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Final Report Submission from the ESSF sub-group on Research, Technological Development and Innovation (ESSF R&I)
Submission from ESSF sub-group on R&I

This document reflects the outcomes of deliberations of the Research & Innovation sub-group of the European Sustainable Shipping Forum of which the European Commission is part. It is not an official document adopted by the European Commission.

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1. Introduction

In order to meet the sustainable shipping challenges faced by the shipping sector in the area of Environment, Safety and Competitiveness, increased activities in research, development and innovation (R&I), coordinated between all EU maritime transport stakeholders are needed. The White Paper for Transport has set ambitious goals for energy efficiency and emission reductions for shipping, which impact significantly in the development of sustainable shipping business cases. The industry is already working on research actions even towards zero emission ships. However, the effective and efficient implementation of innovative approaches requires coordination, exchange of best practices and optimised use of available resources.

The development and implementation of stricter environmental regulations, both at EU and international level, can impact significantly R&D activities by creating new opportunities for research, new funds for innovation and pilot initiatives and, furthermore, to the development of a risk-sharing wider community, where different stakeholders participate in the promotion of sustainable technology and innovative business models, by taking the “first-mover” risks together in shared initiatives. Alternative fuels and energy efficiency are some of the topics that are part of the current sustainable shipping development. Innovative technologies need to be developed together with innovative ways of thinking shipping and trade. Avoidance of modal shift, fair implementation and enforcement of environmental legislation, development of port infrastructures, are examples where R&D can offer breakthrough initiatives to support sustainable shipping.

Given these challenges, a dedicated sub-group examined these aspects in a more integrated manner under the European Sustainable Shipping Forum (ESSF). The ESSF R&I sub-group has established a Work Structure covering all the relevant topics where R&D could assist the conceptual development and implementation of sustainable shipping. The work of the R&I sub-group has been structured in 12 Work Packages, covering from regulations to more specific technological topics.

1.1 Objectives & Tasks

The Objectives, throughout all the meetings held, for the ESSF R&I were:

1. Review existing and new technology options and solutions for the reduction of shipping emissions in view of the regulatory requirements, but also with a long-term perspective towards zero emission and pollution ships.

2. Contribute to Strategic Research and Innovation Agendas with the identification of key research topics, in order to set research, innovation and deployment priorities in support of sustainable shipping.

3. Contribute to the definition of Horizon 2020 work program for 2016/2017

4. Discuss the integration of different Research Associations, including Waterborne TP and “Vessels for the Future” initiative, towards a more effective R&I coverage of all aspects related to the promotion of sustainable shipping.

5. To promote showcase opportunities to different R&D EU co-funded projects.
1.2 Composition

The R&I sub-group includes members drawn from:

- The European Commission (DG MOVE, DG RTD)
- The European Maritime Safety Agency (EMSA)
- Member States
- Research Associations
- Academia
- Classification Societies
- Shipbuilders
- Engine manufacturers
- Shipowners/Associations
- Ports
- Non-governmental Environmental Organizations

2. Analysis of findings

2.1 Work Structure – Deliverables and Work Packages

The analysis of findings, arising from the R&I sub-group activity throughout all the six meetings held, is presented here according to the structure defined in the ToR for the ESSF R&I sub-group, where the following list of sections is defined:

- D.1 Regulatory and policy requirements and user needs
- D.2 State of play of research and innovation and gap analysis
- D.3 A strategic research agenda including most promising technologies
- D.4 A roadmap and programme management structure
- D.5 Information and advice for project proposers
- D.6 Guidance on how to assess and report research results effectively and consistently
- D.7 Proposal for a dedicated portal and/or a communication plan

The R&I sub-group has dedicated the six meetings held to the discussion seen as contributing to the Objectives mentioned in sub-chapter 1.1. The specific discussion on the R&I topics, either in technological, strategic or regulatory terms, has taken the majority of the sub-group attention. Contribution to the EU Strategic Research Agenda, namely by providing input to H2020 Work Programme for 2016/2017, was the main work priority of the R&I sub-group.

Deliverables D5 and D7, as defined in the ToR for the R&I sub-group, were only discussed in the last sub-group meeting. Even though these particular subjects are considered as important and of common interest to a wider analysis of the EU R&I framework, it is also to be noted that:

- Detailed information and advice is available to future project proposers. H2020 online manual\(^1\) is an example of the information available to those who, experienced or not, consider submitting a project proposal for EU co-financing.

\(^1\) H2020 Online Manual - [http://ec.europa.eu/research/participants/portal4/desktop/en/funding/guide.html](http://ec.europa.eu/research/participants/portal4/desktop/en/funding/guide.html) - The H2020 Online Manual offers: 1) an overview of all steps you need to know for the electronic management of proposals or grants; 2) easy navigation by process steps; 3) a brief descriptions on how to complete your tasks. Links and references are available to: a) Guidance notes, templates, b) User manuals of the relevant tools c)
Online portals (from DG-RTD and DG-MOVE, respectively CORDIS and TRIP) are currently active with extensive information and supporting a wide communication plan.

The Work Structure followed the arrangement of twelve Work Packages:

1. Safety vs. Energy Efficiency
2. Success/incentives factors for pioneers/first movers (risk and cost sharing models)
3. The role of infrastructure and ICT in R&D
4. Emission/efficiency measurement/monitoring
5. The Logistics Service Provider/cargo owner / user perspective on shipping R&D
6. Short Sea shipping vs. intercontinental maritime transport – different research needs
7. Methodology for identification of best technologies (vessel type, trade)
8. NOx, PM, CO reduction, methane slip (and other unburned fuels)
9. Research as competitive advantage
10. Alternative fuel options – adequately addressed by R&D
11. New ships vs. retrofitting
12. Assessment/optimisation of system complexity

For the presentation of results in the present Report, the following subchapters are organized according to the “Deliverables” structure from the R&I sub-group ToR, including contributions from all the Work Packages. The diagram in figure 1 presents the basic work matrix reflecting the work of the sub-group. The twelve Work Packages, on the left, with their Coordinators, have prepared specific work on the respective subjects. R&D related discussions, presentations, papers, both on strategic or more technical levels, have been conducted by each Work Package. For the drafting of the Deliverables, presented in the head horizontal, additional coordinators were defined during the 5th R&I sub-group meeting. Each Work-Package contributed with the result from their own individual work, allowing the drafting of the present report to meet the requirements as defined in the ToR for the R&I sub-group. A table describing this arrangement has been included in Annex-A.

The following sub-chapters reflect the outcome from the work structure presented in figure 1.

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Frequently asked questions. The Online manual also offers advice on how to find partners for relevant proposals, e.g. for calls under “Motorways of the Sea”, where only multi-beneficiary proposals were accepted.

2 CORDIS (Community Research and Development Information Service) - http://cordis.europa.eu/home_en.html

3 TRIP (Transport Research & Innovation Portal) - http://www.transport-research.info/web/index.cfm
2.2 D.1: Regulatory and policy requirements and user needs

2.2.1 Introduction

The work performed within the R&I sub-group has focused on the 12 Work Packages listed previously corresponding to specific research areas. The objective of the present D1 section is to summarize the issues related to difficulties encountered because of new, or lack of, policy or regulatory measures, raised during the discussions on these research areas.

The enforcement of stricter environmental regulations can be a driver for changes in market or in technologies. However, clear public policies, and possibly financial measures, may be necessary to support the corresponding necessary investments, and adapted regulations and rules may be required to ensure a safe implementation of new technologies or operational procedures.

From a general point of view, it has been stressed that a holistic assessment of the impact of regulation on environment, economics and safety should be conducted and supported by research, prior to the introduction of new regulations.

Additionally, specific requirements or user needs for regulations or policy have been identified within the Work Packages discussions. They may be grouped into the five following main topics:

- Energy Efficiency Design Index (EEDI)
- Infrastructure
- Alternative fuels
- Financial measures
- Assessment methods

These topics are further developed in the next sub-paragraphs and a table in Annex-A presents the identified Regulatory and Policy topics organized according to the agreed Work Package structure.

2.2.2 EEDI

The introduction of the EEDI regulation by IMO in 2011 has an impact on ships built since 2013. Different needs related to this regulation have been identified by the group as described hereafter. All activities related to this topic should be aligned, and conducted in connection with IMO developments.

2.2.2.1 Speed and installed power reduction

The common solution for EEDI compliance is the reduction of design speed and installed power. This raises the question whether the available power margin is sufficient considering the potential risk of vessels becoming difficult to control in extreme weather. It has been identified that additional research to evaluate minimum power requirements is needed.

2.2.2.2 Other means to reduce EEDI

Research on other means of achieving EEDI targets should be supported. Such research should include safety aspects, possible needs for infrastructure modifications, economic impacts and global carbon footprint. Means of incentivizing the adoption of such alternative means should be considered as well.
2.2.2.3 EEDI formulation

The present EEDI is based on a transportation coefficient that does not take account of the time it takes to transport a cargo. This means that reducing the design speed of a vessel results in a very much reduced EEDI value for that vessel. However, to transport the same amount of cargo in the same time more vessels are required, so the reduction in fuel and CO₂ is not in proportion to the EEDI value. Research could usefully be undertaken on the effect of adopting a transportation coefficient that does take account of time on new ship designs and on the overall resulting transportation system efficiency.

2.2.3 Infrastructure

The important role of infrastructure in the implementation of new environmental regulations has been stressed during the sub-group discussions. Also, encountered or foreseen research needs related to policy or regulation issues have been mentioned by ports representatives.

2.2.3.1 Infrastructure adaptations to allow more efficient ship designs and transport systems to be put in place

Authorities (on all levels but in particular port authorities) play a key role in solving the chicken-or-the-egg dilemma in the transition to new technologies/alternative fuel use, especially where port facilities (such as infrastructure or ICT-tools) are required. Decision making on investment in the development of such innovative (port) facilities is hampered by the lack of knowledge on for example:

- environmental performance of the alternatives,
- the kind of services that are needed (for example the required facilities for production, storage or transport),
- safety aspects,
- the probability and time span that these services will actually be used once they are available,
- Financial aspects.

R&I should aim to yield knowledge on all aspects that support policy decisions.

When infrastructural investments are imposed by regulation, this knowledge could also support the development of sound methodologies to guarantee harmonisation among ports. For instance, to support implementation of the Directive 2014/94/EU on the deployment of alternative fuels infrastructure, Member States need to assess the demand and the cost-benefits for shore-side electricity infrastructure, as well as the appropriate number of refuelling points for LNG. To guarantee a certain level of harmonisation among ports and Member States in the way this assessment is performed, a uniform methodology could be developed for this assessment. Also, the integration of shore side electricity supply would benefit from innovative, flexible solutions with reasonable cost to encourage uptake of the service.

2.2.3.2 Environmental information system

Nowadays, different parties need to receive relevant and accurate environmental data concerning ship related activities, but it is a challenge to obtain such data and to deduce reliable information. A standardization of information to be delivered to the different stakeholders is needed. Various initiatives and standards exist but a scattered landscape makes it difficult to find this information in an efficient way. Due to a constantly moving
landscape and the lack of real worldwide standards the data providers (i.e. carriers) now have to supply environmental information to various parties in different formats. Those in demand for this information are faced with having to address multiple parties.

R&D should aim at the development of a shipping information system that allows efficient retrieval of relevant, reliable, and auditable information in a neutral, scientific and transparent way and the development of inventive ways of analysing, verifying and using the information.

### 2.2.4 Alternative fuels

In the last few years, substantial advancements have been achieved in the development of alternative fuels for use on board of vessels. While it is unlikely to see a fleet-wide uptake of alternative fuels in the immediate future, testing and development is ongoing and vessels propelled by such fuels will come into service, most likely in those areas of the world where emission control regulation is stringent, and adequate fuel quantities are available.

Among existing fuels, the following five groups are considered alternatives for maritime use:

- Diesel fuels (from non-conventional feedstock or production methods, e.g. synthetic diesel obtained from natural gas, soybean and rapeseed methyl ester and synthetic biodiesel from biomass)
- LNG / Methane
- Alcohol Fuels (in particular Methanol)
- Hydrogen
- Other fuels such as liquefied petroleum gases (LPG), dimethyl ether (DME), some other biofuels (e.g. straight vegetable oil or pyrolysis oil)

These groups are consistent with those identified in the European alternative fuels strategy.

From a technical perspective the major regulatory issues for all above mentioned fuels relate to:

- Safety issues in handling procedures and storage onboard and at port (e.g. LNG IGF code, tank locations, concomitant presence of multiple fuels on board, bunkering procedures);
- Classification rules development, design guidelines, recommended practices, and standardisation.

These issues concern not only ships but also infrastructures, as indicated in paragraph 2.2.3, as also addressed, regarding natural gas and hydrogen, in Directive 2014/94/EU on the deployment of alternative fuels infrastructure.

### 2.2.5 Financial measures

Most of the issues discussed above require R&I activities, that would benefit from national or EU financial supports.

Additionally, shipowners face considerable technological, operational and financial risk deploying new solutions to cope with emission legislations that affect international shipping, especially short sea shipping, are affected by ECA regulations. Support should be made available to cover part of the risk, for example financial support or provision of waivers.
covering periods of technical failure. In addition, mechanisms should be investigated to assist first movers that have implemented new solutions, with an environmental and societal benefit, which might not comply with regulations coming into force later (“grandfathering rules”).

Finally, methods for internalisation of costs associated to ship emissions, by giving operational economic benefit in case of reduction of energy use, and consequently of emissions, could bring incentives to the selection of best energy-efficient equipment. The impact assessment of Market-Based Measures should be supported by research.

### 2.2.6 Assessment methods

As explained above, new technologies as well as alternative fuels are being introduced on board ships. This has already shown to increase the complexity of machinery systems onboard and the development of methods and decision support tools to assess and optimise such complex and integrated machinery systems with respect to energy efficiency, emissions, safety and costs are an urgent need.

The major gaps and challenges to answer this need can be grouped into the following two groups:

- Lack of an integrated systems perspective towards the ship machinery assessment and optimization.
- Under-utilisation of shipboard data and measurements in order to assess and improve ship machinery condition.

The following regulatory related recommendations have been formulated by the sub-group to fill in these gaps:

- Support the assessment of performance, safety, and reliability of marine systems using model based system engineering approach.
- Develop Classification Societies’ acceptance of sensors based on new technologies (wireless, MEMS) for ship emissions and condition monitoring purposes. This requires additional lab testing and field validation.
- Develop appropriate data fusion techniques (Good examples from other industries (aviation, process industry etc.) could be bench-marked and utilised)
- Support R&I activities on the three above topics. This would also benefit to the implementation, by shipowners, of the EU Monitoring, Reporting and Verifying (MRV) system.

### 2.2 D.2 State of Play of Research and Innovation and Gap Analysis

The scope of the Research and Innovation sub-group of the ESSF covers technology options and solutions for the reduction of shipping emissions in view of regulatory requirements coming into force in 2015. However, considering the time required for research, the focus is on the longer-term perspectives of future regulatory requirements working towards a zero emission and zero pollution ship.

During the initial meeting the following specific areas of research were identified as requiring further investigation:

1. Safety vs. Energy Efficiency
2. Success/incentives factors for pioneers/first movers (risk and cost sharing models)
3. The role of infrastructure and ICT in R&I
4. Emission/efficiency measurement/monitoring
5. The Logistics Service Provider/cargo owner / user perspective on shipping R&I
6. Short Sea Shipping vs. intercontinental maritime transport – different research needs?
7. Methodology for identification of best technologies (vessel type, trade)
8. NOx, PM, CO reduction, methane slip (and other unburned fuels)
9. Research as competitive advantage?
10. Alternative fuel options – adequately addressed by R&I
11. New ships vs. retrofitting
12. Assessment / optimisation of system complexity

For each work package a short summary of the issue was prepared and discussed in the R&I sub-group. From those discussions, future R&I topics and proposals for further studies were developed and are summarised in a table included as Annex-B.

2.3 D.3: A Strategic Research Agenda

2.3.1 Introduction

Based on the work that the ESSF Sub-group Research & Innovation has performed so far, this chapter consolidates the group’s suggestion for the EC Maritime Strategic Research Agenda.

The objective is to define key strategic research themes and topics aiming at improving and ensuring sustainability and competitiveness of the shipping and shipbuilding industries of Europe, now and in the future.

2.3.2 Alternative Fuels

In the last few years, substantial advancements have been achieved in the development of alternative fuels for immediate or future potential use on board vessels. Such fuels include LNG, Biodiesel, LPG, Methanol, Ethanol and others like biogas and hydrogen. Short-sea shipping vessels are quite appealing for alternative fuels as refuelling requirements are limited to a few ports, also in Europe focus on the environment is strong (supported by EXAP and short sea shipping is a segment where the European shipbuilding industry is also strong. An important issue to be considered is also that the development of alternative fuels for maritime use will proceed at different speeds in different areas of the world, so that in the coming years we are likely to experience a mosaic of fuels being used across the world maritime fleet. As such, alternative fuels should be part of the strategic research agenda, with research needs in the fields of:

- engine technology (e.g. combustion efficiency, blending, methane slip);
- compatibility with maritime use (e.g. long storage, corrosion, water infiltration, high salinity environment, ship movement, limited options for accident management);
- life-cycle environmental impacts;
- safety issues in handling procedures and storage;
- supply and feedstock availability (e.g. refinery capacity, demand from other modes of transport, bunker availability at every port);
- distribution constraints (e.g. availability of storage and transport capacity, storage and transport costs);
- retrofit and conversion costs;
- port storage and bunkering infrastructure (e.g. technical challenges, infrastructure development);
• Market constraints and pricing (e.g. price levels, legal constraints, policy, and impact of incentives).

### 2.3.3 Big Data and ICT

Recently, it is becoming common knowledge in the maritime industry that data and connectivity will play a crucial role in the near and distant future in shipping. Data analytics will create value to a wide range of data allowing for drastic changes in all the aspects during the life-cycle of modern vessels and fleets. The collection of high-frequency, high-volume, versatile environmental, navigation, performance and condition, both for the hull and all machinery, data will give ground for “almost” real-time health and efficiency monitoring and optimization of routing and ship operations. Other potential uses include fleet management, collision avoidance, and monitoring of high-risk cargos transport to avoid accidents.

The collection and processing of such amounts of data give rise to “big data” concepts, which will change the future of shipping drastically. It is an area that needs to be researched in the context of shipping and shipbuilding. An area of research work and opportunities will be in the big data management and stewardship, developing effective data management platforms and business models that will tackle ownership, intellectual property and security of data by third-party vendors. Mechanisms for the effective cooperation of industry stakeholders should also be promoted alleviating technology barriers. European initiatives on ship data management and storage should also be undertaken to increase the European competitiveness against overseas initiatives. Further research in the area of sensors is also required to identify new sensors, improve measurements accuracy, stability and consistency, with focus technologies on wireless sensor networks, micro-electro-mechanical systems (MEMS) and optimal virtual sensing systems. Measurements and data management onboard, time synchronization, and fast / reliable data transfer onshore over the internet in a cost-effective manner on 24/7 model, able to sustain the global fleet is also a focus. Finally, coupling of the data streams with intelligent data analytics and model-based computer tools with sophisticated algorithms of ship and systems behaviour predictive capabilities will lead to preventive diagnostics and “almost” real time operational optimization.

### 2.3.4 Environmental Technologies

During the past years several solutions have been developed aiming at improving the environmental performance of seagoing vessels. However, to improve sustainability targets further research and development is required to achieve further reductions in NOx, SOx, and CO2 emissions through engines and systems improvement and optimization as well as optimisation of existing and development of new after-treatment technologies. The traditional division of in-engine and after treatment emissions reduction methods should gradually be bridged resulting in holistic technology solutions. In that prospect, technologies affecting the micro and nano-scale of components and systems should be investigated for emissions reduction and adaptive control. The continuous reduction of methane slip from LNG/dual-fuel engines should also be a focus. Research on the development and demonstration of new technologies for the detection and reduction of particulate matter and black carbon emissions as well as noise, above and below waterline, will be also a focus area. Finally, CO2 capture and utilization technologies in shipping should also be investigated.

### 2.3.5 Alternative Powering

The demonstration of a hybrid electric propulsion configuration on an offshore supply vessel in Europe has shown impressive results in emissions and fuel consumption reduction by
utilising energy storage up to now. As such, significant research efforts should be devoted in developing and demonstrating further hybrid electric, solar, wind and other radical alternative powering technologies for shipping. Energy harvesting and storage technologies that are proven in other industries or currently emerging should be investigated for maritime use. In addition, next generation fuel cell technology considered in an integrated system level could also offer significant advantages both on efficiency and emissions reduction. This will also align the European research agenda with USA and Asia based initiatives in the transport sector. A focus area should also be the distributed power systems and, in addition, further exploration of heat and energy recovery methods including Organic Rankine Cycles, degassing, thermoelectric generators, thermal storage, and other should be performed. Finally, the introduction of new technologies and fuels increases the complexity of ship systems and operations. The continuous development of methods and smart computer tools able to assess and optimise such complex systems and operations with respect to performance, environmental footprint, safety, and costs at an integrated systems perspective is mandatory.

2.3.6 Production Processes and Business Models

Shipping is a major component of European supply chains providing cost-effective, reliable and frequent service between EU ports and other trade partners. Continuous research efforts are hence needed in the area of logistics networks optimisation, improvement of service reliability methods and ICT support tools, decision support tools for multi-objective optimisation of fleets and service at the strategic, tactical and operational levels, as well as port-vessel synchronisation. Big data analytics will have a key role in the improvement of such concepts and potential applications should be identified and implemented, especially when linked with real-time ship AIS data. Port infrastructures are also a significant part of the European shipping value chain. Availability of cold ironing facilities, alternative fuels like LNG, advanced ICT tools for vessels operations and berthing, and cargo handling in an environmentally friendly and cost-effective manner is of key importance.

2.3.7 Production Processes and Business Models

Finally, further research efforts should be devoted in the development of new production processes and business models that are capable to improve technology, quality, and product diversification while controlling better costs and having better ability to adapt to the more rapid changes of the global and shipping business environments. Alliances and product co-evolution should also be exploited strengthening the European ship-building and shipping industry, departing from traditional competitiveness and silo mentalities.

2.4 D.4 A roadmap and programme management structure

2.4.1 Introduction

In line with the mandate, the sub-group on R&I should assist the ESSF to further coordinate, evaluate and actively get involved with research and innovation actions with the aim to advance the implementation of the Sustainable Waterborne Transport Toolbox (SWTT).

The roadmap should highlight how to further develop R&I activities to improve the implementation of the SWTT. On the basis of the discussion the roadmap is articulated in four steps:

1) Identify urgent R&I themes
2) Develop synergies with existing initiatives
3) Identify gaps in current R&I initiatives (e.g. limitations, issues and possible improvements)
4) Define possible implementation strategy

2.4.2 Identify key R&I themes

A roadmap definition starts with the identification of objectives and requires the involvement of stakeholders. The ESSF constitutes a solid base for such exercise. The discussion took place through voluntary Work Packages on specific themes that have been presented and discussed in detail. These themes resulted in the following research areas with specific relevance for the ESSF:

- Alternative fuels
- Big Data and ICT
- Environmental and Energy-Efficient Technologies
- Alternative Powering
- Logistics and Infrastructure
- Production processes and business models

The discussion associated with the presentation of these research areas resulted in the identification of urgent topics with particular relevance for the implementation of the SWTT.

The topics that emerged as research priorities that have been presented to the ESSF plenary are:

- Revision of design concepts for vessels under EEDI; focus on safety in adverse weather conditions
- Innovative port facilities (alternative fuel use with different environmental, safety, time span, economic performance
- Assess the demand and cost-benefit for shore-side electricity
- Assess the demand and cost-benefit for infrastructure for appropriate number of refuelling points for LNG (to guarantee harmonization among ports and Member States)
- Efficient degassing solutions (technologies for mobile/stationary/on board) for inland shipping
- Condition based maintenance innovative system, provided with distributed sensors and linking data acquisition with system engineering analysis, suitable for optimising the overall energy management on board
- CO₂ treatment on board (utilization of innovative membranes)
- Methane slip abatement methods
- Methanol/hybrid systems/hydrogen fuel cells
- Optimisation of size and location of LNG tanks on board
- Innovative systems-level modelling, simulation and optimization tools.
- Alternative fuels for shipping, for which a separate research agenda has been presented, including technical issues at ports, in distribution chain; uncertainty of fuel availability; fuel prices; safety issues on board and in ports; integration of new technologies on board; environmental and efficiency lifecycle.

In addition a set of topics were selected as valuable for developing additional studies, but not complex or general enough to constitute research topics in their own right. These suggested studies were:

- Study of barriers for new technology in shipbuilding
- Study of positive examples of cooperation between ports authorities and shipowners
- Mapping of current incentive systems that stimulates development in other industries
- Assess the impact of regulations on shipping; and on various specific European supply chains
- Technological solutions focussed on Short Sea Shipping (SSS), especially how deep sea shipping experience can apply to SSS and vice versa
- New application should be supported by demonstrators and infrastructure development
- Shipping firms: make success cases of successful sustainability R&I more visible.
- Study on business models and how they relate to sustainability improvements.
- Assess the use of an holistic approach to study retrofit versus new building that accounts not only of the ship level but also of the infrastructures and other complimentary assets and business models

### 2.4.3 Develop synergies with existing initiatives

An important issue that emerged was ensuring that there is no overlap with existing and past research activities as defined in Maritime Europe Strategy Action (MESA) and the WATERBORNE European Technology Platform. One of the results of the meeting was that of improving coordination with existing initiatives and expanding collaboration. The ad hoc working groups supported and coordinated by *Waterborne* can be used as a tool for advancing some of the topics, such as *Vessel for the future*.

Another area of potential synergy development is with existing expert groups/forums (e.g. alternative fuels).

The distinctive advantage of the R&I sub-group is in additional to offer a platform for a dynamic dialogues with the industry where the European Commission is directly involved, to allow a focus on shipping research in areas such as those listed below that have either not resulted in specific interest in other existing initiatives, or, because of their continuous importance in shipping would benefit to be included in this forum as well.

- SOx, NOx, PM
- Technical and operational measures to respond to Emission Control Areas regulation
- Alternative fuels
- Energy efficiency
- Short term actions and compliance strategies with existing and upcoming regulation
- User needs / perspectives
- Visibility of success stories
- business models
- logistics and user needs
- complementary activities and services (port, fuel distribution)

### 2.4.4 Define possible implementation strategy

It was specifically decided within the group to refrain from prioritising research needs at this stage. The group, however, discussed on the need to further plan and prioritise the remaining work. In particular the following steps can be envisaged for the group:

1. **Short term (6-12 months and ongoing)**
   a. Advise for carrying out selected studies with the Commission
   b. Develop a plan for R&I sub-group future activities
   c. Coordinate with *Waterborne* (e.g. ad hoc working group within *Waterborne* to coordinate with ESSF)
d. Provide list of topics to be included in future research actions (Horizon 2020, TEN-T, CEF, etc.)
e. Monitor uptake

2. Longer term (over 12 months)
   a. Bank less urgent research topics for future actions
   b. Develop a monitoring / implementation plan for R&I initiatives related to the SWTT

2.5 D.6 Guidance on how to assess and report research results effectively and consistently

2.5.1 General Remarks

Over the years, there have been many research projects relevant to shipping which have been supported by the EU. In order to get more ‘value for money’, it is highly beneficial that the results from previous work are available to a wider audience.

It should be considered that generally it is not easy to browse through previous research. Much of the information is available online somewhere, but generally fragmented and/or difficult to find and compare. Some is published by research institutions on their web site, for instance by MARIN (http://www.marin.nl/web/JIPs-Networks/Archived-JIPs-Public.htm).

Several research data base exist, as the CORDIS and the TRIP data base, but not always the information is available and appears sometimes incomplete: it is known that activities are under development in order to suggest improvements to the functionality of the research data base and the ESSF R&I sub-group, even if not already done, could contribute in the future to this goal.

With regards to EU co-funded initiatives it can also be mentioned the role of MESA, an FP7 funded project where one of its objectives is to provide a showcasing platform where research results can be shared with the wider community.

The necessity of having an integration layer of R&D activities has been outlined also in the Leadership 2020⁴ document. The primary focus on shipbuilding should however be complemented with the need to ensure the interests of the wider Waterborne community – including ship owners/operators, classes, etc., delivering on the overall EU/Transport policy. In line with the above, the R&I subgroup has been informed through a Waterborne TP presentation that an integration layer could be developed within the frame of a Public-Private Partnership, with the actual proposed configuration of Vessel for the Future conceiving and developing a concept for a Meta-Demonstrator, further allowing contacts with the association for possible support and feedback.

2.5.2 R&I Results – Assessment & Reporting

The assessment of research results can however be considered in slightly different ways depending on the research area and on the specifics of the project. The success of a research activity can be measured analysing the impact of its achievements in terms of financial benefits (€) aftermarket uptake, and/or emission reduction, and/or improvement in safety, and/or improvement of employment, and/or industrial competitiveness, and/or opening to new policy developments or to new technology development lines.

Specific operational performance indicators are also referred to:

Quality of Research: based on Review Analysis

Projects Output: based on:
- Number of Publications per Technology group (Number of publications in peer review journals), number of citations
- Number of patents registered and Number of copyrights/trademarks/registered designs
- Number of spin-off companies created
- Number of standards/normalization bodies projects contributed to
- Number of projects evidencing quantified improved commercial performance (i.e. increased turnover, profitability, productivity, market share, etc.)
- Number of researchers participating in projects
- Number of project reporting evidence of job creation and/or maintaining jobs
- Number of projects evidencing multi/cross-sectorial participation
- Number of projects evidencing innovations and/or results for reducing emissions
- Number of projects evidencing innovations and/or results for increasing safety

Specifically, for the twelve different Work Packages considered in the structure of the R&I sub-group work it can be considered that different types of project would essentially have different Key Performance Indicators (KPI).

Energy Efficiency related projects would essentially have different assessment plans from projects related to systems’ integration or even port infrastructures. Even though it can be argued that the overarching concept of “sustainable shipping” involves very different aspects it shall also be underlined that the assessment of results for any R&I project within this scope should consider:

- Impact of the project results to the sustainability development in shipping
- Individual merit of the project, according to pre-established, and measurable, KPI’s.
The table below presents the main contribution and comments from the R&I sub-group to the overarching assessment of the R&I results (a deeper analysis could be carried out in the future by the Sub Group—see the "recommendation to the Plenary"):

<table>
<thead>
<tr>
<th>WP</th>
<th>WP Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Safety vs. Energy Efficiency</td>
<td>The aim is to assess how and at which level the purpose to increase energy efficiency without jeopardizing the vessel safety is reached. More efficient hull designs can be developed as an alternative to speed reduction for controlling CO2 emission. Vessel performance can be assessed with a coefficient that considers the time factor, and this coefficient can be used for benchmarking different ships in terms of safety vs. energy efficiency.</td>
</tr>
<tr>
<td>2</td>
<td>Success/incentives factors for pioneers/first movers (risk and cost sharing models)</td>
<td>The success of the adoption, by the end users ship owners and operators, of an innovative solution (in terms of technical and financial benefits) represents the final assessment of the research efforts. Success factors can also be considered on terms of pioneers/first movers' ability to change existing business models, industry standards as well influence on political decision making.</td>
</tr>
<tr>
<td>3</td>
<td>The role of infrastructure and ICT in R&amp;I</td>
<td>The potentialities of big data and industrial internet adoption and use should be taken into consideration in R&amp;I. The use of the data is still in the beginning and mainly driven by equipment suppliers, but benefits in ship owners point of view are still unconsidered.</td>
</tr>
<tr>
<td>4</td>
<td>Emission/efficiency measurement/monitoring</td>
<td>For the different transport modes an assessment and comparison of the status of the research results achieved so far – conducted at EU, national, municipals and corporate levels - highlighting the encountered problems and the followed approaches could be quite beneficial.</td>
</tr>
<tr>
<td>5</td>
<td>The Logistics Service Provider/cargo owner/user perspective on shipping R&amp;I</td>
<td>The different business models and interests of the ship-owner and of the ship operator and charterer should be taken into consideration when defining research needs and assessing their results. Notably the research results should differentiate between e.g. fuel costs (paid for by charterer) and other operational costs (like operating the scrubbers) and investment costs.</td>
</tr>
<tr>
<td>6</td>
<td>Short Sea shipping vs. intercontinental maritime transport – different research needs?</td>
<td>Short Sea Shipping and intercontinental shipping are distinctly different sectors of maritime transport with distinctly different KPI. While there are similarities, research done for either one sector does not automatically apply to the same degree to the other sector as well.</td>
</tr>
<tr>
<td>7</td>
<td>Methodology for identification of best technologies (vessel type, trade)</td>
<td>Because of the great variety in cargo type and vessel boundary conditions, there is not a 'one size fits all' solution. Research should be vessel- or cargo specific.</td>
</tr>
<tr>
<td>8</td>
<td>NOx, PM, CO reduction, methane slip (and other unburned fuels)</td>
<td>As for WP4.</td>
</tr>
<tr>
<td>9</td>
<td>Research as competitive advantage?</td>
<td>While for ship builders and equipment suppliers assessments of the benefits of the investment in research are generally available, for the end-users (shipping companies) this is not generally valid. Deeper studies on this aspect should be undertaken focusing on the business model of the ship owners, correlating company performance with research and innovation propensity.</td>
</tr>
<tr>
<td>11</td>
<td>New ships vs. retrofitting</td>
<td>Due to the long operational lifetime of a seagoing vessel, gains in efficiency as well as in environmental performance might be made by retrofitting an existing vessel. Research can be beneficial of the achieving of improvement in several ship services.</td>
</tr>
</tbody>
</table>
### 3. Summary

Throughout a total of six meetings the ESSF R&I has worked towards the Objectives laid out in the ToR for the R&I sub-group, and in sub-chapter 1.1 of the present report.

The R&I sub-group has defined a work structure with twelve Work Packages, contributing together to the overarching theme of sustainable shipping. Papers and presentations were produced under each Work Package as a result of expert discussion and individual coordination under each of the twelve work titles. The analysis, results and summary of this work have been arranged and presented in chapter 2 of the present report.

The R&I sub-group included expert members from industry, research associations, classification societies and shipowners. When compared to research associations, such as the Waterborne TP, mostly stimulated by industry associates, the ESSF R&I has a more varied composition, bringing also shipowners and ports into the sustainable shipping research discussions. The holistic approach of the R&I sub-group has been demonstrated throughout the meetings held, where a variety of views and positions have contributed to the discussions.

During the first five meetings the R&I sub-group has essentially constructed its work with a view to provide specific contribution to the development of an EU Strategic Research Agenda. In practical terms, research topics and associated recommended studies have been developed for further scoping under future/forthcoming EU co-funding programs. Furthermore, along this line, the list of research topics and recommended studies, included in Annex-D, has materialized the R&I sub-group contribution to the 2016/2017 Work Program of Horizon 2020. The contribution has supplemented and endorsed Waterborne TP earlier contribution to the same program.

The discussion of the research topics and key research areas for sustainable shipping as a concept have been the core work of the ESSF R&I, in line with the ToR for this sub-group. The R&I as a process, its structure, evaluation and assessment of results, information management and other procedural/practical aspects of the R&I strategic planning process would have to be worked further for a substantiated proposal on possible improvement points in the process. Improving the success of future project proposals would only be possible by working closer with DG-RTD and DG-MOVE/INEA, integrating their expertise and lessons learnt and discussing further the possible solutions to overcome present difficulties. This has not been entirely achieved and would only be possible in future R&I sub-group meetings, should a continuation of its activities be possible beyond June 2015.

Further to the definition and discussion on research areas and recommended topics/studies for the EU Strategic Research agenda on Sustainable Shipping, the R&I sub-group has also analysed and discussed the activity of other initiatives contributing to the goal of maritime EU R&I. In this regard Waterborne TP, Vessels for the Future research association and MESA project have been focus and subject of presentations and discussions. The R&I sub-group has considered that the integration of its work along with these different associations could generate very positive synergies for the future. The possible integration of the ESSF R&I into any of the existing research platforms was however not agreed upon, having however been

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<th>WP</th>
<th>WP Title</th>
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<tr>
<td>12</td>
<td>Assessment / optimisation of system complexity</td>
<td>Many equipment providers – following strategic business lines and achieved research results - start to promote themselves as “solutions” providers, and take charge of ship systems integration. Yards can benefit of their know-how while Owners can have a single interface to refer to in case of issues. Analogies can be found in the energy sector where providers sell turn-key solutions for investors or utility companies.</td>
</tr>
</tbody>
</table>
identified that a future proposed role for the R&I subgroup, as a group of experts, to provide support on specific R&D topics and/or dissemination of specific research results. The activities from other research associations were however seen with great interest from the ESSF R&I sub-group, with several of its members also belonging to the aforementioned organizations.

The future role of the R&I subgroup is to be considered in a constructive nature aiming at facilitating consensus among the stakeholders and ensuring minimum fragmentation among other initiatives.

The 6th, and final, R&I sub-group meeting, and part of the 5th, were dedicated to the analysis of all the Work Package results, according to the organization proposed by the ToR for the ESSF R&I. It was possible to establish a relation between the necessary deliverables/sections and the work structure that served as a basis to the R&I sub-group activities. The R&I sub-group has then structured itself with new coordinators to lead the analysis of results according to the Deliverables presented in Chapter 2.1, and also in Annex-A.

Regarding deliverables D5 and D7 these are not part of the present report as these have only been discussed during the last meeting. The results from discussions have not substantiated any relevant outcome that could be part of the present report. Nonetheless the importance of these topics has justified some presentations (DG-RTD) concerning the R&I EU co-funding programs, such as the Horizon2020. Analysis of the topics under D5 and D7 would require further time to discuss the specific challenges of EU co-funding programs management, to identify particular difficulties and possible points to improve and, finally, to draft feasible solutions. As a further motivation to continue working on these lines it has been noted that some members of the R&I sub-group would welcome more accessible information and dissemination of results, from past and current research activities funded by the EU.

The work of the ESSF R&I can only be considered effective if the scoping of the suggested studies and research topics can be further developed and evolved into effective calls within existing or future funding programs, either at Commission or Member State level. The necessary integrated vision of R&I would however require the results from R&I initiatives to be brought together in order to favour the consistent development of knowledge in support of sustainable shipping.

In summary the R&I sub-group has discussed and analysed the current challenges in sustainable shipping, outlined the current state-of-play in different technological and research areas and identified the bridges that future initiative would have to build in order to meet current research needs. Research topics were listed, along with recommended studies, assisting the development of an EU Strategic Research Agenda in the area of sustainable shipping. A roadmap and programme management structure was with a staged approach consisting of four steps:

1) Identification of urgent R&I themes
2) Development of synergies with existing initiatives
3) Identification of gaps in current R&I initiatives
4) Definition of a possible implementation strategy

Assessment of research results was also a topic where, even though more discussion and work would be required, it was possible to include some recommendations based on the particular nature of different research activities.
As result of the activities carried out and of the six meetings held:

- The sub-group reached a current and efficient approach of “working together”, also reinforced by the achieved personal knowledge among the attendees and the acknowledgment of their respective areas of expertise.

- The sub-group is characterized by a particular involvement of ship-owners, ship-operators and ports, actively contributing to support their views on the R&I themes and needs, which are not adequately represented in other R&I forums like Waterborne TP/Vessels for the Future.

- The sub-group acknowledged that it can effectively contribute to the European Maritime R&I agenda and roadmap for a Sustainable Shipping, as demonstrated by the suggestion of research topics and recommended studies for the H2020 2016-17 Work-Program. These achievements can effectively integrate and supplement the activities the maritime community carries out inside the Waterborne TP.

4. Request to the Plenary

The ESSF Plenary is invited to approve this report as representative from the sub-group’s activities, following the specific mandate outlined in the ToR for the ESSF R&I.

The Subgroup recommends to the Commission the continuation of the ESSF R&I subgroup, in its form being chaired by the EC and also including full and direct participation of ship-owners and manufacturers in addition to classification societies, shipyards, and research institutions.

Its proposed role would be to supplement the EC assessing, and prioritizing key strategic research themes and topics with the view of the EU industry on the identification of the R&I needs and the definition of corresponding research work programmes, to ensure sustainability and competitiveness of shipping and EU shipbuilding industries.

This strategic focus of the R&I subgroup should take into account also regulatory and policy developments at various levels, and be in line with the broader EU Maritime R&D Strategic Agenda and contribute to it. In addition it should be interacting and pursuing alignment with the WaterborneTP and its initiatives. Duplication of efforts should, in this sense, be avoided with the R&I subgroup aiming towards an optimized integration with the relevant initiatives, such as the Vessels for the Future association.

Furthermore, some outstanding issues were not possible to cover during the time scope of the R&I sub-group activities. The R&I sub-group succeeded to discuss some topics only in the last meeting, namely the Information to Future Proposals. The discussion touched only general terms and it was not possible to develop a deeper discussion on the peculiarities of this topic when addressed specifically to the Sustainable Shipping interests.

The sub group intends to revert on open topics in a possible further continuation of the activities.
Anexes

• ANNEX-A - ESSF R&I Work Structure - ESSF R&I Deliverables vs Work Packages

• ANNEX-B - ESSF R&I Work Structure - Work Package Summaries - State of Play & Recommended Research Topics

• ANNEX-C Table - Regulatory and policy requirements and user needs

• ANNEX-D - Table - Related Research Topics/ Recommended Studies - Contribution to H2020
ANNEX-A

ESSF R&I Work Structure

ESSF R&I Deliverables vs Work Packages
<table>
<thead>
<tr>
<th>1. Safety versus Energy Efficiency</th>
<th>D.1 Regulatory and policy requirements and user needs</th>
<th>D.2 State of play of research and innovation and gap analysis</th>
<th>D.3 A strategic research agenda including most promising technologies</th>
<th>D.4 A roadmap and programme management structure</th>
<th>D.5 Inf'advice proposal</th>
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<td>H</td>
<td>L</td>
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<tr>
<td>2. Success factors for pioneers/first movers</td>
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<tr>
<td>3. The role of infrastructure and ICT in R&amp;I</td>
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<td>H</td>
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<tr>
<td>4. Emission / efficiency measurement / monitoring</td>
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<tr>
<td>5. Cargo owner / Logistic service providers / User perspective on shipping R&amp;I</td>
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<td>6. Short Sea Shipping vs. Intercontinental maritime transport - different R&amp;I needs</td>
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<td>7. Methodology for identification of Best Technology (vessel type – trade)</td>
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<tr>
<td>8. NOx, PM, CO reduction, Methane slip (and other unburned fuels)</td>
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<tr>
<td>9. Research as competitive advantage</td>
<td>H</td>
<td>L</td>
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<tr>
<td>10. Alternative fuel options – Adequately addressed by R&amp;I</td>
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<td>11. New ships s retrofitting</td>
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<tr>
<td>12. Optimization of system complexity</td>
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</tbody>
</table>
ANNEX-B

ESSF R&I Work Structure - Work Package Summaries

State of Play & Recommended Research Topics
<table>
<thead>
<tr>
<th><strong>Work package 1</strong></th>
<th><strong>Safety vs Energy Efficiency</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinator(s)</td>
<td>BMT</td>
</tr>
<tr>
<td><strong>Summary</strong></td>
<td>Reducing service speed, i.e. slow steaming, has been shown to significantly reduce fuel use and thus CO2 emissions. For new vessels reducing installed power and service speed is one option to meet EEDI targets. The raises safety concerns as underpowered vessels risk becoming uncontrollable in extreme weather and may lead to a rise in vessel losses; tankers and bulk carriers are more susceptible to this risk due to their low power in relation to size of vessel. A holistic approach to the transportation system is needed considering overall efficiency, as design speed reduction means more vessels to achieve the same transport work. Thus the overall optimum solution may well involve fundamental revision of existing designs, involving not only the use of efficient designs, but also and importantly, revision of the overall dimensions of these vessels. Such designs may well be longer, narrower and deeper than current designs of the same displacement; producing vessels which are intrinsically more fuel efficient and which also experience less added power in adverse weather conditions. This would result in safe and efficient vessels which can operate at reasonable speeds and can thus contribute to an effective and efficient overall transportation system. Clearly, ships are not designed in isolation, but in the context of existing shipyard building berth and dock size, water depth in ports, size of port berths and maintenance docks, depth of approaches, canal and channel size and depth (Suez Canal, Panama Canal, Malacca strait etc.). However, this change occurs relatively slowly and is controlled by the need to update the infrastructure with the complexities of who pays for the investment and where the rewards are realized. Larger and/or longer vessels would require significant investment in infrastructure and would tend to increase the initial capital costs of vessels (but with the benefit of significantly reduced through life cost). A thorough cost benefit analysis is needed to understand the opportunity.</td>
</tr>
<tr>
<td><strong>Related Research topics</strong></td>
<td>• Constraints to EEDI driven Ship Design</td>
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<td></td>
<td>• Vessel Operations &amp; EEDI driven design</td>
</tr>
<tr>
<td></td>
<td>• Effect of Infrastructure</td>
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<td></td>
<td>• Improved Vessel Design for safe and efficient in-service operation</td>
</tr>
<tr>
<td><strong>Recommended Studies</strong></td>
<td>Investigation on the effect of vessel dimensional constraints due to existing infrastructure limitations on efficiency and safety. (Noting that meeting the conflicting requirements of safe operation and low EEDI within existing vessel dimensions for some classes may be difficult).</td>
</tr>
<tr>
<td><strong>Work package 2</strong></td>
<td><strong>Success/incentives factors for pioneers/first movers (risk and cost sharing models)</strong></td>
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<tr>
<td>Coordinator(s)</td>
<td>Stena</td>
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<tr>
<td><strong>Summary</strong></td>
<td>Shipping operates in the context of long timeframes, in an industry with many players with a strong focus on cost and performance. Hurdles for investments in innovative technologies include uncertainties about their performance and the regulatory environment. The business environment is changing though and with more focus on environmental performance the willingness of ship owners to invest in safety and environmental technologies in advance of legislation is increasing. Stimulating forerunners to speed up the uptake of innovative processes will benefit the whole industry as it increases the rate of change, and will facilitate meeting regulations. To encourage first movers/pioneers, blockers and incentives to investments need to be understood.</td>
</tr>
</tbody>
</table>
| **Related Research topics** | • Technological gaps/barriers in shipbuilding  
• Positive development stimulation – comparison exercises with other industries  
• Process Mapping for incentive systems |
| **Recommended Studies** | • Study of barriers for new technology in shipbuilding  
• Study of good examples of cooperation between ports, authorities and shipowners with positive developments  
• Mapping of current systems that stimulates development in other industries |
## Work package 3  
### The role of infrastructure and ICT in R&I

<table>
<thead>
<tr>
<th>Coordinator(s)</th>
<th>Port Of Antwerp</th>
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</table>
| **Summary**   | Solutions for the reduction of shipping emissions often require infrastructural adaptations or new port facilities, in which case (port) authorities play a key role in solving the chicken-or-the-egg dilemma in the transition to these solutions. However, choices need to be made and decision making is hampered by the lack of knowledge on for example environmental performance of the alternatives, on the kind and amount of services that are needed (for example the required facilities for production, storage or transport of alternative fuels), on safety aspects, on the probability and time span that these services will actually be used once they are available, or on financial aspects. R&I should aim to yield fundamental knowledge on all aspects that support this decision making. When infrastructural investments are imposed by regulation, this knowledge could also support the development of sound methodologies to guarantee harmonisation among ports.

The development of new infrastructural solutions remains an area for future R&I, for instance aiming at innovative, flexible and affordable shore side electricity or degassing technology.

Concerning ICT, a challenge is to handle the large amount of environmental data linked to ship related activities that need to be collected, exchanged and reviewed among multiple parties. R&I should aim at the development of a shipping information system that allows efficient retrieval of relevant, reliable, and auditable information in a neutral, scientific and transparent way and the development of inventive ways of analysing, verifying and using the information. The increased accessibility of data could in turn feed R&I in several fields that are relevant for sustainable shipping. |
| **Related Research topics** | • Decision making for efficient port facilities  
• Innovation in the following topics: environmental performance/safety/time span /economic performance of alternative fuels & scrubbers-infrastructural needs for storage, production, transport, waste facilities  
• Degassing  
• ICT for environmental data sharing in neutral, safe, scientific and transparent way  
• Port-vessel synchronization technologies |
| **Recommended Studies** | • Studies on all aspects that support decision making on Port facilities for innovative solutions (environmental performance/safety/time span /economic performance of alternative fuels & scrubbers-infrastructural needs for storage, production, transport, waste facilities)  
• Methodology to assess the demand and cost-benefit for shore-side electricity infrastructure and for appropriate number of refuelling points for LNG (guarantee harmonisation among ports and member states)  
• Efficient degassing solutions (technologies for mobile/stationary/on board)for inland shipping |
<table>
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<tr>
<th>Work package 4</th>
<th>Emission/efficiency measurement/monitoring</th>
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</thead>
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<tr>
<td>Coordinator(s)</td>
<td>DNV-GL</td>
</tr>
<tr>
<td>Summary</td>
<td>WP4 provided an outline of the state of the art, technology and applications gaps and suggestions for further developments in the areas of ships air emissions monitoring and condition monitoring. IMO's MARPOL Annex VI regulations on air emissions and the new introduced MRV scheme by the EC are strong drivers for the introduction of ships emissions monitoring as a means to measure and confirm ship compliance with the regulations. Today there exist direct emissions measurement and monitoring systems for pollutants like NOx, SOx, CO2. Open issues that should be the focus of further development include the reliability of measurements accuracy, the degradation of sensors materials, the need for maintenance and costs, and the combination of such monitoring systems with system engineering techniques to provide preventive diagnostics. Condition monitoring is vital in reducing in-service failures and unplanned downtime, with ultimate goal the implementation of condition-based maintenance. Currently, there exist sensors to monitor strain, vibrations, temperatures and pressures, etc. However, full-scale onboard instrumentation, sensory accuracy, data transmission onshore and post-processing techniques are at basic level and need further development. Complexity and costs are also significant parameters to be explored. Other sensor technologies to be investigated for that purpose include wireless sensor networks and micro-electro-mechanical systems (MEMS).</td>
</tr>
</tbody>
</table>
| Related Research topics | • Condition, performance and emissions monitoring  
• Propulsion Performance monitoring  
• Emissions monitoring |
| Recommended Studies | • Unification of measurements: condition, performance, emission.  
• Propulsion performance monitoring system,  
• Emission monitoring system  
• Real time onboard energy management advisory system.  
• Condition based maintenance innovative system, provided with distributed sensors and linking data acquisition with system engineering analysis, suitable for optimising the overall energy management on board |
<table>
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<tr>
<th>Work package 5</th>
<th>The Logistics Service Provider/cargo owner / user perspective on shipping R&amp;I</th>
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<tr>
<td>Coordinator(s)</td>
<td>Kühne Logistics University</td>
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<tr>
<td>Summary</td>
<td>Prices are only one parameter taken into consideration by cargo interests and users in the selection of a shipping service. Other factors influencing the operational decision by owners include speed, number and location of ports of call, vessel sizes, etc. and quality of transport service provided. The importance of the above-mentioned factors depends on the specific characteristics of the cargo and its supply chains, and the consumer preferences for passengers. Therefore understanding the importance and impact of all factors attributes is important for forecasting market response to regulation and understanding the impact of innovation. It is therefore valuable to assess the impact of regulation and innovation on various specific supply chains, and in particular to those most likely to be affected by price increases such as forest products or paper, or those more likely to shift modes, such as refrigerated products or ro-ro cargo on certain routes.</td>
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<tr>
<th>Related Research topics</th>
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<tr>
<td>• Modal Shift</td>
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<tr>
<td>• Regulations and Sector Compliance</td>
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<tr>
<td>• Compliance Strategies</td>
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<table>
<thead>
<tr>
<th>Recommended Studies</th>
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<tbody>
<tr>
<td>• Assess the impact of regulations on shipping in terms of modal shift and sector competitiveness</td>
</tr>
<tr>
<td>• Include the study of the shipper/passenger/cargo owner perspective on specific technical solutions and compliance strategies</td>
</tr>
<tr>
<td>• Evaluate the impact of regulation on various specific European supply chains (e.g. wood products)</td>
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<td>Work package 6</td>
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<td>Coordinator(s)</td>
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<td>Summary</td>
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<td>Related Research topics</td>
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<td>Recommended Studies</td>
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<td>Work package 7</td>
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<tr>
<td>Coordinator(s)</td>
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<td>Summary</td>
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<tr>
<td>Related Research topics</td>
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<tr>
<td>Recommended Studies</td>
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<td>Work package 8</td>
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<tr>
<td>Coordinator(s)</td>
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</table>
| Summary | In the development of work package 8 several issues were recognized:  
• The market would like to see the development of more active (e.g. at low load) and poison resistant SCR catalysts that tolerate high temperatures.  
• There is a market requirement for lighter/smaller footprint/compact SCR.  
• Concern over ammonia slip from engine/SCR systems, with recognition that ammonia slip catalysts generally require cleaner fuels (e.g. ULSD, NG).  
• Natural gas engines can emit methane at concentrations of 6g/kWh – there is growing consensus that the growth in NG engines will lead to complexities in terms of European GHG emissions (and a recognition that high temperatures are required for oxidation catalysts to treat methane slip).  
• A growing concern with regard to the technical feasibility of treating PM within high-sulphur marine emission streams, where there are opportunities to demonstrate state of the art filter technology for ship engines using ULSD (e.g. inland waterways) and HFO.  
• It would be useful to establish emission envelope for all marine fuels (including newer fuel types such as methanol) and a catalogue of technology options for reducing emissions.  
Taking this into account, there are several objectives for R&I which could be taken forward from ESSF work package 8. |
| Related topics | Research topics |  
• Methane Slip from Natural Gas / Dual Fuel engines.  
• Particulate matter emissions.  
• Fuel optimised engines  
• Engine systems with lower emission and improved operational range and lifetime.  
• NOx, SOx, and CO2 reduction through engine optimisation with different types of fuels, engines and after treatment systems.  
• Local control of emissions, e.g. for ports, sensitive areas, etc. |
| Recommended Studies |  
• Assessment studies on the impact of first prototypes in operations.  
• Impact and effectiveness analysis from first prototypes solutions – operational data analysis and integration.  
Note: During the past years several solutions have been developed aiming at reducing the emissions, in several cases with the support of public funding. First prototypes are therefore already in operation. An analysis of the impact and effectiveness of such solutions in operation will be beneficial for further optimizations and improvements by both technology providers and shipbuilders |
<table>
<thead>
<tr>
<th>Work package 9</th>
<th>Research as a competitive advantage</th>
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<tbody>
<tr>
<td>Coordinator(s)</td>
<td>Kühne Logistics University</td>
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<tr>
<td>Summary</td>
<td>In a competitive homogeneous industry like shipping competitive advantage can be achieved through two main avenues: cost efficiency or service differentiation. Investment in R&amp;I in the area of sustainability can benefit companies by enabling them to identify the best option to comply with regulation; it can help reduce reputational risk factors and a sustainability lens can reveal inefficiencies that previously were not in scope. R&amp;I expenses, however, are often perceived as a direct cost rather than a long-term investment; and for many companies the competitive benefits of R&amp;I on Sustainability are poorly understood. The majority of shipping companies are SME without dedicated research departments providing an additional barrier. Therefore it would be valuable to make cases of successful sustainability R&amp;I more visible and provide support to (cooperative) forms of R&amp;I for SMEs.</td>
</tr>
<tr>
<td>Related Research topics</td>
<td>None identified</td>
</tr>
</tbody>
</table>
| Recommended Studies | • Compilation exercise on a number of concise cases where R&I has delivered economic benefits for the first mover in the area of green shipping  
• Analysis of success stories - how can innovation be turned in competitive advantage? |
<table>
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<tr>
<th>Work package 10</th>
<th>Alternative Fuel Options</th>
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<tbody>
<tr>
<td>Coordinator(s)</td>
<td>Carnival, DNV-GL, Kühne Logistics University</td>
</tr>
<tr>
<td>Summary</td>
<td>Demand for “cleaner” fuels is rising with SOx, NOx, Particulate Matter (including Black Carbon), CO, unburned hydrocarbons and CO2 emissions from shipping being increasingly scrutinised. Liquid fossil fuels is the main source of power in shipping, alternatives fuels include LNG, LPG, Ethanol, Methanol, Biodiesel and Hydrogen. Challenges for alternative fuels include:</td>
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<td>• Access to fuels internationally (fuel availability itself and infrastructure to supply)</td>
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<td></td>
<td>• Sustainability performance (well to wake emissions performance, implications of using Biofuels based on food crops)</td>
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<td></td>
<td>• Operational aspects (safety concerns, compatibility with existing systems, new technology state of readiness, system integration and performance)</td>
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<td></td>
<td>• Regulatory uncertainty</td>
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<td></td>
<td>• Cost</td>
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<td></td>
<td>For alternative fuels to move from niche application, advantages and disadvantages need to be understood to enable sound business cases to be developed so that the industry including shipowners, fuel suppliers and ports can make sound investment decisions.</td>
</tr>
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</table>

**Related Research topics**

- Methane slip abatement methods
- Methanol/hybrid systems/hydrogen fuel cells
- Optimisation of size and location of LNG tanks on board

**Recommended Studies**

- Studies on alternative fuels for shipping- specific case studies considering the whole value chain (technical issues at ports, in distribution chain; uncertainty of fuel availability; fuel prices; safety issues on board and in ports; integration of new technologies on board; environmental and efficiency lifecycle)
- LNG fuelled ship Formal Safety Assessment, risk models, including bunkering operations
Summary

Typically, the implementation of technological R&I solutions could be achieved through new build or retro-fit approach at a vessel level. Factors such as requirements of space, integration complexity, operational performance, duration, cost and quality drive the decision associated with the choice of implementation approach. However, to ensure successful commercialisation, market adoption and the scale up of technological R&I solutions, the implementation of new build and retro-fit solutions should take into account additional R&I needs at complimentary asset level (i.e. infrastructure) and business model level (i.e. value proposition, target customers, distribution channels, cost and revenue structure, etc) as well as the interaction and the integration between the three proposed levels. In some cases, availability and the readiness of complimentary asset and business model may become the enablers to support the implement of the technological R&I solutions at a vessel level. In other cases, successful implementation of R&I solutions in complementary asset level may help to further enhance the benefits of R&I implementation at vessel level. In summary, to enable the effective implementation of R&I solutions to achieve sustainable shipping objectives, a holistic assessment approach including the assessment of R&I needs and the assessment of risks and returns covering all aspects of new build and retro-fit discussed above is recommended.

Related Research topics

None identified

Recommended Studies

- Research and Innovation should be performed not only at ship level but also on the infrastructures being complimentary assets and on the business models as well.
- Take holistic approach to study retrofit versus new building. Note: Innovative business models in these areas are needed.
### Work package 12

<table>
<thead>
<tr>
<th><strong>Optimization of system complexity</strong></th>
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<tbody>
<tr>
<td><strong>Coordinator(s)</strong></td>
</tr>
<tr>
<td>DNV-GL</td>
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<tr>
<td><strong>Summary</strong></td>
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<tr>
<td>WP12 provided an outline of the state of the art, technology and applications gaps and suggestions for further developments in the area of methods and decision support tools for the assessment and optimisation of integrated ship machinery systems. The increased use of such technologies in the industry practice is necessitated by the increase in complexity due to the introduction of new technologies and fuels as a response to market conditions and environmental-focused regulations. Computer-Aided-Engineering tools in general are extensively used in the shipping industry. However, when it comes to machinery systems per se there is a lack of market adoption of tools for holistic/integrated-systems assessment and optimisation with respect to energy efficiency, emissions, safety, and costs. In addition, there is under-utilisation of shipboard data and measurements to assess and improve ship machinery performance besides condition. Further development is therefore suggested in those areas, with particular emphasis on formal systems engineering methodologies and computer tools implementations with embedded advanced capabilities on modelling, simulation and optimisation under steady and transient behaviour. Fusion of such technologies with on-board sensory measurements will lead to “almost” real-time performance optimisation and condition monitoring.</td>
</tr>
<tr>
<td><strong>Related Research topics</strong></td>
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</table>
| • Innovative systems-level modelling, simulation and optimization tools to assess performance, design, retrofit solutions  
• New technologies with respect to energy efficiency, emissions, safety, costs |
| **Recommended Studies**              |
| • None                               |
ANNEX-C

Table - Regulatory and policy requirements and user needs
| 1. Safety versus Energy Efficiency | Regulation –Reduction of installed power, reduction of design speed; vessels will be uncontrollable in extreme weather  
Policy – Incentivize infrastructure changes to accommodate bigger or longer ships for better energy efficiency  
Regulation – Review of EEDI formulation to account for the time taken to transport the cargo and allow for larger power margins |
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<tr>
<td>2. Success factors for pioneers/first movers</td>
<td>N/A</td>
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</table>
| 3. The role of infrastructure and ICT in R&I | • Definition of standards for environmental related information system, reporting and exchanging information between the various parties  
• Under the up-coming Directive on the deployments of alternative fuels infrastructure, Member States will probably need to assess the demand and the cost-benefits for shore-side electricity infrastructure in their ports, as well as the appropriate number of refuelling points for LNG; need to define a common assessment methodology. |
| 4. Emission / efficiency measurement / monitoring | Class acceptance of sensors based on new technologies (wireless, MEMS) for ship emissions and condition monitoring purposes. This requires additional lab testing and field validation |
| 5. Cargo owner / Logistic service providers / User perspective on shipping R&I | It is important to forecast market response to new regulations. Many factors need to be accounted for to evaluate the impact of new regulations since prices are not the only parameter taken into consideration by cargo interests and users in the selection of a shipping service. The importance of the above-mentioned factors depends on the specific characteristics of the cargo and its supply chains, and the consumer preferences for passengers. It would be therefore valuable to assess the impact of regulation on various specific supply chains, and in particular to those most likely to be affected by price increases such as forest products or paper, or those more likely to shift modes, such as refrigerated products or ro-ro cargo on certain routes etc. |
| 6. Short Sea Shipping vs. intercontinental maritime transport - different R&I needs | The changes in emissions legislation pose a challenge to both SSS and IS, and especially SSS in the immediate future. At short term, SSS is much more concerned by new ECA regulations than IS. Shipowners face considerable technological, operational and financial risk deploying new solutions. Support should be made available to cover part of the risk, for example financial support or provision of waivers covering periods of technical failure |
| 7. Methodology for identification of Best Technology (vessel type – trade) | Policy measures should consider also infrastructures (e.g. for LNG), not only ships.  
Methods for internalisation of costs associated to ship emissions, by giving operational economical benefit in case of reduction of energy use, and so of emissions, would incentivize the selection of best equipment from energy efficiency point of view. |
| 8. NOx, PM, CO reduction, Methane slip (and other unburned fuels) | Worldwide regulations regarding carbon dioxide emissions are projected to increase 46% by 2040. No regulation barrier reported. |
| 9. Research as competitive advantage | No regulatory related issues reported |
| 10. Alternative fuel options – Adequately addressed by R&I | • Safety issues in handling procedures and storage onboard and at port (e.g. LNG IGF code, tank locations, concomitant presence of multiple fuels on board, bunkering procedures);  
• Classification rules development, design guidelines, recommended practices, and standardisation; |
| 11. New ships s retrofitting | No regulatory related issues reported |
| 12. Optimization of system complexity | Assessment of performance, safety, and reliability of marine systems using system engineering approach; integrated system perspective; modelling. Is there any regulatory issue? |
ANNEX-D

Table - Related Research Topics/ Recommended Studies – Contribution to H2020

(as submitted to the 3rd ESSF Plenary Session on the 4th December 2014)
<table>
<thead>
<tr>
<th>Work Package</th>
<th>Related proposed RESEARCH TOPICS</th>
<th>Recommended Studies</th>
</tr>
</thead>
</table>
| 1. Safety vs. Energy Efficiency - Effect of Dimensional Constraints on Vessel Efficiency and Safety | • Constraints to EEDI driven Ship Design  
• Vessel Operations & EEDI driven design  
• Effect of Infrastructure  
• Improved Vessel Design for safe and efficient in-service operation | • Investigation on the effect of vessel dimensional constraints due to existing infrastructure limitations on efficiency and safety. (Noting that meeting the conflicting requirements of safe operation and low EEDI within existing vessel dimensions for some classes may be difficult). |
| 2. Success/incentives factors for pioneers/first movers (risk and cost sharing models?) | • Technological gaps/barriers in shipbuilding  
• Positive development stimulation – comparison exercises with other industries.  
• Process Mapping for incentive systems- | • Study of barriers for new technology in shipbuilding  
• Study of good examples of cooperation between ports, authorities and shipowners with positive developments  
• Mapping of current systems that stimulates development in other industries |
| 3. The role of infrastructure and ICT in R&I | • Decision making for efficient port facilities  
• Innovation in the following topics: environmental performance/safety/time span /economic performance of alternative fuels & scrubbers-infrastructural needs for storage, production, transport, waste facilities  
• Degassing  
• ICT for environmental data sharing in neutral, safe, scientific and transparent way  
• Port-vessel synchronization technologies | • Studies on all aspects that support decision making on Port facilities for innovative solutions (environmental performance/safety/time span /economic performance of alternative fuels & scrubbers-infrastructural needs for storage, production, transport, waste facilities)  
• Methodology to assess the demand and cost-benefit for shore-side electricity infrastructure and for appropriate number of refuelling points for LNG (guarantee harmonisation among ports and member states)  
• Efficient degassing solutions (technologies for mobile/stationary/on board)for inland shipping |
| 4. Emission/efficiency measurement/monitoring | • Condition, performance and emissions monitoring  
• Propulsion Performance monitoring  
• Emissions monitoring | • Unification of measurements: condition, performance, emission.  
• Propulsion performance monitoring system,  
• Emission monitoring system,  
• Real time onboard energy management advisory system,  
• Condition based maintenance innovative system, provided with distributed sensors and linking data acquisition with system engineering analysis, suitable for optimising the overall energy management on board |
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</table>
| 5. The Logistics Service Provider/cargo owner / user perspective on shipping R&I | - Modal Shift  
- Regulations and Sector Compliance  
- Compliance Strategies | - Assess the impact of regulations on shipping in terms of modal shift and sector competitiveness;  
- Include the study of the shipper/passenger/cargo owner perspective on specific technical solutions and compliance strategies;  
- Evaluate the impact of regulation on various specific European supply chains (e.g. wood products)" |
| 6. Short Sea Shipping vs. intercontinental maritime transport – different research needs? | Technological solutions focussed on SSS (how IS experience can apply to SSS and vice versa?) |
| 7. Methodology for identification of best technologies (vessel type, trade) | New application should be supported by Demonstrators and infrastructure development |
| 8. NOx, PM, CO reduction, methane slip (and other unburned fuels) | - Methane Slip from Natural Gas / Dual Fuel engines.  
- Particulate matter emissions.  
- Fuel optimised engines  
- Engine systems with lower emission and improved operational range and lifetime.  
- NOx, SOx, and CO2 reduction through engine optimisation with different types of fuels, engines and after treatment systems.  
- Local control of emissions, e.g. for ports, sensitive areas, etc. | - Assessment studies on the impact of first prototypes in operations.  
- Impact and effectiveness analysis from first prototypes solutions – operational data analysis and integration.  

Note: During the past years several solutions have been developed aiming at reducing the emissions, in several cases with the support of public funding. First prototypes are therefore already in operation. An analysis of the impact and effectiveness of such solutions in operation will be beneficial for further optimizations and improvements by both technology providers and shipbuilders" |
| 9. Research as competitive advantage: | - Compilation exercise on a number of concise cases where R&I has delivered economic benefits for the first mover in the area of green shipping  
- Analysis of success stories - how can innovation be turned in competitive advantage? |
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| **10.** Alternative fuel options – adequately addressed by R&I? | • Methane slip abatement methods.  
• Methanol/hybrid systems/hydrogen fuel cells.  
• Optimisation of size and location of LNG tanks on board.  
• Alternative fuels for shipping - a research agenda. | • Studies on alternative fuels for shipping - a research agenda: (technical issues at ports, in distribution chain; uncertainty of fuel availability; fuel prices; safety issues on board and in ports; integration of new technologies on board; environmental and efficiency lifecycle).  
Make specific cases build-up considering the whole value chain.  
• LNG fuelled ship Formal Safety Assessment, risk models, including bunkering operations |
| **11.** New ships vs. retrofitting | | • Research and Innovation should be performed not only at ship level but also on the infrastructures being complimentary assets and on the business models as well.  
• Take holistic approach to study retrofit versus new building. **Note: Innovative business models in these areas are needed.** |
| **12.** Assessment / optimisation of system complexity | • Innovative systems-level modelling, simulation and optimization tools to assess performance, design, retrofit solutions,  
• New technologies with respect to energy efficiency, emissions, safety, costs. | |