Biologiche Chimiche e Farmaceutiche (STEBICEF), Università degli Studi di Palermo -, Via Archirafi, 18 - 90123 Palermo, Italy. Contacts: manuela.mauro01@unipa.it

.

d College of Allied Health Sciences, Augusta University, 987 St. Sebastian Way, EB 204, Augusta, Georgia - 30912, USA. Contacts: +1 7067218792, gdeleo@augusta.edu.

e Dipartimento di Informatica, Bioingegneria, Robotica e Ingegneria dei Sistemi (DIBRIS), Università degli Studi di Genova -, Viale Causa, 13 - 16145 Genova, Italy. Contacts: +39 0103352707, francesco.beltrame@unige.it.

INTRODUCTION

Since the late 1990s, researchers have discouraged the practice of dividing pollution into categories (air, water, land) and they have stated that there is only `one pollution' because, by traveling streams and rivers, oceans accumulate the majority of pollution we produce on land, even if we live far from the coasts. Oceans control the weather, clean the air, provide food to the world, and offer work to millions of people.

Over the past 150 years, due mainly to the continuous increasing of commercial activities around the world, the global consumption of oil, gas and coal has exponentially grown, and it is now considered the main cause of high amounts of Greenhouse Gas (GHG) emissions. These emissions have contributed to increase, in average, the temperatures around the world by 1 degree Celsius.

In 2018, the International Maritime Organization (IMO) has implemented a strategy aimed to reduce the GHG emissions from maritime traffic by at least 50% by 2050. From January 1, 2020 all ships operating outside the Emission Control Areas (ECA*)* will have to either use a fuel with a sulfur content of 0.5% or install on board a scrubber, a system for cleaning exhaust gases. Sulfur oxide emissions produce sulfur sulfate aerosols that increase risks to human health. Sulfur oxides, nitrogen oxides and particulate matter cause premature death, including lung cancer and cardiovascular diseases. These pollutants also contribute to acidification in terrestrial and aquatic environments (Transport Environment, 2019). Nitrogen oxides, in addition to causing acidification and eutrophication of land, lakes and seas, contribute to the formation of particles that are moved over long distances in air (Winnes, Fridell, Yaramenka, Nelissen, Faber, & Ahdour, 2016).

Every year, around 300 million tons of plastic are produced worldwide, of which only 14% is recycled, and 10% ends up in the sea. An estimated 270 thousand tons of plastic float on the surface of the oceans; in the Pacific Ocean the amount of floating plastic waste is twice the surface area of France. Plastic constitutes about 80% of the solid waste present in the seas of the world. Plastic is the main type of waste that we find on the beaches or deposited on the seabed (Galgani, Hanke, Werner, & De Vrees, 2013). Of this waste, 80% is of terrestrial origin, only 20% is due to activities taking place on the sea (Andrady, 2011).

Since the world population keeps growing, the demand for minerals and metals necessary to produce various products continues to increase. Valuable mineral deposits have been found under the floors of the oceans around the world and in the near future such deposits will need to be extracted (Rakhyun, 2017; Miller, Thompson, Johnston, & Santillo, 2018; Petersen, Krätschell, Augustin, Jamieson, Hein, & Hannington, 2016). Example of mineral deposits are: Seafloor Massive Sulfide (SMS) in Papua Nuova Guinea, cobalt-rich ferro manganic crusts which are found at seamounts worldwide with the largest deposits in the Pacific Ocean and manganese nodules on the abyssal plains, particularly in the Pacific Ocean (Miller, Thompson, Johnston, & Santillo, 2018; Petersen, Krätschell, Augustin, Jamieson, Hein, & Hannington, 2016; Hein, Mizell, Koschinsky, & Conrad, 2013). The exploitation of the floors of the oceans is managed by the International Seabed Authority (ISA), which is tasked with the writing of an international agreement, a *mining code,* before the start of the extraction activities. The goal of the code is to prevent and to reduce the impacts on biodiversity, while guaranteeing a fair distribution of benefits among the populations (Mengerink, et al., 2014).

Due the over-exploitation of nature, the environment is deteriorating. For this reason, environmental awareness has grown in society and it is considered essential for environmental sustainability. The growing concerns for exploited resources combined with environmental degradation have led to a demand for sustainability. In 1987 with the publication of the Brundtland Report of the World Commission on Environment and Development (WCED) sustainability was defined as: "*Sustainable development is development that meets the needs of present without compromising the ability of future generations to meet their own needs.*"

During the last wave of economic development, human activities in the oceans have increased significantly. Nations and institutions around the world are developing new governance guidelines and laws characterized by policy integration and by a commitment to sustainability. Sustainable development is a fundamental principle in most national and international policies related to the oceans around the world. Sustainable development aims to meet the needs of the present, without compromising the possibility for future generations to see their needs respected.

Thirty years ago, the interest was mainly focused on technological change, finished products and their supply chain, current innovators draw on knowledge through networks, systems that use free innovation are part of the communities affected by the mode of operation, and innovation is done locally but with global reach (OECD, 2008). The definition of innovation is “the introduction of something new” (Merriam-Webster's collegiate dictionary, 2020). Innovation is a process of change which increases the value and heritage of knowledge. The innovative process passes through the generation of new ideas and their transformation into output. While innovation is often used as a word by itself, it is important to note that, in the absence of clarification on what type of innovation is under discussion, there is a risk that it will be ill-defined. We believe that the word innovation should not be used by itself, but it should always provide precise information on the type of innovation. Policy innovation, strategy innovation, system innovation, process innovation, technological innovation are examples of well-defined innovations.

Innovative and sustainable solutions are needed to reduce GHG emissions, manage plastic waste and regulate deep see mining activities. Sustainable innovation is a type of innovation that is more effective, competitive, and successful at the same time. A Sustainability Oriented Innovation (SOI) is characterized by

intentional changes since in addition to economic returns it also thinks of a social and environmental value (Adams, Jeanrenaud, Bessant, Denyer, & Overy, 2016). Sustainable innovative solutions are the process by which sustainability considerations (environmental, social, economic) are integrated at each step from idea generation, to research and development and marketing approach. The concept of sustainable innovative solutions is fundamental. For example, a new technological innovation, resulting from scientific research activity, must be sustainable in order to benefit the sustainability of society and the environment.

Since April 2019, Snam S.p.A., an Italian energy infrastructure company, has developed a sustainable and innovative technological solution that uses hydrogen to reduce pollution. Hydrogen is not present as a free element in nature, but it can be produced through a wide range of chemical and physical processes. Currently, three types of hydrogen are identified. Hydrogen is mainly obtained for industrial uses starting from natural gas, through a thermochemical conversion process that produces CO2 (gray hydrogen), which will then have to be torn down. To this mode, the Carbon Capture and Storage (CCS) technology can be added to obtain decarbonised hydrogen (blue hydrogen) and the water electrolysis that allows to obtain green hydrogen using electrical energy to break down the water in hydrogen and oxygen, without CO2 production (DNV-GL, 2019). The current share of green hydrogen in the world is only 4/5% of global hydrogen. Snam S.p.A is the first industrial actor in Europe to mix 5% green hydrogen with natural gas while maintaining the same transmission pipeline. Snam reported that by adding 5% of hydrogen to the total gas transported by the group, carbon emissions could be reduced by 2.5 million tons a year. According to a Snam-McKinsey report, hydrogen could supply up to a quarter (23%) of national energy in Italy demand by 2050 (SNAM, 2019). This growth could occur thanks to the progressive and now consolidated decrease in the cost of producing solar and wind renewable electrical energy and to a simultaneous reduction in the cost of electrolysers. In Italy, hydrogen has great development prospects due to the significant natural potential for the production of solar and wind energy, from which it is possible to obtain green hydrogen through water electrolysis. Italy has more than 34,000 Km of existing pipelines for transmission and over 250,000 Km of existing pipelines for distribution. Hydrogen can be mixed in current pipelines.

According to a recent report by Bloomberg New Energy Finance the costs of producing green hydrogen worldwide, following the reduction of renewable energy production costs, may fall by more than 70% over the next ten years (SNAM, 2019). By increasing hydrogen production capacity and decreasing hydrogen costs, many new hydrogen technologies can be competitive against oil and gas. The greatest potential for using hydrogen concerns the transport sector (trucks, buses and trains), the residential sector (climatization) and some industrial applications (refining and processes that require high temperatures). Hydrogen can be a key driver towards sustainability and there has never been such an opportunity to progressively exploit the potential of this colorless and odorless gas in building a safe, clean and sustainable energy mix for all consumers (IRENA, 2019).

In this paper, we highlight three new innovative and sustainable solutions capable of addressing rapidly worsening pollution of the oceans. The first solution is a combined process and technological innovation with the goal of reducing marine pollution from plastic waste. The second is a technological innovation for the reduction of pollutants in maritime traffic and the third is a policy innovation aimed at drafting guidelines for the acoustic impact of extraction activities related to Deep Sea Mining. In the next sections, we introduce the pollution problem, we describe the innovative solution and we discuss how these solutions are not only innovative but also sustainable.

A COMBINED PROCESS AND TECHNOLOGICAL INNOVATION FOR REDUCING MARINE POLLUTION FROM PLASTIC WASTE

Plastic remains in the sea for periods ranging from 20 years for a shopping bag to 600 years for a fishing net thread. The plastic waste is fractionated and degrades very slowly into smaller pieces reaching dimensions of a few millimeters. These tiny residues and microplastics are then ingested by living beings and therefore enter the food chain (Pham, et al., 2014). Some microplastics are formed directly in the sea, following the degradation of larger residues due to wind, wave, or ultraviolet rays. Others are produced by industry, such as pellets, exfoliating agents, additives to soaps, gels, toothpastes, or they are accidentally generated, for example, from tire dust or from the use and washing of synthetic clothes fibers (WWF, 2018). The millions of tons of plastic that end up in the oceans each year cause over 13 billion dollars in damage to marine ecosystems. Also included are economic losses in fishing and tourism sectors, as well as beach cleaning costs (UNEP, 2014).

Currently, there are efforts focused on reducing the use of plastics: clothes with a 70% recycled plastic component are produced, plastic bricks are being experimentally used in house construction, and asphalt surfaces are being tested using plastic instead of bitumen. Straws and glasses are being made with marine algae. Many companies are committed to use only recycled plastic in their packaging (WWF, 2018). The amount of waste brought on board while fishing is increasing daily, creating inconveniences and delays to the fishing activities. Furthermore, current laws like the ones in Italy state that the waste collected at sea when is taken to land is classified as special waste and therefore need to be disposed according to specific and costly procedures, creating serious economic damage to fishermen who may rather decide to leave the waste at sea.

The combined process and technological innovation is to transform the waste collected into a resource for both the fisherman and the community, thus transforming the fishermen from a potential source of pollution into ecological sentinels. To achieve this, an innovative technological solution is being designed with the goal of transforming plastics and other waste collected during fishing activities into reusable materials or energy gas, capable of being transformed into energy without combustion, using technology of fuel cells and recovering the CO2 produced for industrial use in order to avoid its dispersion in the atmosphere. This type of system will be placed on board of ships capable of docking in all fishing ports of the Sicilian Region and smaller islands in Italy, while the energy produced on board will be used to generate drinking water, from desalinization, to continuously supply the smaller islands, which often suffer of natural water sources. The sustainable and innovative process begins with the transfer of the plastics and waste by the fishermen to special storage points in the various fishing ports. From these points the waste is collected by the ships that process them at sea and use part of the energy produced as propeller for the vessel itself. The solution of a self-propelled vehicle able to take the material recovered from the sea directly to the ports and able to use the energy obtained to move the vessel also has the objective of eliminating the pollution produced by land transports that otherwise need to be used for the transfer of the material to disposal centers.

There is an awareness of the problem but to achieve an acceptable balance constant work is needed on the side of all governmental competent Institutions. Obsolete regulations such as the one that in Italy considers "special waste" and the procedures and costs for the disposal of plastic that the fishermen recover in the sea really call for a sustainable update.

3. A TECHNOLOGICAL INNOVATION FOR THE REDUCTION OF POLLUTANTS IN MARITIME TRAFFIC

Maritime transport is responsible for 3% of global annual CO2 emissions (Gielen & Roesch, 2019). The naval sector is one of the most difficult to decarbonize, since current fuels are low -cost refining residues (Kee, Zhu, Goodwin, 2005). There are many ways to reduce emissions from ships: engine improvements such as exhaust gas recirculation, two stage turbocharging, intelligent combustion chamber design and advanced fuel injection systems, exhaust gas post-treatment such as scrubbers or Selective Catalytic Reduction (SCR), and the use of various fuels such as low-sulfur diesel or liquefied natural gas (Millo, Bernardi, & Delneri, 2011; Burel, Taccani, & Zuliani, 2013). Among the possible alternatives, Fuel Cells (FC) are considered one of the most promising future technologies (Stambouli & Traversa, 2002). Energy production through fuel cells is an innovative technology that can reduce emissions of carbon dioxide and acid gases. Fuel cells are also known for the absence of moving mechanical parts and low noise emissions (Markowski & Pielecha, 2019). However, fuel cells have a high production cost mainly due to the high technological manufacturing process and the small production scale.

The project *TecBIA* (*Low Environmental Impact Technologies for the Production of Energy on Ships*) (FINCANTIERI, 2014/2020), led by Fincantieri S.p.A., aims to experimentally verify the sustainability of fuel cell technology for naval applications through the construction of a prototype of a naval vessel propelled by fuel cells with the goals of studying the scale-up of Polymer Electrolyte Membrane (PEM) fuel cell modules. The goal is to determine if fuel cells could be used for the generation of distributed energy for hotel services on board cruise ships, and to investigate the possibility of using the heat produced in the electrochemical conversion process to feed the air conditioning systems and the production of hot water on board cruise ships. Instead of having compressed gas or liquefied gas, with relative danger and criticality, hydrogen will be stored in the form of Metal Hydrides (MH). Since the hydrogen release mechanism from the cylinder is not instantaneous, batteries are needed to have a stable load of energy.

Currently there is no internationally recognized regulation for the use of hydrogen as fuel and fuel cells on board of ships. Therefore, this regulation, in accordance with internationally consolidated procedures, is being studied and drafted by the *National Institution of Italy for Standardization Research and Promotion (ENR).* ENR, which is specifically concerned with analyzing, modifying and technically drawing up regulations, is contribuiting on the preparation of the documentation necessary to obtain the release of the Safety and Navigability Certificate from the Italian Authorities of competence (Italian Ministry of Infrastructure and Transport, MIT) so that the prototype a naval vessel once built can sail in Italian waters for testing purposes.

4. A POLICY INNOVATION AIMED AT DRAFTING GUIDELINES FOR THE ACOUSTIC IMPACT OF EXTRACTION ACTIVITIES

Scientists from around the world have analyzed the possible impacts of extraction activities in the oceans by classifying them as: fragmentation and loss of habitats, loss of biodiversity, changes in the structure of deep communities, production of waste materials and plumes rich in toxic elements, impacts due to artificial brightness and sediment production, water temperature changes and noise impact (Kaikkonen, Venesjärvi, & Nygård, 2018). The least studied and known impact is the acoustic pollution since the frequencies and acoustic intensities emitted by the technologies that are going to be used are not yet known (Hawkins, Pembroke, & Popper, 2015). The noise produced by human activities at sea is today already a real pollutant for which negative impacts have been reported on marine species at physical, physiological, and behavioral level (Parliament, 2008).

Several regulations, which attempt to manage and monitor environmental impacts on biodiversity, have been issued by the ISA, but the information is far to be completed and the problem of noise impact is still neglected (Christiansen, Denda, & Christiansan, 2019; Jaeckel, 2019). Before extraction activities take place at large scale, it is necessary to produce and possibly agree at international level on a technical standard that will contribute to monitor and set limits to the noise emitted with the goal of reducing the envisaged damage on marine ecosystems. Currently there is no single and well-defined protocol for measuring the level of marine noise pollution (André, et al., 2011).

ENR has carried out an Innovative Industrialization project (MIUR, 2014-2020) which supported the writing of the first technical standard on the acoustic impact of marine-maritime activities related to Deep Sea Mining, indicating the possible minimum criteria of acceptability (ENR, 2019). The drafting of the standard took into consideration the different conclusions existing today between the scientific results obtained on field and the laboratory experiments (Vazzana, et al., 2020). The standard provides recommendations for the management of the acoustic impact to be implemented in all operational phases of the extraction. The standard allows the management of mineral extraction activities from the ocean depths protecting as much as possible the life of the deep ecosystems ensuring a balance between exploitation of resources and the protection of biodiversity. In the proposed standard, the difficulty of evaluating acoustic impacts was taken into consideration together with the high variability and interaction with various environmental aspects. The standard has been created with the vision that it should be modified, improved, and updated when new data become available.

5. BLUE ECONOMY AND BLUE CARBON

Seas and oceans are huge renewable energy sources. Development activities and research programs by the European Commission focus on technologies in the field of ocean energy to exploit the potential of the tides, wave motion, differences in temperature and salinity. The Blue Economy (BE) covers all economic activities related to the oceans, seas, and coasts, taking into consideration both sectors that are actively contributing today and emerging and innovative sectors, which show a high potential for future development. At the base of the Blue Economy is the need for maritime economic development that leads to an improvement in human well-being and social equity, while simultaneously reducing environmental risks and ecological deficiencies, contributing to Europe's decarbonisation objectives set for 2050.

Globally the Blue Economy is currently valued at USD $1.5 trillion (2.5% of the world's gross value added) and employs 31 million people. By 2030, it is expected to increase to USD $3 trillion, with growth driven primarily by aquaculture, fish processing, offshore wind, shipbuilding, and repair (Steven, Mathew, & Bohler-Muller, 2019).

The sectors currently contributing to it are fishing, aquaculture, fish processing, maritime oil and gas extraction, port activities, shipbuilding, maritime transport, coastal tourism. The emerging sectors include energy from waves and tides, off shore wind production, mining in the seabed, carbon capture & storage, desalination, integrated maritime surveillance, use of the potential of marine organisms for the medical, pharmaceutical, food sector and energy production, especially algae biomass energy.

Sustainable development is the strength of the Blue Economy, which intends to take care of its assets and exhaustible natural reserves, with economic growth that respects the environment and its limits. With the Blue Economy, the EU has the objective of eliminating CO2 emissions by contributing to economic growth through innovation and the use of sources from renewable energy and creating new jobs. The Blue Economy is also seen as the development of the Green Economy, as the latter provides for the reduction of CO2, while the blue economy aims at zeroing CO2. The Blue Economy represents a valuable investment both in the short and long term and at different levels: economic, social and environmental (Attri & Bohler-Muller, 2018). From an environmental point of view, carbon emissions will be reduced thanks to the promotion of long-term sustainable growth and the enhancement of the protection of the sea, land and fresh water which otherwise would quickly become increasingly scarce and expensive resources.

Blue Carbon (BC) is carbon stored in coastal and marine ecosystems, including mangrove forests, tidal, seagrass meadows, marshes. It is captured by the world's oceans and coastal ecosystems, unlike the green carbon that is stored by forests and their soils and stored in the form of sediment and biomass. These ecosystems trap large quantities of carbon by capturing it from carbon dioxide in the atmosphere and storing it for millions of years in plant sediments that are found underwater. Carbon dioxide is one of the main factors that contribute negatively to climate change.

Although these ecosystems are much smaller in size than the world's forests, they sequester carbon faster and can continue to sequester it for many years. When these ecosystems are damaged, their destruction poses a high risk. In fact, when these ecosystems are damaged, not only their sequestering capacity is destroyed, but the carbon already stored is released into the atmosphere. This contributes to the increase of gas levels in the atmosphere. Therefore, protecting the coastal ecosystem is a great way to slow down climate change by preventing the emission of stored carbon and protecting the coastal environment (Macreadie, et al., 2019).

The International Blue Carbon Initiative is a program focused on the mitigation of climate change through the conservation and restoration of coastal and marine ecosystems. Blue Carbon satisfies all three essential elements of sustainability: economic, social, and environmental, therefore it can be considered an essential component of the Blue Economy. Blue Carbon, together with the renewable energy sector and the carbon capture and storage industries, can be considered to contribute to the development of low carbon economies.

6. CONCLUSION

In the upcoming decades, the world will face a complex challenge: to continue to grow economically while reducing CO2 emissions. Hydrogen can be a key driver towards sustainability of innovative solutions and there has never been such an opportunity to exploit the potential of this colorless and odorless gas in building a safe, clean, and sustainable energy mix for all consumers. Hydrogen can act simultaneously as a source of clean energy and as an energy carrier for storage.

Plastic makes up about 80% of the solid waste present in the seas of the world and the main type of waste that we find on beach or deposited on the seabed. The oceans, seas and marine resources must be preserved and used in a sustainable way. A sustainable process is fundamental: the waste collected by fishermen must be transformed from a problem into a resource, both for the fisherman and the community. Time constants must be properly considered and pursued in order to propose and complete gradual but effective steps. An immediate dream may result into irreversible damage rather than progressively growing improvements.

Recent IMO regulations introduced for the protection of the environment and health aims at reducing greenhouse gas emissions (CO2 and CH4), NOx, SOx and particulate matter. For this reason, a valid alternative to traditional fuels is needed and the trend of requests for eco-sustainable ships is constantly growing. Among the possible alternatives to reduce emission levels from ships fuel cells are considered one of the most promising future sustainable and innovative technologies.

In view of the rapid growth of the world population, the resources available from land mines are running out and new deposits have been found in the ocean depths. In the immediate future, mineral extraction from the deep sea will become a reality in front of the lack of land equivalent resources. The noise produced by human activities at sea is today already a real pollutant and, for this reason, it is essential to issue guidelines and standardization rules to reduce damage to marine ecosystems in view of sustainability.

REFERENCES

Adams, R., Jeanrenaud, S., Bessant, J., Denyer, D., & Overy, P. (2016). Sustainability-oriented Innovation: A Systematic Review. International Journal of Management Reviews, 18, 180-205.

Andrady, A. (2011). Microplastics in the marine environment. Marine Pollution Bulletine, 62, 1596-1605.

André, M., Solé, M., Mercé, D., Quero, C., Mas, A., Lombarte, A., et al. (2011).

Attri, V. V., & Bohler-Muller, N. (2018). The Blue Economy handbook of the Indian Ocean region. Pretoria:

Africa Institute of South Africa Press.

Burel, F., Taccani, R., & Zuliani, N. (2013). Improving sustainability of maritime transport through utilization of liquefied natural gas (LNG) for propulsion. Energy 57, 412-420.

Christiansen, B., Denda, A., & Christiansan, S. (2019). Potential effects of deep seabed mining on pelagic and benthopelagic biota. Marine Policy.

DNV-GL. (2019). Research sees long-term expansion of hydrogen for energy. Fuel Cells Bulletin, 1, 10-11. ENR. (2019, Settembre). ENR - Ente Nazionale di Ricerca e promozione per la standardizzazione. Retrieved from Norma ENR 14001 - Impatto acustico: http://www.enrstandards.org/it/files/ENR_14001_DSM_it.pdf

FINCANTIERI. (2014/2020). Progetti di innovazione. Retrieved from MISE PON - Grandi Progetti R&S:https://www.fincantieri.com/it/innovazione/progetti-di-innovazione/

Galgani, F., Hanke, G., Werner, S., & De Vrees, L. (2013). Marine litter within the European Marine Strategy Framework Directive. ICES Journal of Marine Science, 70 (6), 1055–1064.

Gielen, D., & Roesch, R. (2019). Shipping: commercially viable zero emission deep sea vessels by 2030. Hawkins, A., Pembroke, A., & Popper, A. (2015). Information gaps in understanding the effects of noise on fishes and invertebrates. Reviews in Fish Biology and Fisheries, 25, 39-64.

Hein, J., Mizell, K., Koschinsky, A., & Conrad, T. (2013). Deep-ocean mineral deposits as a source of critical metals for. Ore Geology Reviews, 51, 1-14.

IRENA. (2019). Hydrogen: a renewable energy perspective. Report prepared for the 2nd Hydrogen Energy Ministerial Meeting in Tokyo, Japan.

Jaeckel, A. (2019). Strategic environmental planning for deep seabed mining in the area. Marine Policy. Kaikkonen, L., Venesjärvi, R., & Nygård, H. (2018). Assessing the impacts of seabed mineral extraction in the deep sea and coastal marine environments: current methods and recommendations for environmental risk assessment. Marine Pollution Bulletin, 135, 1183-1197.

Kee, R., Zhu, H., & Goodwin, D. (2005). Solid-oxide fuel cells with hydrocarbon fuelS. Proceedings of the Combustion Institute, 30 (2), 2379-2404.

Macreadie, P., Anton, A., Raven, J., Beaumont, N., Connolly, R., Friess, D., et al. (2019). The future of Blue Carbon science. Nature Communications.

Markowski, J., & Pielecha, I. (2019). The potential of fuel cells as a drive source of maritime transport. 2nd International Conference on the Sustainable Energy and Environmental Development. Earth and Environmental Science, 214. .

MARPOL(73/78). (n.d.). International Convention for the Prevention of Pollution caused by Ships.

Mengerink, K., Van Dover, C., Ardron, J., Baker, M., Escobar-Briones, E., Gjerde, K., et al. (2014). A Call for Deep-Ocean Stewardship. Science, 344.

Miller, K., Thompson, K., Johnston, P., & Santillo, D. (2018). An overview of seabed mining including the current state of development, environmental impacts, and knowledge gaps. Frontiers in Marine Science,

Millo, F., Bernardi, M., & Delneri, D. (2011). Computational Analysis of Internal and External EGR Strategies Combined with Miller Cycle Concept for a Two Stage Turbocharged Medium Speed Marine Diesel Engine. Sea International Journal of Engin.

MIUR. (2014-2020). PON Ricerca e Innovazione 2014-2020: Dottorati innovativi con caratterizzazione industriale – XXXIV Ciclo. Retrieved from https://www.miur.gov.it/web/guest/-/pon-ricerca-e-innovazione-2014-2020-dottorati-innovativi-con-caratterizzazione-industriale-xxxv-cicloOECD. (2008). Harnessing the power of innovation framework for the strategy. The OECD Innovation Strategy Parliament, E. (2008). Directive 2008/56/EC of the European Parliament and of the Council. European Parliament Official Journal of the European Union. L 164/19.

Petersen, S., Krätschell, A., Augustin, N., Jamieson, J., Hein, J., & Hannington, M. (2016). News from the seabed: Geological characteristics and resource potential of deep-sea mineral resources. Marine Policy, 70, 175-187.

Peukert, A., Schoening, T., Alevizos, E., Köser, K., Kwasnitschka, T., & Greinert, J. (2018). Understanding Mn - nodule distribution and evaluation of related deep-sea mining impacts using AUV-based hydroacoustic and optical data. Biogeosciences, 15, 2525–2549.

Pham, C., Ramirez-Llodra, E., Alt, C., Amaro, T., Bergmann, M., Canals, M., et al. (2014). Marine Litter Distribution and Density in European Seas, from the Shelves to Deep Basins. Biodiversity Conservation.

Rakhyun, E. (2017). Should deep seabed mining be allowed? Marine Policy 82, 134-137.

SNAM. (2019). The Hydrogen Challenge: The potential of hydrogen in Italy.

Stambouli, A., & Traversa, E. (2002). Fuel cells, an alternative to standard sources of energy. Renewable and Sustainable Energy Reviews 6 (3), 2, 95-304.

Steven, A., Mathew, V., & Bohler-Muller, N. (2019). A new narrative for the Blue Economy and Blue Carbon. Journal of the Indian Ocean Region, 123-128.

Transport&Environment. (2019). One Corporation to Pollute Them All: Luxury cruise air emissions in Europe.

UNEP. (2014). Valuing Plastics: The Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry.

Vazzana, M., Mauro, M., Ceraulo, M., Dioguardi, M., Papale, E., Mazzola, S., et al. (2020). Underwater high frequency noise: Biological responses in sea urchin Arbacia lixula (Linnaeus, 1758). Comparative Biochemistry and Physiology, Part A.

Winnes, H., Fridell, E., Yaramenka, K., Nelissen, D., Faber, J., & Ahdour, S. (2016). NOx controls for shipping in EU Seas, IVL and CE Delft.

WWF. (2018). Out of the plastic trap: Saving the Mediterranean from plastic pollution.