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Maritim21, An integrated maritime strategy
for research, development and innovation

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MARITIM21

SUMMARY AND CONCLUSIONS

Norway's internationally leading maritime sector has competitive companies across the entire spectrum of maritime industrial activities, and is of major importance to value creation and employment. Together with seafood production and offshore energy, Norway's marine industries form a complete industrial cluster.

Norway's population accounts for only one thousandth of the global population, but Norwegian-controlled shipping companies own five per cent of the global fleet in terms of value. Due to the international focus of the maritime sector, a large share of revenues comes from abroad. In 2013, the maritime sector accounted for nearly 40 per cent of all Norwegian exports, excluding crude oil and natural gas.

The Maritim21 strategy group was appointed by the Ministry of Trade, Industry and Fisheries in December 2015 for the purpose of developing a holistic and unified, stakeholder-inclusive strategy for research, development and innovation for the maritime industry. The objective is to encourage research, development and innovation activities that will promote sustainable growth and value creation, improve the competitiveness of the maritime industry and realise the potential of the maritime industry through synergies with the other marine industries.

The overall recommendations set out in the Maritim21 strategy report are based on the reports submitted by the four working groups in the areas of maritime operations, transport and logistics, greener maritime activities, and enabling technologies. These reports also explore three cross-cutting topics: safety and security at sea, the Arctic and northern areas, and value creation and framework conditions.

RECOMMENDATIONS FROM THE STRATEGY GROUP

In order for the Norwegian maritime industry to maintain its world-leading position, companies must continue to develop and apply knowledge and new technology that promote innovation and facilitate increased value creation within new and existing ocean-based industrial activities. This calls for an intensive effort across the board, from basic research, education and competence development, via applied research and development, to testing and demonstration of solutions. The strategy group recommends that investments in research, development and innovation (RD&I) for the maritime sector are significantly strengthened, in order to maintain Norway's status as a leading maritime nation.

ENABLING TECHNOLOGIES

Innovation is increasingly fast-paced in the current economic climate, and in an economy like Norway's it is critically important to be a technological leader. The enabling technologies, and the expertise needed to apply them, will undoubtedly be the strongest technological drivers in the years ahead, and are important for innovation, growth and restructuring in the maritime sector.

The strategy group recommends implementing measures to ensure that the Norwegian maritime industry and research and education environments develop specialist expertise in enabling technologies and are equipped with the knowledge and innovation experience needed to apply these.

OPPORTUNITIES IN OCEAN INDUSTRIES

To offset the challenges of the decline in maritime activities related to offshore oil and gas activities, the industry must innovate and find new markets and opportunities in existing markets. It is important to look into growing markets and/or markets where Norway has competitive advantages. Within the framework of the emerging global ocean-based industries, Norway has much to gain from exploiting the synergies between its various marine industries.

Importance must be attached to identifying the perspectives and drivers that will open up future opportunities. New technologies can offer fresh opportunities in new and existing industries and markets. Autonomy, automation and remote control are very promising in terms of cutting costs and enhancing the safety of operations, and may make sea transport competitive in entirely new market segments.

The major opportunities opened up by new technologies and markets will call for new business models. The strategy group recommends carrying out integrated, interdisciplinary RD&I activities along the entire value chain to take full advantage of this potential.

DIGITAL TRANSFORMATION OF THE MARITIME INDUSTRY

The digital transformation of the maritime industry will affect the varieties of products and services to be delivered, the methods that will be used for production, and the design of future business processes and models. Digitalisation will be important throughout the entire maritime value chain, from design and production to vessel operations. Digital interfaces must be developed and standardised, components and equipment must be developed and tested, and data must be stored and shared – and all of the stakeholders must cooperate to realise this. Digitalisation will also be key in developing solutions that enhance the efficiency of and optimise technical and commercial operations and logistics, and will make it possible to analyse large amounts of data from marine observation and monitoring systems. The strategy group therefore recommends carrying out targeted RD&I activities to implement the digital transformation of the industry.

PROMOTING GREENER MARITIME ACTIVITIES

Given the current level of emissions and projections for the future, dramatic measures are called for to reduce energy needs and increase energy efficiency as well as develop new energy carriers and cleaning technology. There is great potential for value creation in technologies and methods for reducing emissions to air and water. The reduction in emissions called for by commercial actors, the public authorities and society at large will drive the need for effective, scalable solutions.

The strategy group recommends carrying out RD&I activities to optimise the design and operation of vessels to increase energy efficiency and reduce emissions. The group also recommends focusing on solutions where Norway has competitive advantages, such as electric propulsion systems, hybrid solutions and gas-driven vessels.

SAFETY AND SECURITY AT SEA

In years to come, the risk picture will change as a result of new energy carriers, new technology and climate change, among other factors. It is important to generate awareness and understanding of various types of risk and threats. The strategy group recommends carrying out RD&I activities that can help to improve safety and security through both preventive and proactive measures in order to reduce the probability of an undesirable event and improve preparedness to limit the impact of an undesirable incident should it occur.

THE ARCTIC AND NORTHERN AREAS

Activity in northerly waters is on the rise, and the most highly trafficked waters are located within Norway's jurisdiction. Norway should therefore aim to be a leader in developing technology and operational expertise for cost-effective, safe, environment-friendly transport and operations in the Arctic and northern areas. The strategy group recommends further tailoring technology, operational systems and logistics to the conditions in these waters. Norway must also implement targeted RD&I activities to improve safety and preparedness in these areas and ensure that good communications infrastructure is in place.

TARGETED FUNDING INSTRUMENTS

A wide range of funding instruments and substantial investment in RD&I will be needed to further develop the Norwegian maritime sector. The strategy group recommends allocating funding for infrastructure, both for RD&I and for demonstration and verification, as well as more funding for larger-scale demonstration projects. There is also a need for *dedicated* long-term schemes that facilitate targeted activities in important maritime areas. In addition, the various programmes and initiatives offered by each of the public agencies within the research and innovation system must be made more seamless and less fragmented, and the agencies must better coordinate their activities vis-à-vis the industry and the research community.

Collaboration between education, research and industry is critical for fostering innovation at an early stage of the educational pathway, and collaboration across subject fields and industrial sectors must be strengthened to take advantage of the new opportunities emerging in the ocean space industries. The potential inherent in military technology as well as capacity and competency in operations should be exploited to a greater degree in the civil maritime sector.

Norway is a leader in many fields of maritime research. Nevertheless, there is great potential for collaboration with research institutions in other countries. Cooperation within the EU is of key importance, and the strategy group recommends that the Norwegian authorities work to ensure greater focus on maritime research in future framework programmes. It is also important to engage in RD&I cooperation with emerging markets.

The public authorities have a clear responsibility to mitigate risk when funding RD&I projects through the public research and innovation system. It is important that support schemes and incentives outside this system are designed to promote innovation and industrial development. The industry must itself take steps to ensure that research and innovation activities are of relevance to industry, must contribute funding for projects and equipment and make data available.

If a significant increase in value creation and employment is to be achieved, all the stakeholders and all the funding instruments and incentive schemes must pull in the same direction to avoid fragmentation. A collective effort is needed from all those involved in the most promising opportunities and the most pressing challenges in the industry.

Given that the industry is undergoing major changes, it is critical to ensure that this RD&I strategy is updated on a regular basis. The strategy group recommends establishing a permanent Maritim21 secretariat. This will ensure continuity in strategy development, lend credence to future RD&I initiatives, promote cooperation between the industry and the research community, and contribute to the effective implementation of the strategy.

MARITIM21 RECOMMENDATIONS

Greater investment in research, development and innovation for the maritime sector is needed to uphold Norway's status as a leading maritime nation.

NORWAY – A LEADING MARITIME NATION

Norway has an internationally leading maritime sector with competitive companies across the entire spectrum of industrial activities. The sector is of major importance to value creation and employment.

The Norwegian maritime industry has its roots in a unique combination of talented seamen, risk-taking shipowners, technologically advanced ships and ship's gear, world-leading research groups and a tremendous capacity for innovation.

In order for the Norwegian maritime industry to maintain its position, it is essential that companies continue to develop and apply knowledge and new technology that promote innovation and facilitate increased value creation within new and existing ocean-based industrial activities. This calls for an intensive effort across the board, from basic research, education and competence development, via applied research and development, to testing and demonstration of solutions. Investment in research, development and innovation (RD&I) for the maritime sector must be strengthened significantly in order to uphold Norway's status as a leading maritime nation.

Underway in the effort to draw up this strategy, it has become clear that the enabling technologies will be important drivers for RD&I in the future and a key to further growth and value creation. Following an introduction describing important framework conditions, this chapter of the strategy document addresses challenges and recommendations in six thematic areas. *This structure is illustrated in Figure 1.* The recommendations of the Maritim21 strategy group are based on and supplement the more specific recommendations of the four working groups. The final section here addresses targeted funding instruments for RD&I and the relationship between private sector and public sector responsibilities.

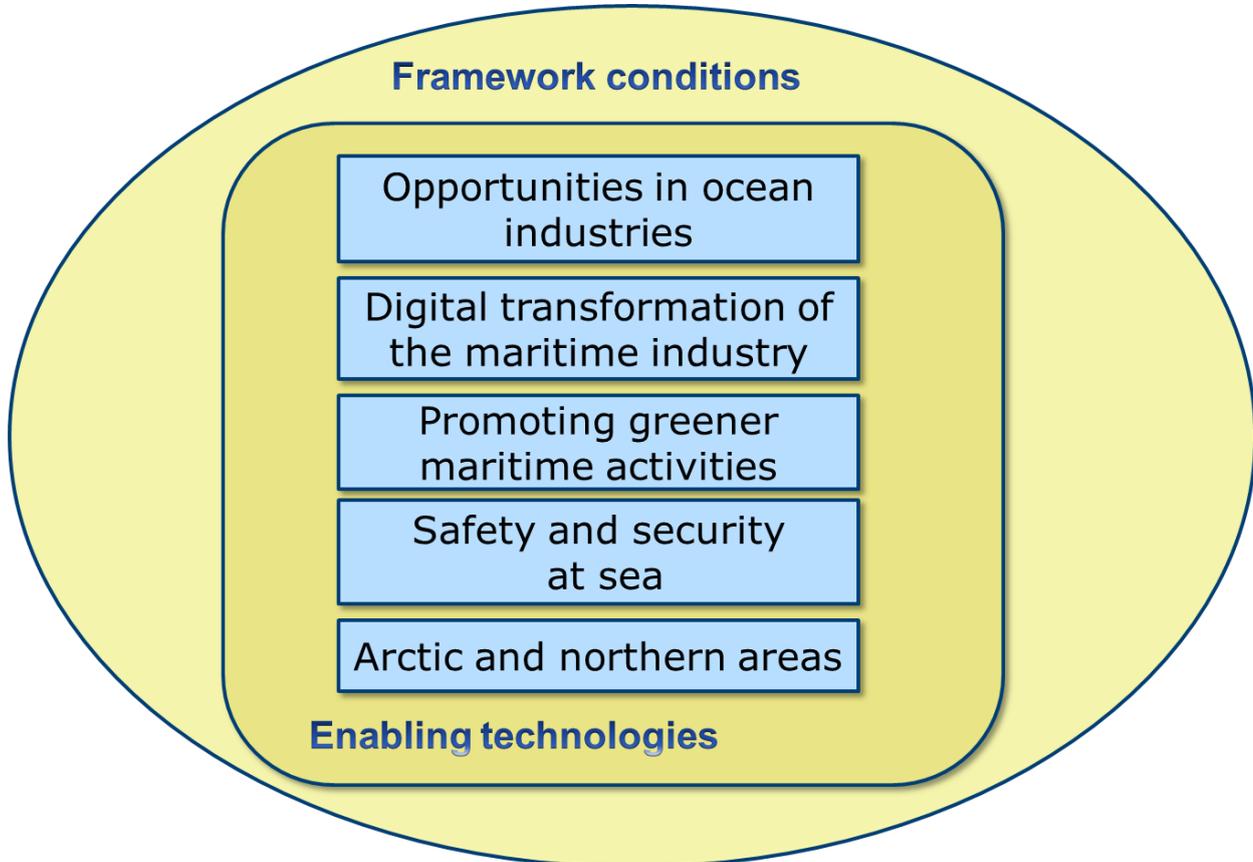


FIGURE 1: Main priorities of Maritim21

FRAMEWORK CONDITIONS

Good, long-term and predictable framework conditions are critical to the development of the maritime industry in Norway. The underlying conditions for industrial activities determine the extent to which Norway can exploit the potential for value creation inherent in the marine industries. Such conditions encompass a wide range of areas, from overarching policy and regulations to detailed instruments and research infrastructure.

In order to achieve the objective of the Maritim21 strategy, it is essential to ensure that the necessary framework is in place to foster the research, development and innovation required to increase value creation and employment within new and existing ocean-based industrial activities.

The seas and oceans, including the maritime sector, are a priority area in the Government's *Long-term plan for research and higher education 2015–2024*. The Government's maritime strategy of 2015 also emphasises the importance of competence, education, research, development and innovation in the area. It is important that these documents are followed up by prioritising maritime research in the annual national budgets.

Norway's complete maritime cluster, with excellent expertise in all segments of the value chain and internationally leading research and education environments, makes the country an attractive location for maritime activities. A targeted, well-designed overall framework for activities also plays an important role and is a prerequisite for encouraging international companies to invest and establish a presence in Norway. The presence of major international companies in Norway has in turn made the Norwegian maritime cluster even better and more complete, creating a highly internationally-oriented Norwegian maritime industry with a firm foothold in the global market. Norway must clearly identify what has made it an attractive host country and implement measures to ensure further development along these lines. Innovation in the maritime industry has had good help from the petroleum sector, which is now under pressure cost-wise. Efforts to maintain Norway's attractiveness must be intensified in light of a weaker petroleum industry and increased international competition.

Access to infrastructure for research, innovation and demonstration is critical, as is a well-functioning public research and innovation system. This can give international companies an incentive to establish their research and development activities in Norway, and will draw the most talented Norwegian and international researchers to Norwegian research environments.

ENABLING TECHNOLOGIES

Innovation is increasingly fast-paced in the current economic climate, and in an economy like Norway's it is critical to be a technological leader to be able to justify high salary levels. The enabling technologies, and the expertise needed to apply them, will undoubtedly be the strongest technological drivers in the years ahead, and are important instruments for innovation, growth and restructuring in the maritime sector.

The enabling technologies are traditionally defined as ICT, nanotechnology, advanced materials, biotechnology and advanced production processes. ICT is essential for the maritime industry. The following briefly describes key areas where the industry and research and education environments need to have world-leading knowledge, expertise and technology.

AUTOMATION

Automation and control systems enhance safety and efficiency by reducing the number of manual operations necessary for vessel management, maritime operations and ship production. Robotics and automation are closely linked technologies. There is tremendous potential for cheaper, faster robots built using lighter materials in the building, development and operation of the next generation of ships, ports, shipyards and marine monitoring systems.

Remote control and autonomy technologies will play a key role in next-generation vessel management, and will lead to more operational decisions being taken outside the vessel, as shipping company's offices or equipment suppliers will be monitoring a vessel or fleet of vessels, including the equipment. Greater, more reliable bandwidth for satellite communications has made this possible. Autonomy, adaptability, equipment failure prediction and artificial intelligence will be part of the next generation of decision support systems.

Sensors play a vital role in all types of automation systems. Advancements have led to smaller, smarter, cheaper and wireless sensors. The digital transformation of the maritime sector will depend on greater access to sensor data and improved communications infrastructure.

Cyber-physical systems are becoming more and more important, and represent an integration of, and smart interconnections between, the physical and digital worlds to enable system control and monitoring. Such systems will be an increasingly important part of operational functions such as dynamic positioning, safety-critical functions and crisis management.

DECISION SUPPORT AND INTERACTION

Decision support is the smart compilation of data to provide the best possible basis for taking the right decisions. Humans will play an important role in future maritime decision support systems and interaction technology, and effective interface solutions will be critical. Developing this kind of technology requires multidisciplinary expertise, such as knowledge about technology, human behaviour during maritime operations, and an understanding of the relationship between humans and machines.

Maritime simulators are an important component of decision support technology. Personnel can be trained in navigation and management of most vessel types, from supertankers with cargo to submarines. Simulators for ocean operations are important for testing new operations, safety and risk analyses, innovation in operations and to extrapolate experience-based knowledge and training.

Direct simulation and advanced computational methods are essential for assessing the properties and capabilities of different vessel design solutions. These can be used in designing the hull, propulsion systems, energy production, equipment and more. Developing simulation tools that truly mirror reality requires good experimental laboratories and data from actual operations in order to identify the physical parameters for these tools. The use of virtual prototyping makes it possible to test the performance of different design variants in different operational scenarios.

COMMUNICATIONS AND NAVIGATION

The demand for communications and navigation services will increase as more advanced ICT systems and decision support systems are introduced on board, especially in connection with the use of remote-controlled and autonomous vessels in the future. These solutions will have strict cybersecurity requirements.

NEW MATERIALS AND PRODUCTION METHODS

3D printing is a quick process in which a physical prototype of a digital model is built layer by layer. 3D printing facilitates rapid testing of multiple design concepts, and the potential for using mineral or metal filament will open up alternative uses, such as for production of parts and production of spare parts on board or in port.

Advanced materials. Biologically inspired materials, nanomaterials, and stronger, lighter materials will help to advance the development of new design and production methods. These materials can be used to tailor a ship's performance at sea and to integrate sensor systems into the hull, making it possible to monitor sea conditions and improve sailing efficiency.

IMPLEMENTATION

The implementation of new technology will help the maritime sector to take a major step forward and will lead to lower costs, improved efficiency and safer operations. It is therefore important for Norway to develop competencies in and have ownership of the various technology areas that are vital to continued development of the industry and that safeguard Norwegian competitiveness. It will be necessary to establish a nationally leading research environment with specialist expertise in key technologies and other knowledge areas.

Norway has world-leading expertise in research, development and application of enabling technologies in the maritime sector. It is important to acknowledge that much of the research and development in basic technologies is carried out abroad. Norwegian researchers must cooperate with leading international research groups to stay up to date on developments on the research and technology front for enabling technologies and to learn about research conducted outside Norway.

Even if new technology is available, a number of obstacles may stand in the way of its implementation. RD&I studies and analyses may be necessary to identify the barriers to technology development and application and how these may be surmounted.

RECOMMENDATIONS

- **In the years ahead it will be critical to implement measures to ensure that the Norwegian maritime industry and research and education environments develop specialist expertise in enabling technologies and are equipped with the knowledge and innovation experience to apply these.**

OPPORTUNITIES IN OCEAN INDUSTRIES

To offset the challenges of the decline in maritime activities related to offshore oil and gas, the industry must innovate and find new markets and new opportunities in existing markets.

Restructuring often takes place at the edges of existing knowledge, where knowledge from various fields is combined in new ways. New products, services and business models will be emerging and will require different value chains from those known today. Innovation takes place when value chains are linked together in new ways, as evidenced in the development of offshore wind power and offshore aquaculture.

It will be particularly important to identify the perspectives and drivers that will open up future opportunities. New technologies can offer fresh opportunities in new and existing industries. Technological and research-based innovation will not, however, be the sole driver of development. New business models will be equally important, as some will lead to major success, while others will fail.

Norway is facing certain challenges as a high-cost country, and must therefore seek to enhance competitiveness in other ways. The country must look at the potential for developing Norwegian solutions that are commercially scalable for the national market and for international markets. Innovating and establishing new companies is not enough. New companies must be nurtured to grow, and there is potential for this in the Norwegian ocean space industries. A thriving supplier industry with production in Norway is vital for value creation and employment in the Norwegian maritime industry.

EMERGING INDUSTRIES

When scouting out new markets, it is important to turn an eye towards expanding markets and/or markets where Norway has competitive advantages. It is essential to exploit the synergies between existing and emerging marine industries. Energy and seafood are two large and growing markets where Norway has competitive advantages.

Maritime operations in connection with offshore wind power share many similarities with maritime operations in connection with oil and gas activities in the North Sea, and there should be synergies between these two industrial segments that can be exploited. There will be a widespread need for ships and equipment for both construction and maintenance.

In the fisheries industry there may be major opportunities in fishing lower in the food chain and exploiting deep-sea fish. Today's larger fishing vessels feature solutions that fully utilise raw materials. The challenge is to find optimal solutions for smaller vessels and coastal fishing vessels, where there is great potential for bringing more fresh raw materials to shore.

With regard to aquaculture, there will be market opportunities in moving aquaculture activities out to the open ocean. Such a development will be very interesting for the maritime industry, as there will be a need for transport and equipment as well as for vessels that can undertake operations in connection with installation, anchoring, operation and maintenance of aquaculture facilities.

Marine tourism is also growing globally, and Norway's coastline is excellent for adventure travel. There will be a need to design "small", specialised, environment-friendly tourism vessels.

When the level of activity in oil and gas recovery increases again, there will be a need for expertise in operations in deeper waters, in harsh climates and in areas where more equipment will be installed on the seabed. Seabed mining may emerge as an area of great potential in the future.

New markets will also emerge as the result of official directives, such as the final ratification of the International Convention for the Control and Management of Ships' Ballast Water and Sediments. Addressing emerging markets will call for research and development in many areas.

ENABLING TECHNOLOGIES

The enabling technologies are expected to give rise to radical innovations and entirely new kinds of enterprises.

Autonomy, automation and remote control are very promising in terms of cutting costs and enhancing the safety of operations, and may make sea transport competitive in entirely new market segments. Solutions for automated vessel and cargo management will dramatically reduce costs, improve customer service and facilitate higher transport frequency at lower costs. However, the introduction of autonomous vessels will have consequences for safety, legal and ethical norms, among others. The regulatory framework will have to be adapted and the requirements for cybersecurity made more stringent.

Remote monitoring and control of operations from land will enhance reliability, cut costs and reduce emissions. This will enable Norwegian actors to win back market shares in technical and commercial operations.

NEW BUSINESS MODELS AND SERVICES

Successful realisation of innovations will in large part be dependent on the industry's capacity to innovate and the establishment of framework conditions that promote value creation and can effectively accommodate new technological and business solutions. Expertise must be developed and adapted at a pace matching that of technology development. The major opportunities opened up by new technologies and markets will call for new business models that utilise the technologies as well as economic systems such as the circular economy¹ and the sharing economy. All of this will have an impact on decision making and service supply in the maritime industry. The sharing economy will encourage better resource utilisation, increased transparency and optimisation of the entire industry, and will create a new set of business opportunities.

The supply of maritime services is an important segment of the Norwegian maritime industry. New technologies and markets may lead to new services, and service innovation often creates added value. New business models and services often require new organisational solutions, which in itself may lead to new services.

RECOMMENDATIONS

- **New markets, technologies and business models will open up opportunities in existing as well as emerging industries. There will be a need for integrated, interdisciplinary RD&I activities along the entire value chain to take full advantage of this potential.**

DIGITAL TRANSFORMATION OF THE MARITIME INDUSTRY

All of the major maritime companies are working to implement ICT methods and tools or digitalisation², as it is often called. The digital transformation³ of the maritime industry will affect the types of products and services that are to be delivered, the methods that will be used to produce these, and the design of future business processes and models. Digitalisation will be important throughout the entire maritime value chain, from design and production to technical and commercial vessel operations.

DESIGN AND PRODUCTION

Norway is a high-cost country, and in today's market situation it will be especially important to ensure that the design and production of ships and equipment is as cost-effective as possible. In addition, ships and equipment must be designed to operate in the most cost-effective, environment-friendly and safe manner possible.

Digitalisation will be essential to achieving these aims. Simulation, virtual prototyping and virtual testing will enable the testing of complete systems early in the design phase. Using data from actual operations and data on sea conditions will make it possible to test in a virtual environment how ships and equipment will perform under realistic conditions.

Furthermore, automation and robotisation will improve the efficiency of the production phase. Design data can be directly used to generate engineering data and for automatic production

¹ The circular economy is based on reuse, repair, upgrade/improvement and recycling in a loop where the fewest possible resources are lost.

² "The use of data technology, methods and tools to replace or increase the efficiency of manual or physical tasks. This meaning applies when data technology is used to produce goods and services or to establish infrastructures such as data networks and data collections." Source: Store Norske Leksikon, translated from the Norwegian.

³ Digital transformation is the profound and accelerating transformation of business activities, processes, competencies and models to fully leverage the changes and opportunities of digital technologies and their impact across society in a strategic and prioritized way, with present and future shifts in mind. Source: I-Scoop

preparation. Digital production systems can optimise the production sequence and improve the efficiency of operational planning.

A complete digital maritime value chain will be required. Digital interfaces must be developed and standardised, components and equipment must be developed and tested, and data must be stored and shared – and all of the stakeholders must cooperate to realise this. Digitalisation will facilitate innovation in products and processes that will enhance companies' productivity.

OPERATIONS

Vessel operations must be as cost-effective, safe and environment-friendly as possible, and digitalisation will play a key role in achieving this.

Data from the same digital value chain can be used to simulate and plan complex operations as well as to train personnel with the help of simulators. Data from actual operations can be compiled and later used for improving simulation models.

Each ship will have its own digital infrastructure. Sensors will measure data from various systems, networks (e.g. that use the Internet of Things) will collect this data, and advanced interaction technology supported by analysis and simulation models will provide the operator with decision support. These same systems will also enable a greater degree of automation and optimisation, and with the help of communications technology, the ships can be monitored and remote-controlled from land to enhance efficiency and safety.

Creating this digital infrastructure will require developing necessary technology and components along with the digital interface to tie these together. It will also be important to give adequate consideration to the human element when developing technology. Equipment and components from different suppliers must be able to “communicate” and the stakeholders involved will have to work together to achieve this. In the area of sea transport, advanced commercial and operative decision support systems for operations can yield a higher degree of efficiency, utilisation, reliability and safety. More complex analysis models will help to enhance understanding of vessel performance under different conditions. Good, inexpensive communications solutions will lead to new operational and business models that can boost the competitiveness of Norwegian actors as a result of lower costs and improved customer service. Furthermore, predictive systems for decision support and data analysis will be drivers for optimising and safeguarding technical and commercial operations through more effective prevention and management of undesirable events (e.g. predictive maintenance).

LOGISTICS AND PORT OPERATIONS

If maritime transport is to cover more of the increase in transport volume, more solutions for cost-effective transport and logistics operations need to be developed. Maritime transport resources must also be utilised optimally.

Expertise in fleet management has become a competitive advantage. Optimisation of routes, fleet operations and supply chains can greatly enhance efficiency and will require increasingly more advanced modelling. There is also a need for decision support systems for planning and operations, including comparison of transport solutions.

Providing reliable transport and logistics is dependent on a comprehensive transport chain with good transport solutions and hubs. Effective cargo handling will enhance the competitiveness of Norwegian actors and sea transport in general. Furthermore, there is a general need to generate greater awareness about sea transport as well as deeper understanding of the obstacles involved in, and effective incentives and measures for, shifting more transport from the road to the sea.

OBSERVATION AND MONITORING

The use of marine areas entails challenges relating to weather, climate, the environment and sustainable resource use. These set a framework for industrial development and maritime operations. Monitoring and observation above, on and below the sea are critical for all the marine industries. Effective marine management requires technologies for diverse and tailored monitoring, data collection, mapping, navigation and communications. Expertise and technology are needed to analyse the large amounts of data generated. There may be fresh opportunities for Norwegian maritime companies in this area.

RECOMMENDATIONS

Prioritise funding for RD&I on the digital transformation of the maritime industry, particularly targeted towards:

- **developing technology, equipment, components and interfaces that together form a complete digital value chain for design, production and operations;**
- **developing solutions that enhance the efficiency of and optimise technical and commercial operations and logistics;**
- **developing solutions for compiling and analysing large amounts of data from marine observation and monitoring systems.**

PROMOTING GREENER MARITIME ACTIVITIES

It is essential to explore greener solutions for priority areas in maritime research and development, and these solutions are a common denominator in the recommendations given in the various thematic areas encompassed by the strategy report.

Given the current level of emissions and projections for the future, dramatic measures are called for to reduce energy needs and increase energy efficiency as well as to develop new energy carriers and cleaning technology. There is great potential for value creation in technologies and methods for reducing emissions to air and water. The reduction in emissions called for by commercial actors, the public authorities and society at large will drive the need for effective, scalable solutions.

As part of the process of drawing up its report, the Norwegian Government's Expert Committee for Green Competitiveness received roadmaps for reducing emissions from a number of sectors. The roadmap for the transport sector, which includes seaborne passenger and cargo transport, shows that it is possible to reduce transport emissions by 50 per cent by 2030. The target of the roadmap for the Norwegian continental shelf is that maritime activities on the shelf will be conducted with low or zero-emission technology from the offshore fleet by 2030.

REDUCING ENERGY NEEDS AND INCREASING ENERGY EFFICIENCY

Reducing the energy needed to carry out a given operation as well as increasing the degree of utilisation of the energy will cut associated energy costs. Good detailed measurements will be an important step in the right direction. Data on a vessel's operational profile, energy consumption and emissions are essential for identifying the potential for improvement and assessing technologies and measures. Better simulation models that support the optimisation of design and operation will also help to reduce energy needs.

In order to reduce energy needs it is important to look at optimising vessel design and operation. This includes solutions for operational optimisation, designs that lower energy consumption (hulls, propulsion systems, etc.), new antifouling materials, technology to prevent or remove marine growth

on hulls, as well as methods to actively decrease frictional resistance, e.g. by using air lubrication. There is a need to increase energy efficiency in every component of a vessel, from tanks to propellers.

ALTERNATIVE FUELS/ENERGY CARRIERS

The most readily available alternatives to traditional oil-based fuels are liquefied natural gas (LNG), electricity, biofuels, liquefied petroleum gas (LPG) and hydrogen. These can reduce emissions of greenhouse gases and other environmentally and health hazardous substances to varying degrees, depending on how they are manufactured.

Norway is at the forefront of energy storage for ship propulsion, either in the form of fully electric or hybrid solutions. There should be further investment in developing and commercialising electric solutions, where Norway, with its access to clean electricity, serves as an incubator. This will require the construction of charging infrastructure and a deeper understanding of how electrified ships affect and are affected by the electrical grid. The aim should be to implement fully electric solutions when a ship's range allows for this.

Norway is also a leader in the use of LNG as fuel for ships. There should be significant investment in making LNG and LPG competitive alternatives for vessels travelling longer routes.

CLEANING AND REDUCING EMISSIONS TO AIR AND WATER

The market potential for cleaning of emissions is affected by regulatory measures, so research and development in this area must be closely linked to the regulatory regime. In relation to existing regulations, there is greatest market potential in – and competence needs for – SO_x scrubbers, NO_x catalysts and ballast water treatment. In the future there may be a need for systems for removal of soot, methane and CO₂ from exhaust.

FRAMEWORK CONDITIONS AND MARKET MECHANISMS

Many of the solutions for achieving an environment-friendly maritime industry involve technology. Implementation of solutions is dependent on whether framework conditions are in place to help the industry to dismantle obstacles and introduce incentives for developing and applying environment-friendly solutions. A common understanding of climate and environmental impacts may provide a shared value base for cost-benefit analysis of measures and a basis for the design of policy and regulations.

More knowledge is needed about incentives in the form of quotas, fees and deductions. Effective solutions for quantifying consumption and emissions can provide a basis for future fee regimes. Furthermore, it will be important to generate more knowledge about how contracts and tendering and licensing terms and conditions can be designed to encourage more environment-friendly solutions.

RECOMMENDATIONS

Prioritise funding for RD&I to promote greener maritime activities, particularly targeted towards:

- **optimisation of the design and operation of vessels to increase energy efficiency and reduce emissions;**
- **electrical propulsion systems, competitive gas-driven vessels and hybrid solutions;**
- **optimal design of framework conditions and incentives as well as contract structures that encourage good environmental solutions.**

SAFETY AND SECURITY AT SEA

Safety and security at sea involves ensuring the *safety* of humans, values and the environment as well as *security* and protection against external attack. Safety and security can be improved through both preventive and proactive measures in order to reduce the probability of an undesirable event and improve preparedness to limit the impact of an undesirable incident should it occur.

Pressures to cut costs, new vulnerabilities and rapid change have ramifications for the risk picture and the way risks are managed. It is important to generate awareness and understanding of various types of risk and threats.

New technology is changing the security panorama and types of risk. Widespread digitalisation and remote control are accompanied by new types of risk and a need for more stringent cybersecurity. While unmanned vessels can potentially reduce risk to human life and improve navigational safety, they may be vulnerable to cyberattacks.

New energy carriers entail new and changed risks that must be understood before such energy carriers can be implemented. Climate change also poses challenges for safety and security at sea, and there is a need for better understanding of the impact of changing climatic conditions on the maritime industry, operational patterns and operating conditions.

Emergency preparedness, monitoring and evacuation will be critical as ocean-based activity increases, and these should be prioritised in order to improve operational safety and protect the environment. Vulnerability caused by system failure is a key operational safety challenge. Investment should be made in developing next-generation vessel bridge systems and security systems, as these will be particularly important for unmanned and remote-controlled vessels.

Operator error, interaction failure, and a lack of competence and organisational learning are pressing problems in the context of operational safety. The interaction between operational safety, the human element and organisational decisions must be highlighted. New technology and increased autonomy will place new demands on the personnel operating and monitoring the systems. Technology development must take place in parallel with the development of personnel's skills and interaction. There must be both acceptance for implementing new technology and adequate training in using it. Further refinement of training simulators and new training systems will play a critical role here.

RECOMMENDATIONS

Prioritise funding for RD&I on safety and security at sea, particularly targeted towards:

- **enhancing knowledge about changes in the risk picture and their impact on safety and security and about risk management solutions;**
- **enhancing knowledge about how interaction between humans and machines affects safety and security.**

THE ARCTIC AND NORTHERN AREAS

Maritime activity in the Arctic and northern areas is on the rise in connection with tourism, fisheries, exploration and recovery of oil and gas, and sea transport. Norwegian maritime actors are engaged in commercial activities in these areas, and the most highly trafficked waters are located within Norway's jurisdiction. Norway should therefore aim to be a leader in developing technology and operational expertise for cost-effective, safe, environment-friendly transport and operations in the Arctic and northern areas. Operations in this region are demanding. Systems for enhancing safety, monitoring, emergency preparedness, search and rescue, and towing and salvage as well as personal and collective rescue equipment must be developed for the Arctic. Cooperation between the civilian, military, public and private sectors is essential to ensuring effective emergency preparedness, as is

the organisation of trans-border cooperative measures. In harsh polar conditions adaptations must be made to safeguard health, safety and the environment, particularly in connection with equipment and work routines, which must be adequately designed to accommodate weather conditions, cold, darkness, ice and icing.

Traversing long distances entails many challenges, and it is important to develop logistics solutions that optimally utilise infrastructure and services for land-based, air and sea transport in the region. Operations in parts of the Arctic region are highly demanding, and call for the development of technology and operational systems adapted to the Arctic climate.

Arctic operations require reliable communications. In the face of strategic and safety and security-related considerations, it will be important to establish suitable, Norwegian-controlled infrastructure.

RECOMMENDATIONS

Prioritise funding for RD&I in the Arctic and northern areas, particularly targeted towards:

- **developing technology, operational systems and logistics tailored to Arctic conditions;**
- **improving safety, security and emergency preparedness in the Arctic.**

FUNDING INSTRUMENTS FOR RD&I

To be effective, a public research and innovation system must be comprised of good support schemes across the entire value chain, from basic research and competence development, via applied research and development, to testing and demonstration of solutions. Furthermore, an effective research and innovation system must have clear priorities, adequate financial capacity and competent personnel. The system currently in place in Norway by and large satisfies these requirements.

There is, however, a lack of instruments in certain segments of the value chain. In particular, too little support is available for larger-scale demonstration projects and commercialisation in important areas of the maritime sector. Furthermore, there is a great need to strengthen financial capacity in important segments of the research and innovation system. The Research Council of Norway's programme for industry-oriented research in the maritime sector (Innovation Programme for Maritime Activities and Offshore Operations, MAROFF) receives far more high-quality grant proposals than it can fund, and its budget should be expanded. The SkatteFUNN R&D Tax Incentive Scheme is an effective scheme that is popular among the maritime industry, and must be continued.

Cooperation and coordination between the various funding instruments will be critical in the years ahead, as the need for RD&I on interdisciplinary and cross-sectoral questions will increase, and it will be important to take full advantage of expertise across industries. Cooperation between the Research Council of Norway, the regional research funds, Siva, Enova and Innovation Norway should be further developed. Actors in the maritime industry currently find it confusing to navigate their way through all the various funding instruments available, and these should therefore be better coordinated and streamlined into a more seamless whole.

Easily accessible, long-term schemes such as the Centres of Excellence scheme (SFF) and the Centres for Research-based Innovation scheme (SFI) are vital for building dynamic research groups, and an effort should be made to explore how to exploit the synergy effects between these schemes more fully. There is also a need for *dedicated* long-term schemes that facilitate targeted activities in important maritime areas, and funding for researcher-initiated projects where companies can contribute their own resources instead of cash financing should be considered.

Various types of RD&I infrastructure are needed to carry out and expedite maritime research. These include research and innovation centres, excellent laboratories and research vessels, sensor and communications networks, centralised databases containing market data and experiential data from

operations and analysis centres for sharing research results. Modern, up-to-date infrastructure is crucial for maintaining and strengthening Norway's leading position in maritime research and expertise. It is particularly important that the Ocean Space Centre in Trondheim is realised and developed into a global competence centre. Excellent research infrastructure attracts excellent researchers, and is also therefore important for recruitment.

Full-scale demonstration and verification are critical to gaining market trust and market acceptance for new solutions, so there should be significant investment in demonstration projects. Infrastructure for full-scale testing of technologies is also needed to ensure that testing and demonstration activities are carried out at the relevant scale and in the relevant environment. Full-scale testing may be conducted on existing vessels, with the limitations this imposes. Alternatively, funding can be invested in laboratory vessels. For certain technologies, full-scale testing in laboratories on land may be sufficient, and this is less costly.

RECOMMENDATIONS

- **Substantial investment in RD&I is needed to further develop the Norwegian maritime sector. Long-term, strategic projects specifically targeted towards the maritime sector will be very important, as will funding for larger-scale demonstration projects.**
- **Infrastructure is needed both for RD&I and for demonstration and verification. It will be particularly important to realise the Ocean Space Centre in Trondheim.**
- **The various programmes and initiatives offered by each of the public agencies within the research and innovation system must be made more seamless and less fragmented, and the agencies must better coordinate their activities vis-à-vis the industry and the research community.**

ORGANISATION OF RESEARCH, EDUCATION AND DISSEMINATION ACTIVITIES

The further development of the maritime industry is dependent on productive cooperation between all of the stakeholders involved. Mechanisms to promote cooperation should be established in academia and in the business sector, between academia and the business sector, and between groups with experience-based expertise, the research community and academia. Collaboration across the sectors covered by the national R&D strategies for the 21st century – Maritim21, OG21 (oil and gas), HAV21 (marine) and Energi21 (energy) – will also be important.

At present, there is little in the way of joint technology and competence development between the Norwegian Armed Forces and the civilian segment of the Norwegian maritime sector. Norway should exploit the potential inherent in the use of military technology and capacity in the civil maritime sector through collaboration between civil and military RD&I groups. There are many potential synergy effects to be found in closer coordination between the two sectors.

Collaboration between education, research and industry is critical to fostering innovation at an early stage of the educational pathway, and to increasing industry participation in education (e.g. the Research Council's Industrial Ph.D. scheme, master's theses). There is a need for schemes to support shorter stays for researchers in companies as well as for representatives of the industry in research groups.

Dissemination of opportunities and new solutions is essential for ensuring that research results are applied. Dynamic meeting places must be created for trade and industry and the research community, and research results should be presented in arenas where the Norwegian maritime industry is well represented as well as via other dissemination activities.

RECOMMENDATIONS

- **Collaboration across subject fields and industrial sectors must be strengthened to take advantage of the new opportunities emerging in the ocean space industries.**
- **Collaboration between the higher education sector and the business sector must be encouraged to further develop experience-based expertise.**
- **The potential inherent in military technology as well as capacity and competency in operations and leadership must be exploited in the civil maritime sector.**

INTERNATIONAL RD&I COOPERATION

Norway is a leader in many fields of maritime research. Nevertheless, there is much to be gained from the transfer of research results from other countries. This applies particularly to more general subject fields and technologies that are of use to the maritime sector.

Europe is a key arena for international RD&I cooperation. The EU Framework Programme for Research and Innovation, Horizon 2020, addresses topics and research areas of importance for stakeholders in the Norwegian maritime cluster. In addition to being a vital funding source, Horizon 2020 gives Norwegian project participants access to useful research results and important contacts in Europe. It is essential that the Norwegian authorities work to ensure greater focus on maritime research in future framework programmes, and that there are instruments available to help Norwegian applicants to write and submit proposals and to encourage participation. Organisations in the maritime cluster should play a role in increasing participation in Horizon 2020 projects to supplement the activities of the public agencies in the research and innovation system.

Steps should be taken to encourage international cooperation to develop standards and a body of rules, and to create markets for Norwegian environment-friendly products. It is also important to engage in RD&I cooperation with emerging markets to create markets for Norwegian solutions. This calls for bilateral initiatives based on industry activities, especially with Asia, South America and the US.

RECOMMENDATIONS

- **The Norwegian authorities must work to ensure greater focus on maritime research in future EU framework programmes.**
- **RD&I cooperation with emerging markets must be expanded.**

PRIVATE/PUBLIC SECTOR RESPONSIBILITIES

Further development of the maritime industry is the responsibility of both the private and the public sectors. It is essential to promote productive cooperation between the various parties that play different roles in RD&I.

Private sector actors must participate actively to help to ensure that research is of relevance to industry and society at large, i.e. to ensure that research culminates in commercialisable results and the capacity to utilise these to promote efficiency, safety, environment-friendliness.

Trade and industry has an important role to play in terms of contributing data for the development of vessels, equipment and ocean space operations. This includes full-scale data from operations, ships for use as measuring stations and experience. Contributing data for financial, organisational and market-related analyses is also important.

The public agencies in the research and innovation system have a clear responsibility to mitigate risk when funding RD&I projects. It is also important that support schemes and incentives outside this system are designed to promote innovation and industrial development. The public authorities have a clear responsibility for researcher training. In light of the decline in activity in the petroleum industry, it is even more important for the authorities to take greater responsibility in this regard.

The public authorities can exert influence on RD&I on environment-friendly maritime activities in several ways, including through allocation of licences and public procurements.

Activities in the maritime sector are subject to strict controls under national and international regulatory frameworks. In order to realise innovation, the relevant authorities must be involved at an early stage of the innovation process and incorporate this into their work on international regulations. International regulations are essential for maintaining an international market and safeguarding the competitiveness of the Norwegian shipping industry. The aim must be for Norwegian innovation to set the bar for the international standard.

Despite the different roles of private and public sector actors, it is important to promote effective, integrated cooperation between them. While innovation is essential to “conquering the ocean”, entrepreneurship is also needed to develop new marine industries. It is vital that the industry innovates and helps to create an entrepreneurship ecosystem. This will require collaboration between industry, higher education, risk capital, the authorities and entrepreneurs.

RECOMMENDATIONS

- **In general, private sector actors must participate actively to help to ensure that research is of relevance to industry and society at large. The public authorities have a clear responsibility to mitigate risk when funding RD&I projects. In light of the decline in activity in the petroleum industry, it is even more important for the authorities to take greater responsibility in this regard.**
- **The regulatory authorities must set targets and have the resources to enable Norwegian innovation to set the bar for the international standard.**

CONTINUATION OF THE MARITIM21 STRATEGY

This revision of the Maritim21 strategy demonstrates that the maritime industry is on the cusp of comprehensive change. Digitalisation, robotisation and enhanced simulation capacity will lead to wide-ranging changes in the design, construction, management and use of ships and installations. This maritime RD&I strategy must therefore be revised on a regular basis. A permanent Maritim21 secretariat should be established to promote targeted strategic activities between revisions. The secretariat would also have the task of creating meeting places for stakeholders in the maritime industry with a focus on cooperation and coordination of RD&I efforts.

The maritime sector plays a very central role in marine exploration and value creation. Norway should strive to become a leading nation in knowledge, expertise and technology development for ocean space operations and systems. This will require investing in and prioritising research and development in the maritime industry.

RECOMMENDATIONS

- **The Ministry of Trade, Industry and Fisheries should establish a permanent Maritim21 secretariat with fixed annual allocations, based on the model used by the Ministry of Petroleum and Energy for the OG21 secretariat.**