European Council for Maritime Applied R&D

A VISION FOR EUROPEAN MARITIME RDI 2030

ECMAR Position Paper

Safer, Smarter, and Greener for a Sustainable European Maritime Sector

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A Vision for European Maritime Research, Development and Innovation for 2030

ECMAR Position Paper

The purpose of this position paper is to provide a catalyst and focus for future research, development, and innovation, in order to address global and societal challenges and to present collaboration opportunities for ECMAR members.

The research topics considered address societal, global, and industrial challenges to deliver a more eco-friendly, safer, smarter, and competitive maritime industry, for a sustainable future. Many of these topics embrace the application of new disruptive technologies with the more traditional areas of research and development carried out by ECMAR organisations. These transformative technologies, in association with human factors, will be key elements for smart manufacturing, shipping, and blue growth, and for improving competitiveness, safety and security.

ECMAR's main mission is to stimulate and promote applied maritime research, development, and innovation at EU and national levels to achieve a safer, smarter, and greener maritime sector. The aim is to achieve a globally connected and competitive European Waterborne Sector, decarbonised and digitalised.

ECMAR will continue to embrace future challenges as well as the opportunities offered. It will endeavour to employ all the advanced technologies and knowledge at its disposal, including the new digital industrial technologies known as the fourth industrial revolution - Industry 4.0.

ECMAR's main objective through Research, Development and Innovation is to achieve a globally connected and competitive European Waterborne Sector, with zero-emission ships and zero-accidents, digitalised shipping and autonomy, to ensure a sustainable marine and maritime economy.

Main Challenges and Drivers for research, development and innovation

EU Maritime Transport

Almost 90 % of the EU's external freight trade is seaborne and around 40% of the EU's internal trade between Member States is transported by water. Short-sea shipping, which represents 40% of intra-EU exchanges in terms of tonne-kilometres, and inland waterway trade are encouraged to grow as a way of reducing congestion and pollution from land based transport, stimulating a modal shift.

The continued growth of global trade makes an absolute reduction in current emission levels very challenging and this will not be achieved by simple incremental development. If growth rates average just 2% over the next 30 years, shipping volumes will increase by 80%[1].

Today´s challenges for the sustainable development of maritime transport include optimal use of energy sources and minimising its environmental influences, in particular with regard to pollutants and greenhouse gas emissions. There is therefore an essential need for research, development, and innovative solutions, in order to address these important issues.

[1] Visions 2025; www.maritime-rdi.eu/media/20003/waterborne-visionplus2025pluspdf-2-.pdf

Main Challenges

The need for waterborne transport will continue to grow towards 2030 and beyond, primarily driven by population growth and rising prosperity. Population growth is increasing the demand for food, energy and water supply, which will result in an increased need for water transport, renewable energy, and aquatic food production. Waterborne transport will remain the most cost efficient means for the global transportation of raw materials, finished goods, fuel, food and water. Infrastructure and links to all other transport modes will grow and adapt in response. Maritime transport, including inland waterways transport, will also become an integral part of an efficient multi-modal logistic chain.

Growth in global waterborne trade and activity will create significant new opportunities for the EU maritime industry, with its expertise in delivering high value-added, sophisticated and innovative products and services. Connection with other transport modalities, including inland-waterway transport, will become seamless. Smart vessels will communicate with smart ports to limit congestion, waiting time and thus costs and they will adapt their sailing speed to match harbour slots automatically.

Autonomous Short Sea ship, fully automated cargo handling, automated berthing, hybrid propulsion, with LNG, biofuel, and methanol.

Society's increasing expectations about health, safety and security and the environmental impact of industry will lead to stricter regulations. This will require the Waterborne sector to improve in this area. Societal expectations will lead to the maritime sector becoming more socially and environmentally responsible by complying with stricter regulations and even adopting voluntary standards. Concerns over health risks and extensive pollution of coastal areas, particularly in South Asia, caused by ship dismantling and recycling has led to IMO's Hong Kong International Convention for the Safe and Environmental Sound Recycling of Ships and the EU Ship Recycling Regulation (1257/2013).

Concerns about climate change has led to legislation imposing limits on greenhouse gas emissions (GHG). This will require a reduction of energy consumption by waterborne transport, the use of cleaner fuels, such as LNG, the electrification of ships, the use of fuel cells, and renewable energy resources. Monitoring of ship's emissions is also required with regulatory enforcement by coastal states. Climate change will lead to more extreme weather events and polar ice melting will affect all waterborne sectors. This will require ships and offshore structures that are more robust, to operate in these more severe weather conditions.

Transformative Technologies

The speed of innovation is increasing, particularly with the rise of new digital industrial technologies known as Industry 4.0, underpinned by transformational technologies of the Cyber Physical Systems (CPS) – see diagram. These systems are combinations of several major innovations in digital technology poised to transform industry.

The technologies include cloud computing, the Internet of Things (IoT), sophisticated sensors, data capture and analytics, advanced robotics, artificial intelligence and Blockchain. Industry 4.0 will be transformative for managing interconnected systems and will be a key element in both smart manufacturing and shipping and for improving competitiveness[2,3]. However, predicting which of these technologies will transform maritime transport and blue growth opportunities remains a challenge for the future.

Credit: SINTEF Ocean.

The European Commission has been actively promoting increased automation and better use of ICT. The core vision is to enable seamless information exchange to streamline transport operations, increase safety, improve competitiveness and reduce the environmental impact. The use of advanced information and communication technology (ICT) in the maritime transport sector is not a new concept. In the future connection between ships and ship and shore will be seamless. Digitalisation and communication technologies will create new services to support shipping and logistic chains will become more integrated for all modes of transport[4]. In the maritime transport sector, vast amounts of data are available that could support new opportunities to improve ship operation, safety and logistics.

In the future, more vessels will offer superior energy efficiency through measures such as improved hydrodynamics, use of lightweight materials, and advanced hybrid power generation systems, with energy storage to optimise performance[5]. Transformative technologies will lead to advances in ship

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[2] Karl Hribernik, Industry 4.0 in the maritime sector: potentials and challenges, Sea Japan 2016; www.mlit.go.jp/common/001127983.pdf

[3] Ørnulf Jan Rødseth, Sustainable and Competitive Cyber-Shipping through Industry 4.0, Singapore Maritime Sustainability Forum 2016; http://www.mpa.gov.sg/web/wcm/connect/www/05c0a992-fb5c-48b4-bbc3-4d0611c286a5/Presentation+-+%C3%98rnulf+Jan+R%C3%B8dseth.pdf?MOD=AJPERES

[4] ICT Maritime Opportunities 2030- Maritime Connected and Automated Transport (MESA); http://www.maritime-rdi.eu/media/24884/mesa-brochure-2016.pdf

[5] DNV - GL Technology Outlook 2025; http://to2025.dnvgl.com/

design, shipbuilding, propulsion and powering, and will undoubtedly improve commercial and operational performance of ship operation.

Digitalisation will spur automation, lead to the development of smart ships and positively impact safety and environmental performance. New cloud technologies will dramatically affect how vessels and their components are designed, manufactured, and operated. The Internet of Things promises to be one of the most disruptive technological revolutions since the advent of the Internet.

The future poses many challenges for maritime transport and ocean space, including the Arctic regions, but it opens up many new opportunities for the maritime industry and for the research community. Shipping is undergoing a transformation and facing huge challenges. The oceans are important for fulfilling the growing needs for food, energy, water, mineral resources etc., and these Blue Growth activities will require research, development and innovation. The competitiveness of Europe's maritime industries, and their ability to meet environmental legislation, energy efficiency, safety, security, and human-factor challenges, will also need further research, development, and innovation efforts at much more technological advanced level than in the past.

The EU Council conclusions on priorities for the EU's maritime transport policy until 2020[6], based on the Valletta Declaration of 2017, are Competitiveness, Decarbonisation, and Digitalisation to ensure global connectivity, and efficient internal market and a world-class maritime cluster.

IMO's Third Greenhouse Gas (GHG) Study for Shipping

The International Maritime Organization's (IMO) Third Greenhouse Gas (GHG) Study[7] for shipping stated, "Marine transport emitted 938 million tonnes of CO_2 in 2012, representing 3.1% of the world's total emissions". Furthermore, "the total fuel consumption of shipping is dominated by three ship types: oil tankers, container ships and bulk carriers", which account for almost 62% of the CO_2 emissions. Cruise and RoPax vessels contribute only about 7.75% to overall energy consumption and CO_2 emissions. Consistently, for all ship types, the "main propulsion engines are the dominant fuel consumers".

"By 2050, shipping emissions are predicted to increase between 50% and 250%, depending on future economic and energy developments. This is not compatible with the internationally agreed goal of keeping global temperature increase to below 2°C compared to pre-industrial levels; this requires worldwide emissions to be at least halved from 1990 levels by 2050".

In the assessment of future scenarios, without intervention, the highest scenario indicated a tripling of CO_2-emissions from 2020 to 2050. Looking at the technologies, energy efficiency clearly wins against LNG as fuel in terms of possible global CO_2-emission reduction potential. Compared to regulatory or market-driven improvements in efficiency, changes in the fuel mix have a limited impact on GHG emissions, assuming that fossil fuels remain dominant.

[6] EU Council conclusions on "Priorities for the EU's maritime transport policy until 2020: Competitiveness, Decarbonisation, Digitalisation to ensure global connectivity, an efficient internal market and a world-class maritime cluster", 9976/17, 8 June 2017;
http://data.consilium.europa.eu/doc/document/ST-9976-2017-INIT/en/pdf

[7] IMO, 2015. Third IMO Greenhouse Gas Study 2014 : Safe, secure and efficient shipping on clean oceans;
http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Third%20Greenhouse%20Gas%20Study/GHG3%20Executive%20Summary%20and%20Report.pdf

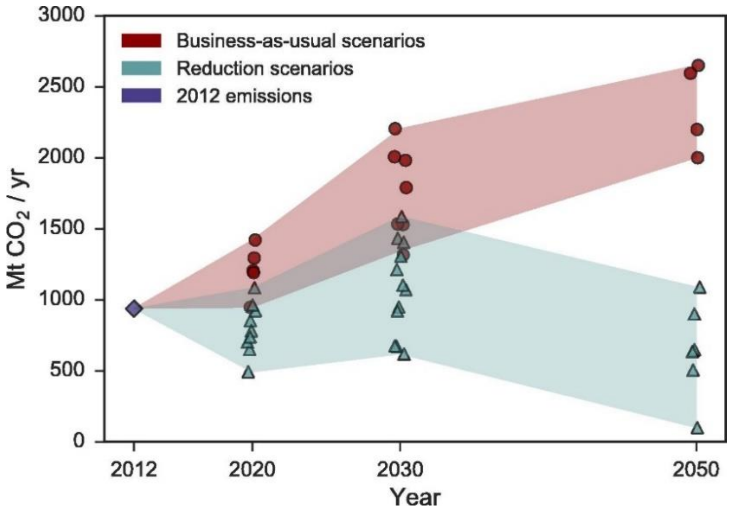
From 2007 to 2012, international shipping emissions were in a relative decline compared to global emissions. This was due to a change in economic activity and the subsequent increasing popularity of "slow steaming". In 2011, IMO introduced the Energy Efficiency Design Index (EEDI) for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for existing vessels, to mitigate the expected increase in GHG emissions. However, ship size is not taken into account, which would also reduce EEDI. The EEDI sets specific ship-class fuel efficiency targets, and aims to tighten them progressively.

The initial CO_2 reduction target levels is -10% from the 2011 datum and tightened every five years to keep pace with fuel consumption and emission-reduction technology developments. These targets are mandatory for all ships. However, the EEDI and SEEMP measures alone will not lead to an absolute reduction in shipping emissions. Although the intention of EEDI is admirable, the technological progress to meet the IMO targets will be challenging.

Annex 1 contains details of the Paris Agreement on Climate Change, which does not bind international shipping and aviation; IMO's Progress on reducing greenhouse gas emissions; EU Policy for reducing greenhouse gas emissions; the EU Emissions Trading System (ETS), and the EC Study on GHG emissions reductions for maritime transport.

Emission Technologies

A recent Norwegian review of around 150 studies[8] provided a comprehensive overview of twenty-two CO_2 emissions reduction potentials and measures, published in the literature. The review aimed to identify the most promising areas, i.e. technologies and operational practices, and to quantify the combined mitigation potential. A significant variation in reported CO_2 reduction potentials was found across the reviewed studies and no single measure was sufficient to achieve meaningful GHG reductions.



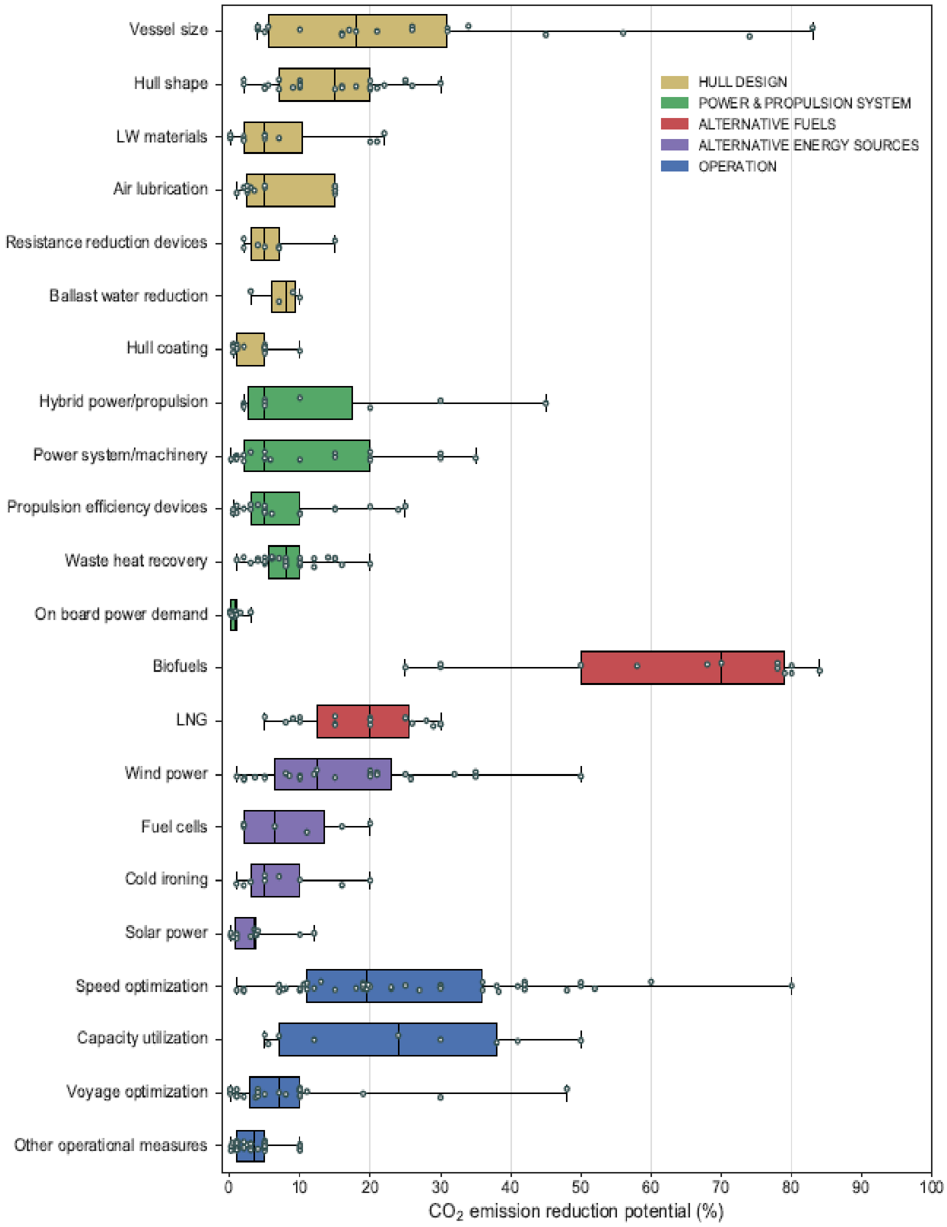
Annual CO_2 emissions from the global shipping fleet, distinguished by business-as-usual and reduction scenario pathways[8]

The maximum potential for emission reduction identified was between 20% and 77%, (excluding nuclear propulsion). The median reduction rates were 35%, 39% and 73% for the years 2020, 2030,

[8] Bouman, E, A, Lindstad, E, Rialland, A, I, Strømman, A, H, State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping – A review, Transportation Research Part D 52 (2017) 408-421; http://ac.els-cdn.com/S1361920916307015/1-s2.0-S1361920916307015-main.pdf?_tid=526c2562-66d8-11e7-9c8d-00000aab0f26&acdnat=1499846674_986b610aa09cc25b58f0095992ebcd6b

and 2050 respectively – see diagram above. The diagram shows an overlap between the business-as-usual and reduction scenarios in 2020 and in 2030, reflecting uncertainty in the scenarios as well as different assumptions on the rate of adoption of emission mitigation measures and the growth rate of global maritime transport. In the long term, there are no overlaps between business-as-usual and reduction scenarios

The Norwegian review also found that it would be feasible to achieve a 75% reduction in fleet emissions using a viable combination of the technologies studied. An example of this combination would include optimised vessel size and hull shape, reduced ballast water, hull coatings, hybrid power and propulsion, propulsion efficiency devices, speed optimisation and weather routing. Emissions can therefore be reduced by more than 75%, based on current technologies and by 2050, through a combination of measures, providing that the policies and regulations be focused on achieving these reductions. In terms of emissions per freight unit transported, it is possible to reduce emissions by a factor of 4–6.



CO_2 emission reduction potential for individual measures, classified in five categories of measures[8]

The Norwegian review drew three main conclusions: "First, it is possible to reduce emissions per freight transport unit by 75% and above up to 2050. Second, reaching such a level is based on the studies that showed reduction potential in the high end, i.e. the 3rd quartile values. Third, achieving such high reduction is necessary to ensure absolute reductions in annual CO_2 emissions of the sector, as the continued future growth of maritime transport offsets the gains made in individual cases. In addition, a remaining challenge is to be able to realise the required GHG reductions, while at the same time meet customer demands and remain competitive in comparison to other transport modes, i.e. road, rail, and aviation."

"The overall success of these emissions reductions technologies and measures is dependent on the growth rates of maritime transport. Policies, regulations, and legislation, such as the EEDI, can facilitate reduction of GHG emissions by the sector, but successful implementation has to be supported by high-quality studies addressing multiple effects and measures simultaneously in order to avoid counteracting and inefficient adoption of mitigation measures."

Growing interest in the Arctic

Maritime transport in the Arctic has attracted widespread attention because of the region's growing strategic importance. Technological development for enabling operations in hostile and remote environments has offered the prospect of new transport routes in the region. These developments have drawn interest from the shipping community as an opportunity to reduce economic costs and CO_2 emissions[9]. The Northern Sea Route is currently available to shipping for about 8-10 weeks during the summer season, as sea ice will reform during winter.

Changing climate conditions have opened new operational and trading opportunities in previously unnavigable areas, and these new opportunities are attractive to the shipping industry. Using the Northern Sea Route for a voyage between the principal Asian and European ports reduces the distance by nearly 4,000 miles compared to the traditional route through the Suez Canal.

Annex 2 gives a brief description of the EU's Policy for the Arctic and IMO's Polar Code.

A new study examining the commercial opportunities of Arctic shipping[10] concludes that the navigation season on the Northern Sea Route (NSR) will remain too short for investments in ice-class vessels to be economically viable until around 2040. Only then could the Arctic shipping route become

[9] ECSA Position Paper: Integrated European Union Policy for the Arctic, December 2016; http://www.ecsa.eu/9-latest-news/293-ecsa-adopts-position-on-european-policy-for-the-arctic

[10] Copenhagen Business School (CBS Maritime); https://services-webdav.cbs.dk/doc/CBS.dk/Arctic%20Shipping%20-%20Commercial%20Opportunities%20and%20Challenges.pdf

competitive. A report on safe Arctic oil and gas operations[11] identified a number of uncertainties in current knowledge, including Metocean data and ice conditions, pipelines and subsea structures exposed to icebergs, and oil spill detection in the Arctic.

ECMAR's vision for the future

ECMAR's main objective through Research, Development and Innovation is to achieve a globally connected and competitive European Waterborne Sector, with zero-emission ships and zero-accidents, digitalised shipping and autonomy, to ensure a sustainable marine and maritime economy.

The ambition is for more energy efficient design and operation for shipping and maritime activities, utilising new technologies and green energy sources. The aim is to achieve a globally connected and competitive European Waterborne Sector, decarbonised and digitalised for a sustainable marine and maritime economy.

Financial, regulatory, and societal pressures will continue to encourage shipping to lower its environmental impact and improve its safety record. In the future more vessels will offer superior energy efficiency through measures such as improved hydrodynamics, use of lightweight materials, and advanced hybrid-power generation systems, with energy storage to optimise performance. Vessels will also have a reduced environmental impact due to the use of alternative fuels and renewable energy.

Digitalisation will spur automation and positively impact safety and environmental performance. New cloud technologies will dramatically affect the design, manufacture and operation of vessels and their components. The Internet of Things will help to deliver smart vessels with shore-based control. Cyber-security and Human Factors will become important issues with digitalisation and automation.

The next generation of connectivity between ship and shore with Blockchain will help shipowners to reduce costs, avoid expensive repairs and improve operational efficiency. Automated processes and the introduction of "big data" in maritime operations will lead to advances in engine monitoring, remote maintenance, and real-time weather data and routing.

An integrated logistics and transport system represents the final integration of the new and emerging waterborne transport system into the other transport systems and the supply and production chains. The focus in the context of waterborne transport is on physical and digital connectivity to the supply and production chains.

Given the new challenges raised by the scarcity of resources and land available, the oceans are the only way to fulfil humanity's growing needs for food, energy, water, organic or mineral resources, etc. This promotes the need for significant industrial activities at sea and the provision of supporting services. Although current economic activities at sea relate mainly to maritime transport and oil and gas exploration, these are not part of the Blue Growth Economy. Blue Growth activities are more diverse, and include renewable energies, biotechnologies, desalination, aquaculture, fish farming, living at sea, sustainable mineral mining, and new forms of tourism. Many of these new economic

[11] Report on safe Arctic oil and gas operations; http://www.psa.no/getfile.php/PDF/Rapporter/Overview%20of%20measures_report_TFOPP.pdf

activities are extremely risky and of marginal profitability at the outset. However, these risks can be mitigated by combining various activities at a single site, while safeguarding safety and shipping.

ECMAR's technology outlook for 2030

ECMAR's technology outlook for 2030 is a contribution to the WATER*BORNE*[TP] strategy, for a more eco-friendly, smarter and safer maritime industry.

The strategic research agendas and road maps of the WATER*BORNE Technology Platform*[12] *for 2030,* developed by the MESA project, and of the Vessels for the Future Research Association[13] for 2050, have been taken into acount. Other relevant publication have also been considered, including DNV-GL's Technology Outlook 2025[14], Global Marine Trends 2030[15], and Global Marine Trends 2030 - Autonomous Systems[16].

Technology development is accelerating and the critical technologies will have a transformative impact on the maritime industry. For example, the combination of advanced technologies, such as Cyber Physical Systems, will undoubtedly make a significant contribution to the competitiveness and sustainability of the industry. Although these advanced technologies are of importance, a human factors perspective is also required in order to make progress in the technology areas. "Technology is important, but it is people that make the difference".

Energy efficiency and Emissions

Shipping is the most energy efficient mode of transport, but there is room for significant improvement in energy efficiency and emissions. Despite recent progress in a number of energy efficiency related technologies, the full potential of the technologies has not been realised. There is still the need for a more comprehensive holistic energy saving approach, which will integrate all the advanced tools and concepts. For example, Big Data Analysis will lead to a better assessment and management of a vessel's energy consumption.

Operational speed reduction appears to be the only current measure that can deliver the substantial and immediate short-term emissions reductions that the Paris agreement demands. A recent Clean Shipping Coalition (CSC) study[17] showed that limiting ship speed could reduce CO_2 emission of up to 33% by 2030, for the three main ship types: containers, tankers and bulk carriers.

Slow steaming could also result in significant additional emission reductions for the other ship types, which are currently responsible for 48% of total ship emissions. However, slow steaming is a short-term measure to reduce maritime GHG emissions. Decarbonisation of shipping to meet emission reduction targets is therefore an opportunity to drive innovation and inspire the industry to improve

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[12] WATER*BORNE*[TP]; www.waterborne.eu
[13] Vessels for the Future Research Association; http://vftf.eu
[14] DNV-GL's Technology Outlook 2025, http://to2025.dnvgl.com/
[15] Lloyd's Register et al, Global Marine Technology Trends 2030; http://www.lr.org/en/projects/global-marine-trends-2030.aspx
[16] Lloyd's Register et al, Global Marine Technology Trends 2030 – Autonomous Systems; http://www.lr.org/en/projects/global-marine-technology-trends-2030-autonomous-systems.aspx
[17] Regulating speed: a short-term measure to reduce maritime GHG emissions, CE Delft, 18 Oct 2017; http://www.cleanshipping.org/download/Slow-steaming-CE-Delft-final.pdf

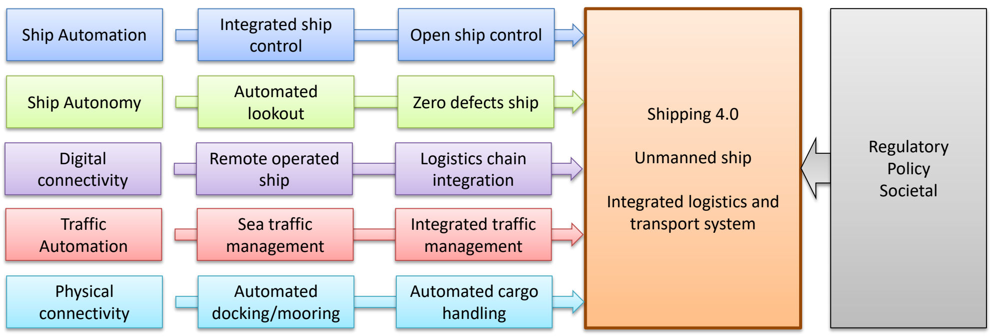
efficiency with new technologies, to move towards low-carbon fuels, electric and hybrid propulsion, and renewable energy systems.

The MESA project concluded that "ultra-low or zero emission ships will use electric propulsion in special areas, such as in ports, or in Emission Control Areas (ECAs). Smaller vessels, such as ferries, will be fully electric and others will have hybrid propulsion systems, wind assisted propulsion, and batteries for non-propulsive power, recharged by solar energy. The propulsive power of ships will also be minimised by highly efficient propulsors, air lubrication, or by special hull coatings and optimal hull design for the actual operational conditions. All new-builds will be equipped with multi-fuel engines, to allow for a smooth transition of main fuels".

There are already many ways to reduce CO_2 emissions for sustainable shipping with existing and future technologies. These include improved energy efficiency, the use of renewable energy, alternative fuels, and hybrid propulsion systems. There is also a growing interest in eco-friendly power generation using fuel cells[18], particularly for cruise ships and for hydrogen-powered ferries. The LeanShips[19] project aims to demonstrate the effectiveness and reliability of energy saving and emission reduction technologies at full scale. **Annex 3** describes recent research and interest in Fuel Cells for maritime applications.

Connected and automated maritime transport

With massive growth in computational capacity and data storage capabilities, globally accessible networks and cloud infrastructure with increasing bandwidth, availability of smart devices and cheap sensors, a significant increase of digitalisation in all waterborne sectors is expected. This will lead to a higher connectivity of systems, which are software dependent and contain of smart devices. The complexity of these systems will challenge the way that they are tested, operated, and maintained throughout their entire life cycle.



A higher degree of systems automation, the availability of smart sensors and global networks for data transfer between ship and shore will promote remote controlled, and semi or fully autonomous operation of assets, e.g. autonomous ships and smart ports. Interconnectivity between sea-based operations and shore-based operation centres will enable increasing support and control from the shore. However, critical interconnected infrastructures will require resilience incorporated into the advanced technology networks, to reduce the risk of cyber-crime.

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[18] EMSA Study on the use of Fuel Cells in Shipping http://www.emsa.europa.eu/emsa-homepage/2-news-a-press-centre/news/2921-emsa-study-on-the-use-of-fuel-cells-in-shipping.html
[19] LeanShip project, http://www.leanships-project.eu/home/

ICT has enabled more far-reaching concepts, such as Big Data analytics, "Internet of Things" (IoT), and cloud computing, to provide the shipping industry with new ways to collect, process and exchange valuable data in real-time. Digitalisation will also lead to data-driven services such as optimising energy use and fuel efficiency, vessel performance, condition monitoring, and weather routing.

The development of remote-controlled and new types of robots that could replace human-operators on board ships is also linked to the new technologies, such as sensors, Big Data analytics, and the IoT. In the future, new types of robots called "SmartBots" will have the ability to carry out specific tasks autonomously.

Safety and Security

Safety, security and pollution prevention are of the utmost importance for maritime transport. The consequences of serious maritime incidents, leading to loss of life, environmental pollution and cargo loss, directly affect European society and the economy. Prior to 2013, the serious accident frequency and fatality rate, which are key safety indicators, were increasing, despite significant investments and the progress of science and technology[20]. In recent years, EU research projects have made a significant contribution to IMO for improving maritime safety, but most of the safety innovations apply only to new buildings.

Costa Concordia - Credit: Enzo Russo, EPA.

According to EMSA's annual overview of marine casualties and incidents 2017[21], there were 3,145 reported casualties and incidents in 2016 and 106 reported fatalities. Over the 2011-2016 period, half of all the casualties were of a navigational nature, such as contacts, groundings/strandings, or collisions. Of all the casualties, 42% took place in port areas. The number of very serious casualties has been steady over this period and the number of ships lost since 2014 has reduced by 50%, but a limited increase in less serious accidents appears to exist.

During the period 2011-2016, the Costa Concordia (32 fatalities and 17 injured persons in 2012) and the Norman Atlantic accidents (11 fatalities and 31 injured persons in 2014) dominated the number of fatalities on board passenger ships. However, since 2014 a continuous decrease of fatalities and injuries is evident. Human erroneous action represented 60% of accidental events and 71% of accidental events were linked to shipboard operations as a contributing factor.

[20] T.E. Svensen, IHS Fairplay, The Future of Maritime Safety, IMO Symposium, June 2013.

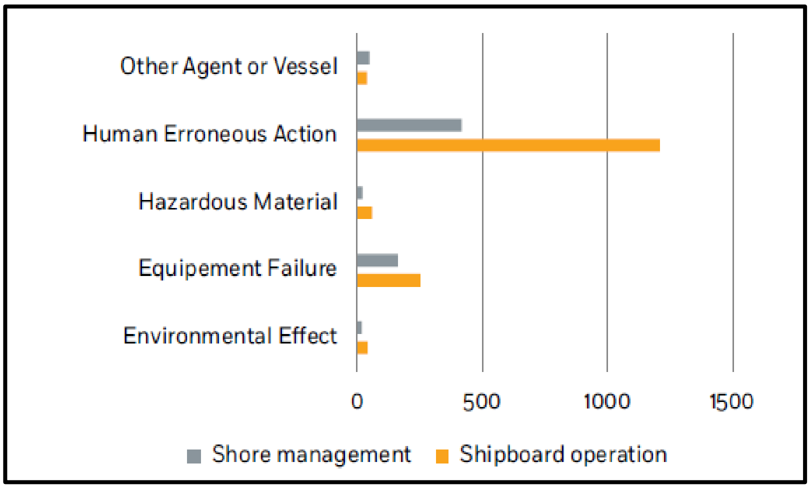
[21] Annual Overview of Marine Casualties and Incidents 2017, EMSA: https://www.safety4sea.com/wp-content/uploads/2017/11/EMSA-Annual-overview-of-marine-casualties-and-incidents-2017_11.pdf

IMO's extended approach for Goal-based Standards (GBS) will include the Safety Level Approach (GBS-SLA) as the future means to improve maritime safety. However, it is widely acknowledged that the implementation of GBS-SLA will require the development of a procedure to determine future risk levels and a procedure to relate risk levels to particular ship functions.

Terrorist threats shows no signs of decreasing and both ships and ports will continue to face the threat of terrorist acts. Furthermore, very serious concerns about cyber-security, acts of piracy and armed robbery at sea persist and non-lethal anti-piracy systems are needed. The EU Maritime Security Strategy (EUMSS)[22] and Action Plan[23] provide an overarching strategy against all challenges from the global maritime domain that may affect people, activities or infrastructures within the EU. New challenges for safety will also arise because of more severe weather due to climate change and for operations in Arctic regions.

Human Factors

Human factors, which contribute up to 80 percent to marine casualties and incidents, defined as acts or omissions, intentional or otherwise, adversely affect the proper functioning of a particular system, or the successful performance of a particular task. The causes of human error in a ship's operation are numerous: fatigue, stress, poor qualifications, negligence, language, and cultural differences on board ships etc. Understanding human factors requires a study and analysis of the equipment design, the interaction of the human operator with the equipment, and the procedures followed by crew and management.



Relationship between accidental event and the main contributing factors 2011-2016[21]

According to EMSA[21], during the period of 2011-2016, human erroneous action represented 60% of accidental events and 71% of these linked to shipboard operations were a contributing factor. For almost all accidental events on cargo ships, shipboard operation appeared to be the most significant contributing factor (77%). Human factors and training are therefore essential to reduce incidents at sea and to manage the applications of new technologies, particularly the interaction between man and machine.

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[22] The European Union Maritime Security Strategy (EUMSS);
https://ec.europa.eu/maritimeaffairs/policy/maritime-security_en
[23] The European Union Maritime Security Strategy (EUMSS Action Plan)
https://ec.europa.eu/maritimeaffairs/sites/maritimeaffairs/files/docs/body/20141216-action-plan_en.pdf

Advanced autonomous systems for controlling modern ships will lead to more complex use interfaces. The maritime human-interface and the associated human factors will therefore be critical, particularly in high-risk and complicated operations. With the introduction of autonomous vessels with shore-based control, new human factor challenges will arise and present opportunities for employing advanced technologies, such as Artificial Intelligence (AI), expert system, and neural networks. Human factors related to autonomy in the maritime domain[24] and in unmanned ship handling[25] are areas of growing interest.

The aviation industry is considered more sophisticated and mature in its approach when facing similar human and organisational challenges to operational safety. Coles[26] has identified five topic areas where shipping can learn from aviation in order to improve safety. The SEAHORSE project[27] is considering technology transfer from air transport to maritime transport, focusing on human factor problems for safer more resilient shipping operations. **Annex 4** describes five topics where shipping can learn from aviation in order to improve safety.

Materials, Production and Recycling

Materials and structures as well as their production, assembly, outfitting, repair, retrofit and recycling processes have an important impact on life cycle cost, environmental impact, and the safety of modern ships.

Future ships will see an increasing combination of different materials in structural as well as outfitting applications. By using smart materials and design solutions, vessels will become more flexible and efficient. New materials for maritime application are highly promising for both weight reduction and environmental protection. This will offer significant efficiency gains and reduce hull resistance. The use of "big data" will also help to make maritime products more suitable for new and extreme operational conditions.

The EU Ship Recycling Regulation (1257/2013), which covers the design, construction, operation and preparation of ships, aims to facilitate sustainable ship recycling, without compromising the safety and operational efficiency of ships – see **Annex 5**. The material flows from ship dismantling are significant, and strengthening of the ship recycling industry in Europe will support the European Commission's circular economy action plan.

Production based on Cyber Physical Systems, such as digitalisation, augmented reality, simulation and optimisation, human-robot interaction, and IoT, have the potential to transform conventional shipyard processes, leading to significant changes for employees and manufacturing for shipyards of the future. These systems will enhance life-cycle management and proactive maintenance.

[24] Broek, J van den, Schraagen, J,M.C, Brake, te G.M, Diggelen, van J, (2017). Approaching full autonomy in the maritime domain: paradigm choices and Human Factors challenges. *MTEC2017*, 26-28 April 2017, Singapore.

[25] Y. Man, M. Lundh, and T. Porathe. "Seeking Harmony in Shore-based Unmanned Ship Handling-From the Perspective of Human Factors, What Is the Difference We Need to Focus on from Being Onboard to Onshore?." Advances in Human Aspects of Transportation: Part I 7 (2014): 231.

[26] Frank J. Coles, Transas, CEO: http://www.thesis2017.com/the-5-things-aviation-can-give-to-shipping/

[27] Strathclyde University et al, SEAHORSE Project: www.seahorseproject.eu

Integrated Transport Logistics

The main challenge that logistics service's providers face is that transport and logistics services sectors are heterogeneous and fragmented. This currently limits the integration of services and the combination of resources, especially in "door to door" logistic chains. An integrated ICT infrastructure for transport and logistics will be imperative for all modes of transport.

In the maritime transport sector, vast amounts of data are available that could support new business opportunities to improve the logistics and ship operation. Value-added services for better management of intermodal freight transport would improve safety, security, environmental performance and competitiveness. There are numerous potential advantages in better exploiting available data and the use of information and communication technologies in transport and logistics, such as improved traffic management in ports and at sea, and reduced administrative cost of regulatory compliance.

Connection of maritime transport with other transport modes, including inland-waterways transport, will eventually be seamless. Smart vessels will communicate with smart ports to limit congestion, waiting time and thus costs. Smart vessels will then adapt their sailing speed to match harbour slots automatically.

Acoustics and Underwater Noise

Maritime traffic and industrial activity at sea has increased steadily, causing underwater noise with an impact on marine life. Underwater noise related to maritime activities needs to be mitigated to prevent negative effects on marine life and in order to achieve a good environmental status, consistent with the objectives of the European Marine Strategy Framework Directive (MSFD) (2008/56/EC). The consequences of noise and vibration emissions from the ships (propeller and cavitation noise etc.), include a disturbance for both passengers and harbour area residents, and possibly health issues for the crew. Prolonged exposure to high noise and vibration levels will cause fatigue, reduce effectiveness in work, and can lead to hearing degradation.

The IMO Code on noise levels on board ships, adopted by resolution MSC.337 (91), recognised the need to establish mandatory noise level limits for machinery spaces, control rooms, workshops, accommodation and other spaces on board ships, and entered into force on 1 July 2014.

Work is now underway in recognition that international legislation is required for underwater sound, as a pollution aspect. For example, ISO are developing international standards related to sound from ships and pile driving. However, the available experimental data on underwater noise effect and on the real emission levels are still very limited and need a wider testing campaign.

Blue Growth

In 2012, the EU adopted a Blue Growth Strategy[28] to support sustainable growth in the marine and maritime sectors as a whole, as the seas and oceans are drivers for the European economy and have great potential for innovation and growth. This is the maritime contribution to achieving the goals of the Europe 2020 strategy for smart, sustainable and inclusive growth.

The EU Council's conclusions on Blue Growth[29] have called upon Member States to manage the oceans and seas sustainably, and to promote renewable resource efficiency and renewable energies. This has reaffirmed the value of marine ecosystem services as a driver for Blue Growth and for sustainable development.

The blue economy covers activities related to the seas and oceans. These activities offer an essential contribution to tackling today's longer-term challenges, such as globalisation and competitiveness, global warming and climate change, increasing scarcity of natural resources, urbanisation and concentration in coastal regions, and demographic change.

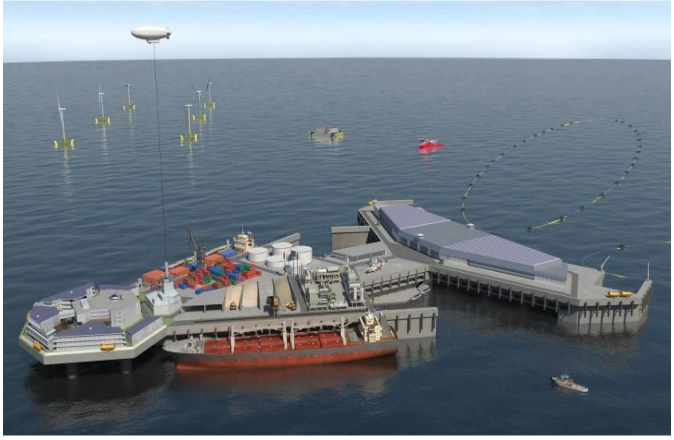

Illustration of a Blue Growth Cluster.

The industrial activities to realise these challenges are diverse and include renewable energies, mining, fisheries, maritime security, biotechnologies, desalination, aquaculture, fish farming, living at sea, and tourism. As these activities are very different from each other, they will require many new technologies and innovations to develop these new concepts.

The most mature new economic activity at sea is wind energy. Although large wind farms have been installed, innovations for efficient installation and maintenance are still required. Another important research topic is the mitigation of noise while piling for these large farms. Floating wind farms, for which many new concept exist, offer an alternative installation approach. However, the motions of the wind energy platform in combination with the sensitive turbine presents a challenge, which currently can only be resolved with a high financial cost.

Tidal energy systems are also slowly becoming more mature, but their main problem is the maintenance. These full-time submerged systems are difficult to reach, and taking them out of the

[28] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Blue Growth opportunities for marine and maritime sustainable growth, COM(2012) 494 final.
http://ec.europa.eu/transparency/regdoc/rep/1/2012/EN/1-2012-494-EN-F1-1.Pdf

[29] European Council conclusions on Blue Growth, 10662/17, 26 June 2017.
http://data.consilium.europa.eu/doc/document/ST-10662-2017-INIT/en/pdf

water for prolonged periods limits their profitability. New concepts are therefore needed that focus on a combination of energy efficiency and maintainability. Other ocean energy sources, such as wave energy, salinity gradients and thermal energy, are being investigated for their profitability, but they are all still in their infancy.

Many new activities at sea involve floating structures, some of them are large and heavy, and others are slender and light. All of these structures will need to be moored in a safe but cost-effective way, leading to new developments in mooring systems and equipment. Safety margins used in the oil & gas industry harm profitability, so that wave and mooring loads on these floating structures and its strength must be predicted with high fidelity. Furthermore, smart and adaptive materials and structures are required to improve the platforms ability to operate in ever-changing environments and conditions.

Arctic Opportunities

Maritime transport in the Arctic has attracted widespread attention because of the region's growing strategic importance. Global warming and the resultant reduction in ice have made the Northern sea route more feasible. Technological development for enabling operations in hostile and remote environments has also offered the prospect of new transport routes in Arctic regions. This development has drawn interest from the shipping community as an opportunity to reduce economic costs and CO_2 emissions. Arctic shipping route is not expected to become competitive until around 2040, however, research and development will be required to prepare for this eventuality.

There will also be new opportunities in economic sectors such as the fisheries, tourism, as tourist cruise vessels are likely to visit both Polar Regions more frequently, oil and gas, and transport. These economic activities will require new developments in monitoring systems, emergency response systems, and search and rescue services in harsh waters.

Shipping in the Arctic.

Vessels operating in Arctic regions with ice will experience abnormal loads and forces on the hull, propulsion system, and appendages, such as rudders and dynamic positioning systems etc. These design aspects need to be addressed. A goal-based design framework will help ensure that vessel design, construction, equipment, training, and search and rescue requirements are connected to the key hazards of ship operation in Arctic regions. These hazards include the rapidly changing weather conditions, ice conditions, and the human- system interface challenges in Arctic regions.

Extremely low temperatures are also a consideration for the materials, equipment, and the environmental systems involved; it also affects ship operations, the crew and human factors. Anti-icing engineering solutions are required to reduce the impact of ice formation on a vessel's stability, safety equipment and on-board safety. Real-time ship monitoring and ice movement predictions in combination with Met-ocean data could also provide reliable decision making for safe and efficient Arctic voyages. This integrated information would also help with oil spill incidents and search and rescue operations, providing that these remote regions have good wireless communication technology.

EU research and innovation – the justification

The aim of the European Union's RTD policy is to strengthen the scientific and technological basis of European industry and to encourage it to become more competitive at international level. It also has the objective of strengthening its scientific and technological bases by achieving a European research area in which researchers, scientific knowledge and technology circulate freely.

"EU support for research and innovation is provided when it can be more effective than national funding[30] i.e. when it offers European value-added. It has one single overriding objective: the achievement of impact. This is realised through measures to coordinate national and private funding and by implementing specific measures to build a European Research Area (for example, transnational collaborative research). These measures generate a series of benefits that are not achieved by Member States acting alone".

The EU helps private companies come together and to implement joint strategic research agendas through tailored instruments, such as European Technology Platforms and Joint Technology Initiatives. The EU also brings together compartmentalised national research funding using instruments such as the ERA Networks (ERA-NETs).

Working in transnational consortia helps firms to lower research risks, enabling certain research to take place. Involving key EU industry players and end-users reduces commercial risks, by aiding the development of standards and interoperable solutions, and by defragmenting existing markets. Collaborative research projects, with the cooperation among academia, research centres and industry, involving end-users, enable the rapid and wide dissemination of results leading to better exploitation; these projects also allow for collaboration on real developments that would otherwise not be possible.

EU countries are encouraged to invest 3% of their GDP in R&D by 2020 (1% public funding, 2% private-sector investment) - this is expected to create 3.7 million jobs and increase the EU's annual GDP by nearly €800 billion.

Appendices

The Appendices, which provide additional information on the topics explored in the text, are included in the Position Paper – Appendices. The Appendices included are as listed below:

ANNEX 1: Climate Change and Emission Polices.
ANNEX 2: Arctic Policy and the Polar Code.
ANNEX 3: Fuel Cells for Maritime Applications.
ANNEX 4: Human Factors.
ANNEX 5: Ship Recycling Regulations and European Recycling Facilities.

[30] Strategic Plan 2016-2020, Directorate-General for Research and Innovation.
http://ec.europa.eu/info/publications/strategic-plan-2016-2020-research-and-innovation_en

ECMAR

European Council for Maritime Applied R&D

Credit: Rolls-Royce

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