Ships of the future

ADEME

French Environment &
Energy Management Agency

STRATEGIC ROADMAP

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Preamble

As a target-driven agency responsible for directing and coordinating research in these fields of operation (renewable energies, air, noise, energy efficiency, soil, waste), the ADEME provides financial support to research projects and research demonstrators, implements research training devices (thesis programme) and coordinates the scientific community in its fields of operation.

More recently **within the scope of the Investments for the Future programme (Investissements d'Avenir)**, the ADEME has been entrusted with several programs or actions relating to its skills:

- The "Vehicles of the Future" programme for a total of €1 billion, one section of which involves "rail, sea and river" ransports with €250 million.

- The "Demonstrators and technology platforms for renewable, low-carbon energy and green chemistry" programme, grouping together two actions:

  • a "Demonstrators, renewable energy and green chemistry" action for a total of €1,350 million;

  • a "Waste sorting and transformation, depollution and product eco-design" action for a total of €250 million.

- The "Smart Grids" section of the "Developing the digital economy" programme for a total of €250 million.

In this respect and following the example of the works conducted by the Agency since 2008 for implementing the research demonstrator Fund on new energy technologies, ADEME is setting up groups of internal and external experts responsible for drawing up strategic roadmaps prior to launching Calls for Expressions of Interest (CEI).

The "Ships of the Future" roadmap, which makes up part of the "Vehicles of the Future" programme, must:

• Highlight the **industrial, technological, environmental and societal challenges**;

• Draw up **coherent and shared visions** of the long-term deployment of shipbuilding technologies and naval maintenance-refits;

• Identify the **technological, organisational and socio-economic obstacles** to be overcome to achieve the visions previously defined;

• Prioritise the **research, development, demonstration and experimentation requirements** to improve the national strategy of the CORICAN (Research and Innovation Guidance Committee for Shipbuilding) and the contents of future calls for research, research demonstrators or experimentation proposals.

This strategic roadmap includes **an international comparison** focusing on the research conducted abroad in several key countries.

The visions drawn up within the scope of this roadmap are based on the consultation of **a group of experts** from the field of shipbuilding, ship owners, ports and waterways in France, a competitive cluster, design offices and classification societies, public research, further education and finally the ADEME.

List of experts involved
List of members of the group of experts:

Nature of the Body	Expert	Member body
Naval Industry	Boris Fédorovsky	GICAN
Shipbuilding	François Duthoit	DCNS
	Stéphane Klein	STX
Ship owners	Patrick Rondeau	Armateurs de France
	Steve Labeylie	CFT
Ports and Waterways	Geoffroy Caude	Union des Ports de France
	Catherine Leleu	VNF
	Jean-Marie Millour	BP2S
Public Research and Further Education	Elisabeth Gouvernal	IFSTTAR
	Philippe Sergent	CETMEF
	Thomas Loiseleux	ENSTA
Competitive Cluster	Patrick Poupon	Pôle Mer Bretagne
Design offices or Classification Societies	Pierre Besse	Bureau Véritas
	Hubert Thomas	ACSA Underwater GPS
Observers	Fabien Paris	MEDDTL/ DGITM
	Jean-Baptiste de Francqueville	MEDDTL / CGDD
	Claude Marchand	DGCIS
	Catherine Ganne	DGA
	Philippe Cauneau	DGA
	Charles Guirriec	DPMA

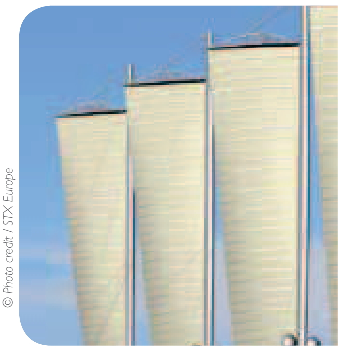
The group of experts received support from **a technical office** of ADEME, held by the Advanced Technologies and Research Department (Valérie Weber-Haddad), under the chairmanship of Anne Varet, Research and Planning director.

This department called upon the skills of **internal experts** including Patrick Coroller, Denis Benita, Gilles Aymoz, Eric Vidalenc, Chantal Derkenne, Didier Violle, Anabelle Vigilant, Jack Fiol and Renaud Michel to contribute to the drawing up of this roadmap.

Other **external experts** also made a contribution: Nicolas Bour and Rudy Priem (VNF), Joaquim Henry (CETMEF), Patrick Baraona (Pôle Mer PACA), Paul Tourret (ISEMAR), Nathalie Stey (Navigation, Ports and Industries), Danielle Rouganne and Antoine Mathot (Entreprendre pour le Fluvial), Jean Gaber (DGITM), François-Régis Martin-Lauzer (IHEST) and Martial Claudepierre (Bureau Véritas).

During different work sessions, the experts expressed their opinions **as individuals**. Therefore, the visions presented within this roadmap cannot be compared to those officially declared by the companies, bodies or institutions to which the different members of the group belong.

The visions differ greatly so as to define **that which is possible**. The reality in 2050 will probably fall within this range. This search for contrast was motivated, on the one hand, by the group's desire to offer the most exhaustive possible view of potential futures, and on the other hand, the desire to avoid neglecting any critical technological, organisational or socio-economic obstacle, due to its association with a vision excluded from this reflection.



1 Scope: subject area and geographic perimeter, deadline

Subject area

The "Ships of the Future" roadmap involves **ships and boats**[1] operating for commercial transport (of persons and/or goods) or work (fishing, installation and maintenance of offshore wind turbines, maritime surveillance, research activities, dredging, etc.).

The following shall be included:

- Equipment directly involved in the ship's use;
- Technologies and services used to design, build, navigate, maintain and transform/modernise ships.

The following shall be excluded from the area of this roadmap, due to their specific means:

- Military ships and equipment;
- Pleasure boats;
- Specific equipment for working boats (e.g. fishing gear).
- Technologies and services used for the end of life recycling of ships. However, the topic of recycling shall be taking into account for ship design.
- Port and river infrastructures. However, the need for innovation in dock facilities required to supply ships with new energies and for other uses (discharge of wastewater, waste processing, etc.) shall be taken into account.

Geographic perimeter

In the scope of this roadmap, the preferred geographic perimeter is that of the **national territory** (mainland France and French overseas territories [DOM-COM]).

Within a market experiencing high international competitiveness, the observations made by the group of experts also apply within the perspective of deploying the naval industry **abroad** and positioning French stakeholders on the international market.

Deadline

The deployment visions for technologies and services within the naval industry and the waterways- industry, developed within this strategic roadmap, target **the year 2050**, in particular so as to remain consistent with the other strategic roadmaps.

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1. For simplicity purposes, the term "ship" shall be used, it being understood that this also relates to boats.

2 Challenges

The "Ships of the Future" must make their contribution to the sustainable development of sea and waterways activities ("blue growth"), by improving their performance levels in terms of navigation and harbour calls, within a transport chain between the sea/waterway and the land, via steps for operating and transforming the sea's natural mineral, biological (including halieutics) and energy resources, but also via monitoring and pleasure activities.

Several examples are provided below:

- **Transport** of goods **by sea** is essential for the world economy with 80 to 90% by volume of all exchanges being shipped by sea. More particularly, this is fundamental for the European Union, which is the first commercial partner throughout the world and where intra-community sea transport represents 40% by volume of all goods shipped. France boasts 5,500 km of coastline, two major seafronts and the number 2 exclusive economic zone in the world. **Sea passenger traffic**, on a global scale, is equivalent to that undertaken by aircraft. The European ferry market is the number 1 market in the world.
- **Transport** of goods **by river** is currently experiencing growth. Taking into account the objectives of the "Grenelle de l'Environnement"and the recent white paper by the European Commission entitled "Transports 2050" for significantly increasing the share of alternative transportation modes, the use of the Seine-Nord Europe canal in 2017, river traffic is expected to double by the year 2020. This will require the structuring of a French river industry to meet the demand for new boats and for modernisation needs of current fleets, in particular in terms of propulsion.
- **Sustainable fishing**. The economic part of professional fishing (annual turnover of approximately €1 billion, 23,000 direct jobs and 3 to 5 times more indirect jobs in the fish trade, transformation and distribution) is a key item for the economy of many coastal areas. The increasing global demand for seafood will lead to an increase in catches, which will be ensured by the development of new more efficient and safer fishing grounds and the optimisation of resources exploited to their full potential (up to the Maximum Sustainable Yield).
- **Marine energies**: today they constitute an important source of jobs with regard to operation and maintenance activities. In particular, the marine sector is directly involved in shipbuilding, ports and sea-related services.

Four challenges more specifically relate to "Ships of the Future" (not provided by order of priority):

Challenge No. 1: The competitiveness of the French naval industry

The French naval industry, ranked 6th in the world, groups together numerous stakeholders involved in a wide range of activities such as shipbuilding, equipments, repair, transformation of ships, offshore technology and the new on-going sector of renewable marine energies. It boasts renowned knowledge in complex high-tech ships.

This industry must be capable, in an international competitive environment, of remaining competitive in order to meet the demands of various users (ship owners, marines, passengers) by offering evolutive and potentially multipurpose ships, **innovative solutions (technologies and services)**, being safe, environmentally friendly and economic, in all or in part, or to modernise existing ships in addition to assembly and manufacturing technologies. The upstream work by both the ship's owner and the shipyard for ship's specification writing is the first importance. **Risk-taking** must be covered by financing means and otherappropiate means(guarantee funds, regulations, developments in offshore and onshore port and river infrastructures, etc.).

One additional challenge involves the skills acquired by the sea industry and the river industry, by supporting the adoption of innovations by operators and crews, conducting initial and further training programmes from the design and shipbuilding phases through to the logistics challenges so that this industry remains attractive to **high-performance staff**.

Challenge No. 2: The competitiveness of ship operations

The competitiveness of **sea and river transport** operations is within an international field and within a European framework defined by the central network and multimodal corridors connecting seaports, waterways and inland ports with their road and rail interfaces. The competitiveness of ship operations is considered within this context of **interoperability**, taking into account the interfaces between the river and port infrastructures in addition to ships and their equipment. This competitiveness therefore involves not only the **cost of sea and river transport** but also problems relating to **intra-modal** transfer and its associated costs (stopover/loading and unloading costs for cargo) in addition to compatibility with other means of transport (rail and road transport). Technological improvements on ships must ease interoperability with other modes of transport in order to find their place in new logistics schemes.

In this multimodal chain, river logistics operations on dedicated platforms, the distribution of goods in an **urban** and transfer between **narrow narrow waterways networks and wide waterways** networks are key elements in designing a modern, efficient fleet. These improvements involve both the building of new units and the modernisation of the existing fleet. Furthermore, the competitiveness gains resulting from these works will be useful in the event that river transport is taking place between two sites located on the river banks, without intra-modal transfer. These technological improvements could aim at improving accessibility in a dense urban environment by easing loading/unloading operations outside of port facilities.

The competitiveness of ship operations also involves the **efficiency of crews** during navigation (steering, maintenance tasks, etc.) and during the transshipment of goods and/or passengwers, however competitiveness must not be sought after at the expense of safety (refer to challenge No. 4).

The **transport conditions for goods** (packaging, refrigeration, etc.) also represent a decisive factor in determining competitiveness insofar as this involves guaranteeing the value of thoses goods (fishing catches, fragile goods, etc.), while optimising the whole ship's energy consumption (refer to challenge No. 3).

Challenge No. 3: Environmental efficiency and adaptation to the major changes taking place globally

Although the majority of sea pollution originates from land activities, approximately **20% of this pollution** originates from sea activities; at the very forefront of this is navigation with hydrocarbon discharges, degassing, domestic garbages, ballast water, wastewater and drops of containers into the sea with toxic substances inside.

Furthermore, 3 to 4% of **global CO_2 emissions** originate from sea transport. Even though sea transport emits much less CO_2 per tonne and per km transported than other transport means, these emissions will rise with the increase in traffic and must therefore be controlled. With regard to waterway transport, CO_2 emission units are between 2 and 4 times less than those of trucks (over a similar distance), the former contributing to reducing congestion near major European conurbations.

The management and reduction of **sea and air pollution** must be considered in the early design of the ships so as to reduce pollution at the source, in particular by means of on-board equipment (new or refitted). **Zero toxic discharge/pollution must be a long-term objective**.

The reduction in the atmospheric emission of **particle pollution** ("particulate matter") or gaseous pollution (NOx, SOx, etc.) imposed by a more draconian regulation in particular for sulphur dioxide (low-cost fuel is generally high in sulphur) is a challenge that must be overcome to reduce the environmental and health impacts of local-level pollution during port transit and of global pollution (alteration of the ozone layer, etc.).

Solutions are also expected to **reduce wake** during navigation or when approaching ports (protection of embankments) and to **reduce sound** (noise and vibrations) **and light pollution** which effect crews and passengers, the marine ecosystem and the environment of port towns or for river transport in dense urban areas.

Moreover, in a future context of rarefaction of oil, improvements in ship **energy efficiency** and the use of new free of oil energy sources are essential. This in particular involves technological solutions (new propulsion systems, etc.), new ship architectures, new organisations (installation of berthing equipment and network connection equipment to port and river infrastructures, specific regulations, etc.) and optimised management of ship speed and load (eco-navigation) and routing.

Finally, the naval industry must also anticipate **the impacts of climate change** (more frequent storms, flooding, drought, opening of new arctic marine routes, etc.) on sea and waterway navigation.

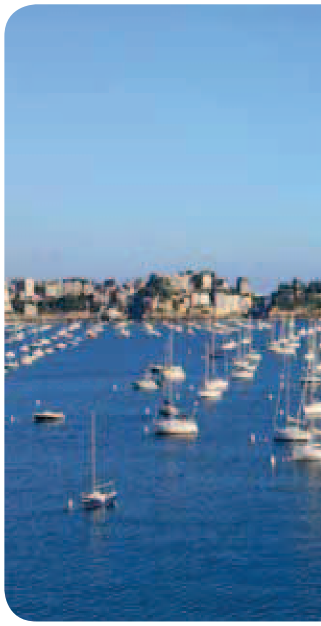
Challenge No. 4: On-board security, safety and comfort

This challenge consists in maintaining the competitiveness of ship owners concerned with the safety of their ships and on-board living and working conditions (crews and passengers), by complying with a high standard of regulations (IMO conventions, Erika III set of rules, passenger evacuation and rescue procedures, the directive EC 2006/87 on building inland waterway vessels, etc.).

Safety is in particular connected to **the quality of the fleet and its maintenance**, in compliance with environmental and health standards, and to improving the self-safety of ships (stability, cargo load, and so on).

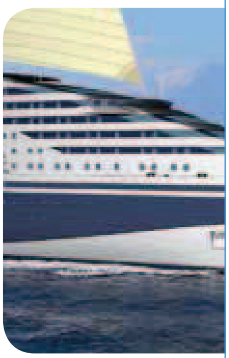
Safety is also connected to **damage-control** (fire, etc.) and **security to controlling threats and illicit acts** (theft, piracy, immigration, terrorism, etc.) both with regard to persons and cargo. This requires a self-protection system for ships, monitoring technologies and navigation assistance in addition to a monitoring and intervention system in coastal area and in high sea.

Improving comfort and acces for passengers and crews in particular involves re-thinking the inside architecture in order to reduce noise pollution and vibrations, take into account design, light and space, ease access on-board and movement onboard the ship and improve the ergonomy of the working stations.



3 Key parameters and prospective visions

The aim of the long-term visions drawn up in this roadmap is to broadly describe differing situations. These visions do not claim to describe the reality in 2050, but to define that which is possible so as to deduce a wide range of obstacles, research priorities and research demonstrator needs associated with the realisation of these long-term visions.



The building of long-term scenarios is based on the identification of key parameters. These **key parameters** are in-puts, the differing evolution of which in the long term will lead to relatively different visions. Given that the long-term visions have the main purpose of informing decision makers, the number of key parameters and therefore the number of visions resulting thereof have been limited.

Key parameters

In addition to the aforementioned challenges, the group of experts has agreed to the existence of two key parameters which, in the long term, will play a decisive role in the design, manufacture and operating conditions for ships of the future:

Key parameter No. 1: ship use

Ships of the future shall continue to fulfil some of their current uses, however will also take on new roles according to the contextual developments taking place (economic, technological, climatic and regulatory developments):

• The continuity of current uses

Demand for long distance transport of goods **by sea** will continue given the needs connected to worldwide exchanges and the demand for **travel** (cruises and ferries) will increase in conjunction with an increase in standards of living in developed and developing countries.

The **geography of transport** systems will continue to undergo structuring by the main world economic centres but also by new sources of growth, which should lead to more complex marine networks in the future, with strengthening of the **role played by trans-shipment ports**.

Increasing regional demands can also be expected for **waterway transport and short sea shipping** as an alternative to congested road transport.

Fishing boats will continue to operate in current zones with improved use of the ultra-marine space according to the availability of halieutic resources, and new species could be exploited, which will lead to a demand for suitable fishing boats.

• The development of new uses

New uses will appear, in particular due to the rarefaction of natural fossil resources and the search for new offshore energies and due to the increasingly strengthening regulations in terms of the environment and safety:

– sea and waterway transport will involve **new kind of goods** (drinking water, hydrogen, captured CO_2, etc.);
– the development of the **offshore economy** will be supported by the need for specialised specialised workking ships (installation and maintenance of wind turbines, exploitation of marine resources, etc.);
– the development of **factory ships** and **multi-purpose floating mega-structures** (pleasure, energies, aquaculture, massive humanitarian operations for evacuating climate change refugees, etc.);
– **urban logistics** and city frontage roads **for waterway transport** (non-massified goods, mobile bodywork, vehicles, etc.).

New maritime navigation (arctic zones, etc.) could also be used due to planetary climate change.

These new uses will create the need for suitable **ships** (zero discharge, etc.), specialised to a given function, **modular or multi-purpose** combining several uses (fishing tourism, scientific use and fishing, etc.), either new or converted from part of the existing fleet.

Key parameter No. 2: structuring of industrial stakeholders within the naval industry

The gain in new market shares on the different home and/or export market segments also involves the structuring of industrial stakeholders within the naval industry.

Shipbuilding is an industry boasting high capital, work and technology. This sector is extremely complex and integrates a wide range of product suppliers and service providers: naval architecture offices, metallurgy, equipment providers (motors, electronics, etc.), etc. These companies can make up a "local-level ecosystem" or be connected to an organisation with a "global business" model (e.g.: importation of raw materials and equipment, data flows).

This sector is highly dependent on the **health of the global economy, availability in terms of raw materials** (steel, oil, etc.) and **energy**, the cost and availability of qualified labour and the more or less ambitious State industrial policies.

Shipbuilding can make use of the rise in demand for ships by increasing the production of **new ships** and/or by **converting** existing ships. Industrialists can choose to develop a **wide range** of ships or to **become specialised** in a given market segment so as to meet the needs of national users and/or develop several export markets, at competitive prices thanks to increased production efficiency (e.g.: automated production chains, increasing efficiency of mass production), by integrating new technologies (low pollution, energy-saving technologies, etc.) and operating and maintenance costs.

Two main types of structuring can therefore be proposed for the naval industry:

- **Fragmented and globalised organisation of the value chain**

The relatively low transport cost and transaction costs (customs duties and legal barriers) leads to a "global business" organisation for shipyards: some of the elements involved in manufacture are imported and/or some of the steps in the value chain are delocalised abroad according to wage costs and/or nearby raw materials (steel, iron, etc.) within these countries.

- **A local-level industrial ecosystem**

A significant part of the value chain is undertaken by companies present nationally (major groups and their subsidiaries, sub-contractors), for the following reasons:

- the quality of the end product, timeframe and proximity to suppliers and customers;
- cost: the economic interest in delocalisation changes according to the development of wages in the countries to which activities have been delocalised, the transportation costs directly connected to energy prices, modifications made to production methods, in particular automation, government aid, etc.
- the capacity to innovate and the flexibility of local businesses;
- the bet placed on top of the range products to compensate for additional labour costs;
- the desire or regulatory need to insert the economic model into a carbon footprint approach or RSE, or even ISO 26000.

The 2050 visions

Variations relating to the two key parameters result in the production of 4 differing visions:

Future uses / Industrial structuring	Current uses	New uses
Worlwide extend of the value chain	**Vision 1** Optimising costs	**Vision 2** New standardised market niches
A local-level industrial ecosystem	**Vision 3** High-tech specialisation	**Vision 4** Complexity and customisation

All visions presume an economic context excluding times of crisis, characterised on the one hand by a general increase in demand for ships, for traditional or new uses, and on the other hand by improvements in living standards and increased wages in developing countries.

Vision 1: Optimising costs

Continuity of uses and fragmentation-globalisation of the value chain

In this vision, ship owners order ships with expected innovations for improved reliability and hardiness (e.g.: better quality steel) for traditional uses. Ship owners also order ships that are expected to at least comply with the regulations. The decisive criteria involve the purchase cost and operating costs with shipyards employing low-labour costs and/or fast production cycles generally being the most competitive, all the more so as they mass produce for a global market and automate their production process.

Industrialists installed nationally can choose to perform manufacturing operations either in full or in part in other countries offering lower labour costs and offer optimised maintenance services.

Equipment suppliers position themselves on the market by the mass manufacturing of sophisticated equipment for the global market.

Interfaces with port infrastructures do not undergo any fundamental modifications.

Vision 2: New standardised market niches

New uses and fragmentation-globalisation of the value chain

In this vision, the demand of ship owners corresponds to a need for ships performing new uses, however relatively standardised with competitive operating and purchasing costs.

National shipyards and equipment manufacturers position themselves within these new market niches by developing new products while adapting the former manufacturing processes used for traditional ships, and by offering services at competitive costs throughout the life cycle of the ship.

Interfaces with port and river infrastructures evolve due to the development of new uses (e.g.: port spaces dedicated to storing/handling offshore wind turbine components, land transport of new energies by pipe lines from/to facilities on port sites); port facilities (multimodal terminals) are used for inland river transport.

Vision 3: High-tech specialisation

Continuity of uses and local-level industrial ecosystem

The demand of ship owners essentially involves ships for current uses.

Shipbuilding and repair activities are highly competitive on a global scale.

In order to maintain their competitiveness, industrialists in the naval industry are organised in the form of local-level ecosystems and position themselves in high-tech specialised shipbuilding operations (for example large passenger ships). The local-level industrial ecosystem makes industries competitive as it limits raw material imports using local materials (for example bio-sourced materials) and renewable energies and integrates data flows for ship design.

Industrialists choose to offer "life cycle" services (renovation-modernisation-conversion) with high added value (electronics, composite materials, propulsion, etc.), in particular for local-level markets (e.g.: fishing boats, river boats). The renovation costs are compensated by reduced future operating costs for the ships thanks to the technological innovations implemented (energy savings, extended engine life, etc.).

New interfaces with port infrastructures are installed for ship refuelling (in particular in new energies) and their maintenance.

Vision 4: Complexity and customisation

New uses and local-level industrial ecosystem

The installation of an upstream to downstream integrated industry on national or European land enables small series of high-tech ships to be delivered on the global market (passenger ships, specialised work ships, floating platforms, artificial islands).

The shipbuilding cost is compensated by the quality and performance levels of the ships made to order and by the customised services offered (financial support, sophisticated maintenance guarantee).

Industrialists can also offer maintenance and modernisation services at an acceptable extra cost, in particular by sharing their facilities.

Innovations are also required, both at production process level and for ship design in addition to the installation of new interfaces with port infrastructures for ship refuelling (in particular in new energies) and their maintenance in addition to for logistics operations (automation of handling machinery, performance levels of the cold chain, etc.).

4 Obstacles

Obstacles are the elements that prevent the defined visions from being reached. They are technological, socio-economic, organisational or regulatory in nature and may appear separately or together. Their prior identification is required to determine the research-development needs and demonstration needs.

1. Obstacles for 2050

Two families of obstacles have been identified by the group of experts:

- **Technological obstacles**

These technological obstacles involve breakthrough innovations or incremental innovations, in particular drawing on the benefits of **tried and tested technologies in other fields** (motor industry, aeronautics, hydrogen technologies and fuel cells, etc.) by adapting these technologies to the specific features of sea and river transport (saline environment, load balancing, etc.) and by designing new logistics and functional organisations.

Obstacle 1.1: The lack of efficient technological solutions to **reduce the consumption of fossil energies** by ships.

Obstacle 1.2: The lack of efficient technological solutions to **reduce the environmental impact** of ships and **guarantee the possibility of 100% recycling** of ships at the end of their life.

Obstacle 1.3: The lack of efficient technological solutions to **resolve the safety/security challenges** faced by ships, their crews, passengers and goods (navigation under extreme conditions, etc.).

Obstacle 1.4: The **lack of permanent monitoring and adaptive maintenance technologies**.

Obstacle 1.5: The **lack of efficient production methods** to increase competitiveness.

- **Socio-economic, organisational and regulatory obstacles**

Obstacle 2.1: The **loss of national skills** in certain key/strategic fields (e.g.: motorisation, high-level training).

Obstacle 2.2: The **barriers hindering the implementation of breakthrough innovations**: lack of guarantee funds to support the risk taken by the ship owner (technology retrofit if inefficient), financialisation of the ship market. Only innovations boasting a return on investments timeframe of less than the provisional ship resale date are accepted by ship owners.

Obstacle 2.3: The need to strengthen the **structuring of research** and **the lack of testing capacities** dedicated to sea transport and adapted to river transport.

Obstacle 2.4: The **restrictions connected** to port and river **infrastructures** (supply in new energies, land take, etc.).

Obstacle 2.5: The **social acceptability of the new uses** of ships and new fuels by stakeholders (public authorities, ship owners, freighters, passengers, local inhabitants, etc.).

Obstacle 2.6: The **adoption of innovations** by crews.

Obstacle 2.7: **Regulations** sometimes absent in certain cases or which may be too pre-emptive or on the contrary block or significantly hinder technological and organisational innovations and make sea and river transport less competitive than other modes of transport.

2. Obstacles for 2015

Some of these obstacles (obstacles 1.1., 1.2., 2.4. and 2.7) have a major short-term impact (2015), given the international **regulatory requirements** for security and the environment, which will become stricter by this date (refer to APPENDIX No. 1). These regulations can either become obstacles that are too difficult to overcome or create a new promising market.

The 2015 priorities are **the development of smoke treatment systems** (washers, catalytic converters, etc.) that can be easily integrated into the ship **and substitution solutions for heavy fuel**, in particular by LNG or by electric propulsion means, which require new propulsion systems, storage infrastructures and dedicated supply and distribution means. This must be supported by adapted regulations, in particular for short-distance sea transport.

5 Research and demonstration needs

In order to overcome the challenges of the naval industry and the obstacles drawn up from the visions proposed, innovations must be directed towards ships and their equipment.

The creation of such innovations is faced with barriers, in particular technological barriers and the absence of appropriate demonstrators, hence the need to conduct research and demonstration programmes on:

- the architecture, equipment and the integration of on-board systems;
- the competitiveness of the naval industry

In order to overcome the identified obstacles, the research and demonstration needs for the ships of the future proposed herein take into account the needs expressed during the Grenelle de la Mer (group No. 12) and on a European level within the scope of the Waterborne platform, the needs specific to fishing as identified by the Ministry of Agriculture and the research needs for river navigation proposed on a European level within the scope of the Platina platform.

1. Research needs

A consensus exists on the expected research, which must prioritise proposing **an energy saving, clean, safe and smart ship** in the medium term.

The research needs have been classed according to four **technological themes**, which work towards overcoming obstacles 1.1 to 1.5: economic ship, clean ship, safe ship and smart ship. These themes are complementary: the research conducted on a given theme should assess their impact on the other themes.

A fifth **transversal theme** entitled "**competitiveness and socio-economy**" involves on the one hand research on the progress expected to be made by technological innovations and the conditions encouraging their adoption, and on the other hand the research conducted on conditions encouraging the structuring of a comprehensive and coherent, competitive French naval industry. This approach works toward overcoming obstacles 1.4 and 2.1 to 2.7.

"Economic ship of the future" theme

The ship of the future must be economic and not only compensate for the increase in energy costs and prepare for the "post-oil" era, but also improve ship autonomy and reliability and reduce the frequency of maintenance operations. This targets a 50% saving in fossil energy consumption.

This theme is defined via two complementary approaches:

– How to make ships consume less energy?

– How to reduce other ship operating costs?

Approach 1.1. Energy efficiency

The level of energy efficiency of the ship of the future involves research on:

- reducing water resistance: shape of hull bottoms and appendages, materials and coatings, lightening of structures, hydrodynamics, aerodynamics;
- improving the propulsion function: propeller efficiency, new propulsion systems;
- integrating renewable energies;
- optimising the global energy footprint.

Approach 1.2. Operations efficiency

The level of operations efficiency of the ship of the future involves research on:

- the level of compactness of the ship's structural installations to provide for spaces for goods, passengers and the crew, and commercial spaces;
- optimising navigation operations, manoeuvres and commercial operations (loading/unloading);

- for fishing: optimising the preservation and value of catches on-board;
- sea-river interoperability (between sea transport and river transport);
- sear-land interoperability (sea and river transport with other modes of transport).

“Clean ship of the future” theme

The clean ship of the future must anticipate and go beyond the regulations in terms of protecting the environment (on CO_2, sulphur oxides SOx, nitrogen oxides NOx, particulate matter PM, wastewater, waste), and ensure that it can be rehabilitated according to developments in the regulations throughout its planned life and that it can be recycled under acceptable economic conditions.

This targets a 50% saving for all of the ship’s environmental impacts (discharge of any kind) throughout its life cycle (construction, operation, maintenance and dismantling).

This theme is defined via four complementary research approaches:

Approach 2.1. Eco-design

Research could be based on:

- implementing manufacturing processes with low environmental impacts;
- reducing the consumption of materials and energy during ship design and maintenance operations, using recycled materials or renewable materials;
- taking into account ship dismantling at the design stage: majority use of recyclable building materials and paints in the identified industries, searching for alternatives hazardous to both human beings and the environment, etc.
- innovative production methods reducing the cost of shipbuilding.

Approach 2.2. Reducing atmospheric emissions

Research could be based on:

- developing propulsion systems and energy production systems emitting low levels of greenhouse gases, atmospheric particulate matter, gaseous pollution and their precursors;
- reducing the emission of particulate matter or gaseous pollution and their precursors via fuel pre-treatment or smoke post-treatment systems that can be easily integrated into the ship, while taking care to avoid transferring pollution into the water;

Approach 2.3. Reducing other pollution

Research could be based on reducing:

- noise pollution and vibrations;
- visual pollution and light;
- other damage caused to the marine, coastal and river ecosystems (wake, vibrations, ballast water, etc.);
- the electromagnetic radiation generated by the ship’s equipment.

Approach 2.4. Solid and liquid waste management

Zero toxic discharge/pollution is a long-term objective. Research could be based on optimising storage, pre-treatment and on-board treatment of waste, or even their recycling or transformation within identified industries, involving:

- wastewater;
- solid waste (organic waste, packaging, etc.);
- waste originating from the ship’s operation (for example: tank cleaning residue, fishing catch residue, laundry waste, kitchen waste, etc.).

“Safe ship of the future” theme

The safe ship of the future must integrate innovative approaches to improve security, safety and comfort standards for the crew, passengers and cargo both with regard to regular activities and under extreme conditions (storms, fires, piracy, etc.).

Active security, which involves looking to avoid and prevent an accident, can be distinguished from passive security, which corresponds to managing an accident once this has occurred so as to limit any resulting damage.

With regard to safety, innovations to be made to the on-board equipment of ships (self-protection, monitoring technologies, etc.) can be distinguished from systems dedicated to monitoring and performing interventions along coastlines and at sea.

This theme is defined via two complementary research approaches:

Approach 3.1. Safety and security of the ship and its activities

Research could be based on:

- improving navigation;
- improving the security of the ship's circuits (fuel, water, air, etc.) and facilities (sanitation, food, etc.);
- the ship's resistance to extreme weather, sea and river conditions;
- improving resistance to damage or events occurring during navigation (collision, fire, waterways, etc.);
- improving safety connected to the use of new energies (LNG, hydrogen, etc.);
- preventing and protecting against illicit acts (theft, trafficking, piracy, etc.) performed against the ship, its crew and its passengers or its cargo.

Approach 3.2. Safety and comfort of persons on-board

Research could be based on:

- active systems and passive security management devices for events at sea or on waterways (fire, evacuation, etc.);
- the security of operations at sea or on waterways (adaptation to working conditions at sea, for example for the installation and maintenance of wind turbines);
- disabled access;
- optimising spaces and services for passengers and new activity concepts;
- the ergonomy of work stations and living areas.

"Smart ship of the future" theme

The smart ship of the future must integrate innovations (information and communication technologies, electronics, etc.) enabling the crew to optimise the ship's navigation, consumption, emissions, regular operations and critical operations.

Approach 4.1. Optimising operations for managing consumption and emissions

Research could be based on:

- real time knowledge tools for the emission of particulate matter, gas and their precursors into the atmosphere;
- decision aid tools for economic navigation (on-board navigation assistance, journey planning, use of satellite data, etc.) in particular according to weather conditions and the ship's load (trim);
- on-board energy management tools (instantaneous consumption, energy-saving mode - shutdown of non-essential auxiliaries - influence of speed reduction).

Approach 4.2. Optimising regular and critical operations

Research could be based on:

- on-board communication tools for internal and external communications;
- real time ship status management tools (sensors, predictive maintenance based on the operation cycle produced, remote maintenance);
- tools working for the comfort and safety of on-board passengers: broadband internet access, telemedicine;
- navigation security systems: obstacle detection and avoidance; automated berthing/steering; dynamic positioning and stabilisation.

"Competitiveness and socio-economy" transversal theme

This theme is defined via three complementary research approaches:

Approach 5.1. Impacts of sea and river transport and instruments for an environmental economy

Technological innovations will lead to improvements being made in the performance levels of ships, in particular in terms of energy consumption and greenhouse gas emissions.

Following the Grenelle de l'environnement, **the Observatoire énergie, envi-**

ronnement, transports (OEET - French Observatory for Energy, the Environment and Transport) was founded in 2007. Led by the ADEME, the SOeS, the CITEPA and the Sétra, this observatory aims at assessing the greenhouse gas emissions produced by transport according to a single methodology common to the different modes of transport, so as to produce a carbon footprint and eco-comparison tools for transport services. Reports have been drawn up with regard to the calculation methods for road, river, rail, sea and air transport.

This data can highlight the progress made by these industries with regard to the targets set, however can also lead to studies being conducted on the different instruments promoting an environmental economy (e.g.: the impact of the use of an international tax on ship emissions, the creation of emission permits, ecological tariff system for modes of transport).

Approach 5.2. Analysis of the conditions required for the success of the innovations proposed

The innovations proposed must not only resolve the technical problems, but also take into account the organisational and socio-economic conditions enabling them to be generalised. Research could be based on:

- **Anticipating evolutions in the regulations**. Pre-normative research will study the feasibility of evolutions in national or even supranational regulations, required to adopt new technologies.
- **Acceptability by stakeholders**. Research will analyse stresses connected to acceptability by neighbouring inhabitants in the event of detected or suspected pollution caused by the implementation of new technologies in addition to any consultation processes potentially in place.
- **Adoption by crews**. Certain technological innovations will be confronted with former practices and habits of crews. They will require research on the man-machine relationship, work organisation (durations, magnitudes, rhythms, new work functions, operation of work populations) and on ship ownership and operation (artisan forms, etc.). New specific training programmes could also be proposed to professionals, for example with the support of use simulators.
- **Adoption by logistics and production chains**. Innovations must be consistent with market demand and the restrictions of production systems (speed, deadlines, batch sizes, location of companies, etc.). Research will be based on analysing current or possible future production systems (freight-passenger co-functions of ships and infrastructures, etc.), new relationships between loaders and service providers and conditions for their development (service needs, tracking, trust, etc.).
- **Economic relevance and external costs**. Research will be based on analysing the direct costs linked to investments (construction, purchasing) and the operation of the ship (fuel, labour, maintenance, etc.) throughout its life-cycle, in addition to the overall cost of sea and river transport including its externalities (pollution, accidents, congestion, etc.). Research will also be based on the competitiveness of sea and river transport compared to other modes of passenger and/or goods transport.

Approach 5.3. Improving the competitiveness and attractiveness of the naval industry

Research could be based on improving:

- the competitiveness of ship **design**: digital models, functional performance simulator, digital simulators for eco-design aid;
- the competitiveness of the **industrialisation** process: virtual shipyard, virtual logistics chain, geopositioning of ship elements, automation, optimisation of the use of handling tools and temporary installations (lighting, fire detection, etc.);
- the competitiveness of **manufacture** and **test** processes: continuity of the digital sector from design to production, optimisation of cutting-welding operations, robotisation of shaping operations, development of new assembly and levelling technologies, spray insulation, non-destructive paint/erosion/welding tests; offshore test bases;

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- the competitiveness of **worldwide enterprise operations**: interoperability of digital tools, information systems on suppliers, capitalisation of multisite and/or multi-enterprise knowledge, protection of the health/safety/security of staff, green shipyard, marketing analysis, technological monitoring, protection of know-how.

Comparisons with organisations from the motor and aeronautics industries structured around a network of suppliers and equipment manufacturers will provide relevant information.

Research can be conducted to understand the **factors determining the attractiveness** of the naval industry to qualified staff and propose action plans.

2. Experimentation and demonstration needs

Given the specific characteristics of the marine environment (hostile and demanding environment for equipment and crews) and waterways (confined environment subject to weather hazards), innovative solutions (technologies or services) cannot be fully validated on land, on models, and/or via simulations and modelling. The reliability of innovations must be demonstrated via real use operational missions so as to reassure users, given the risk of using non-validated innovative solutions.

2 types of demonstrators can be distinguished:

- **technological** demonstrators;
- **ship and equipment** demonstrators.

Projects could be deployed on mainland France and/or its overseas territories, each time taking into account the **reproducibility** of the options deployed in similar energy and geographical contexts.

Projects will be based on the **different ship uses** encountered or considered for the future. The adaptation of multi-purpose transverse solutions shall be studied in detail.

The chosen size for research demonstrators must be adjusted so that the technological, organisational and economic options proposed represent real proof of feasibility and relevance with regard to the commitment to a later commercial and industrial development action.

In addition to the suitability of projects to the aforementioned criteria, particular attention must be paid to the **environmental footprint** (greenhouse gas footprint, energy footprint, air and water pollution footprint, life-cycle analysis and eco-designed equipment) **and economic footprint** of the projects proposed, in addition to the **safety** conditions for persons and goods on board in addition to those of neighbouring inhabitants.

A reduction in costs throughout the entire ship life cycle also represents a priority objective.

Demonstrators should ideally be accompanied by assessments performed on:

- user practices and behaviour;
- the acceptability of innovative solutions for users and stakeholders.

2.1. Technological demonstrators

Technological demonstrators are **an experimentation support for one or several innovative technologies tested either at port, on a dedicated site or at dock or via small or real scale simulations** (digital models). They do not necessarily target commercialisation.

These demonstrators must fulfil the following functions:

- **Function No. 1: validate** the economic, environmental and social performance levels of the technology under controlled experimental conditions.
- **Function No. 2: validate the compatibility of technology** with the existing or forecasted fleet, and if relevant, with the existing or forecasted port and river **infrastructures**, or propose realistic adaptation transitions to achieve this compatibility.

- **Function No. 3: validate the compliance of technology with the existing regulations** and identify any regulatory developments or their modification where applicable.
- **Function No. 4: prepare for the industrialisation of technologies**, by specifying the terms and conditions for replacing classic technologies and by proposing industrial organisations optimising their design, construction and maintenance costs.

2.2. Ship and equipment demonstrators

Ship and equipment demonstrators shall be **real scale**. This may involve **existing ships** into which innovative technologies have been integrated or onto which innovative equipment has been assembled. This may also involve innovative **new ships**. Their purpose is to target commercialisation.

The involvement of **the ship's operational users** is essential over at least two years (smoothing out of navigation conditions connected to weather hazards and infrastructures).

These demonstrators must fulfil the following functions:

- **Function No. 1: demonstrate the** economic, environmental and social **performance levels** of the solutions proposed, **under real use conditions** during operational missions.
- **Function No. 2: define the organisational and socio-economic conditions** (including legal requirements and business models) for generalising the application of the solutions proposed, by optimising their design, construction and maintenance costs.

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- **Function No. 3: validate the compatibility of ships** with existing or forecasted port and river infrastructures, or propose realistic adaptation transitions to achieve this compatibility.
- **Function No. 4: prepare for the industrialisation of the ship of the future**, by proposing industrial organisations optimising their design, construction and maintenance costs
- **Function No. 5: validate the compliance** of demonstrators **with the existing regulations** and identify any regulatory developments required and take part in their modification where necessary.

6 International comparison

The “Sea and river ship of the future” roadmap includes an international comparison of the research priorities provided and research demonstrators, focusing on several key countries in Europe and Asia (refer to appendix No. 2).

It should also be noted that the specific characteristics of shipbuilding are provided in the **community agenda** in two ways:

- Supporting European networks dedicated to sea and river research (see below);
- The implementation of a specific system providing national support for naval innovation (notified scheme of December 2003 within the scope of the community guidelines for State aid). The European commission has recognised the need for new instruments meeting the interests and needs for research, development and innovation within this sector. Indeed, a large share of innovation activities in shipbuilding is integrated into the design and production process itself: new ships are highly sophisticated products, normally sold as single copies or in very small series. This process therefore involves a very high level of industrial and technological risk for the shipyard.

1. European networks for sea and river research

The European technological platform WATERBORNE is a forum where partners from the **maritime industry** (CESA-COREDES for shipyards, EMECRID for naval equipment suppliers, etc.) share a long-term vision of lead markets and innovation efforts, known as **Vision 2020**, in addition to a **strategic research agenda** describing the initiatives required in Research-Development-Innovation to achieve this vision.

The coordination action CASMARE (Coordination Action to maintain and further develop a Sustainable MAritime Research in Europe) is dedicated to the implementation of this strategic agenda for sustainable maritime research in Europe.

Requests for proposals are launched annually (with an average budget of €30 M) on topics originating from (or more or less based on) the Vision 2020 document, complemented by the subject area covered by the Framework Programme for Research and Technological Development (FPRTD) and the **Martec ERA-NET**[2] on **marine technologies** (equipment and services, naval architecture, environmental impacts, renewable energies, port operations) with an annual average budget of €8 M.

In parallel, **the PLATINA platform** was launched in June 2008 (grouping together 23 partners from nine countries[3]) to implement the Naïades programme, an initiative of the European Commission aiming at developing the use of **waterways** for transporting goods and improving the European inland navigation system, with regard to consistency, competitiveness and the environment. This platform covers 5 strategic domains: markets, fleet modernisation, employment and skills, the image of waterways, and infrastructures. The main purpose of the “fleet modernisation” section, led by Voies Navigables de France, is to improve logistics efficiency and performance levels in terms of energy-saving, the environment and the safety of transport on waterways. Experts from different partner organisations have drawn up a **strategic research agenda** for river transport by **the year 2020**. Secondly, these needs will be incorporated into a common research agenda shared with the WATERBORNE platform.

2. Germany, Norway, Sweden, Finland, Poland, France, Spain and Croatia.
3. Germany, Austria, Belgium, Croatia, Finland, France, Hungary, the Netherlands and Romania.

The European Commission is currently developing a strategic framework for future transport research, innovation and deployment, intended to ease the coordination of public and private research and innovation efforts throughout Europe. This framework will be presented in the form of a **strategic transport technology plan** integrating proposals for a set of leading-edge technologies, identifying the policies to be set up and the financial and organisational requirements connected to their implementation.

The first E-fishing symposium took place in May 2010 on energy economy for fishing boats and presented different innovative ship projects on an international level (European, North American, Australian and Japanese projects). This event also saw the launch of the European Fisheries Technology Platform (EFTP), the purpose of which is to **coordinate innovation actions in the field of fishing on a European level**: assessing halieutic resources and fishing technologies. Important works are underway, compiling existing studies, which will lead to the drawing up of research and development priorities for the years to come.

2. The R&D programmes of the major shipbuilding countries

Under the aegis of the "Ship of the future" Group of the Grenelle de la Mer, documents were collected in 2009 by the French Embassy services present in 5 major shipbuilding countries (Germany, Italy, the Netherlands, Norway and Japan). This information was complemented by data from other countries (Finland, Spain, Korea and China) and extended to river transport and fishing boats thanks to the experts of the "Ships of the future" roadmap and to bibliographical research conducted over the Internet. This collection of data highlights the following points:

- Research programmes are based on **ships of the future connected to** wider subjects such as **sustainable and intermodal transport** and **the exploitation of natural underwater resources**.
- The topic of **the environment (energy savings and reducing emissions)** is present in all R&D programmes within these countries. Research also involves security, safety and comfort, or the competitiveness of production methods.
- An **organisation for research within integrated approaches**: coordination of research, industrial and community stakeholders; coordination of support tools (research/testing means, industrialisation of new technologies, deployment of new ship supply infrastructures, specific regulations, etc.).

Appendix No. 1: Main regulations

The international shipping law is comprised of 4 pillars:

- The major conventions of the **International Maritime Organisation (IMO)** in terms of safety and the prevention of marine pollution: the SOLAS convention for the safety of life at sea, the MARPOL convention for the prevention of pollution from ships, the BWM convention on ballast water management, the AFS convention on anti-fouling systems, the SR convention on the sound recycling of ships and the STCW convention relating to the standards of training, certification and watchkeeping.
- The maritime labour convention of the **International Labour Organisation (ILO)**. This sets out seafarers rights to decent working conditions and fair competition conditions between ship owners.

Given their multiple updates, these conventions have been followed by more recent discussions on crew quality.

In order to enter into effect, these international conventions require ratification by a large number of signee States (30 to 50 States), which represents a very large share (25 to 50%) of the gross tonnage of the world's merchant fleet. Once adopted, the rule must be complied with by ships sailing under the flag of the signee countries and by other ships when navigating in the territorial waters of the signee countries.

International regulations of the IMO

CO_2	IMO regulations est up in july 2011. An energy efficiency design index (EEDI) is defined for some merchant ships, and will be in force in 2015.
SO_x	MARPOL: reduction up to 1.5% to 0.1% of sulphurs by 2015 in emission control areas ECA (English Channel, North Sea, Baltic Sea, US and Canadian.
NO_x	MARPOL: reduction of 20% by 1 January 2011 for all ships; reduction of 80% by 2016 in ECAs for new ships.
Particulate matter	No regulatory requirements planned.
Wastewater	Ships must be equipped with an approved wastewater treatment system. The most restrictive regulations: Alaska and the Baltic Sea (in particular for the treatment of nitrates and phosphates).
Ballast water	IMO convention of 2004: mandatory treatment of ballast water by filtration systems during loading and discharge phases; loading and discharge possible outside of the territorial waters of a State; port facilities for reception and treatment. This convention has not yet taken effect.

Waste	MARPOL Appendix V: discharge forbidden at sea or controlled according to the areas and types of waste at several nautical miles from the coast.
Anti-fouling paint	IMO convention of 2001: general ban on applying, as from 1 January 2003, anti-fouling products or systems containing TBT (tributyltin) on the outer surfaces of ships, so as to prevent the attachment of marine organisms; and as from 1 January 2008, mandatory requirement to remove coatings containing these substances or to cover them with an overlay countering their transfer to the aquatic environment. These rules have been pre-emptively applied in Member States of the European Union.
Ship recycling	The SR convention of the IMO has not yet taken effect. It will contribute to protecting the environment and increasing worker safety.
Safety	Marpol I: Phase-out of single hull oil tankers. Common structural rules for tankers and bulk carriers. Solas: structure, communication, fire protection, damage, return to port conditions in the event of damage (safe return to port). Regulations for nuclear-powered ships.

The Convention on long-range **transboundary air pollution**, signed in Geneva in 1979, in particular relates to reducing the effects of acid rain and preventing eutrophication by controlling sulphur, nitrogen oxides and VOC emissions (volatile organic compounds

French energy regulations	
LNG	It is forbidden to transport passengers over long distances using LNG. A risk analysis is required for passenger ships and distribution infrastructures.
Hydrogen (H_2)	The SOLAS Convention (international journeys, ships with a gross tonnage of more than 500) does not in theory allow for the use of H_2 on-board ships. Works are underway at the IMO regarding the use of gas (including hydrogen) in on-board motors, which could lead to the creation of an international code. The European directive 2006/137/EC forbids the use of any fuel with a flash point of less than 55 °C on-board river boats. Classification companies have drawn up recommendations for the installation of fuel cell systems with on-board hydrogen storage. Experiments and demonstrators have been produced on this basis: the "Protium" river boat in Birmingham, the "Zemship" passenger ship operating on the Alster Lake in the Hamburg region. Current regulations relating to shipbuilding do not tackle the issue of battery / H_2. Therefore, a navigation permit cannot be obtained by a shipyard for a ship using H_2.

European fishing regulations	
Tonnage	The Common Fisheries Policy (CFP) introduced a tonnage restriction to measure the fishing effort.
Fishing fleet	The size of European fishing fleets is controlled via a quota system, with each country being required to comply with power ceilings (kW) and ship volume limits (GT). The European Commission can forbid the use of certain fishing gear.
Fishing quotas	The CFP determines the list of stocks (species and zones) for which catches must be monitored (not all stocks are subject to quotas). TACs (Total Allowable Catches) are therefore determined for each species and fishing zone, and are negotiated each year and distributed between Member States. Each country is attributed a precise fishing quota and catches must be recorded.

River regulations	
Construction and equipment	The directive EC/2006-87 is one of the general documents concerning the technical provisions for building and fitting out river boats. This directive is complemented by the ADN[4] for boats transporting dangerous goods. In this event, the boat must be classified and comply with the societal classification regulations.
Composition of crews	French decree No. 1991-731 defines the national regulations regarding the composition of crews and the operation of river boats.
Pollution emissions	Directive EC/97-68 defines the rules concerning pollution emissions from motors installed on-board river boats.

In addition to this general regulation, specific enforcement regulations exist, which may set specific provisions or require specific equipment (Traversée de Paris, Canal de Tancarville, Golf de Fos, French orders 2007-01-10 and 2007-08-30 for access to Port 2000, etc.).

4. ADN (European agreement concerning the international carriage of dangerous goods by inland waterways).

Appendix No. 2: Benchmark for civil shipbuilding R&D programmes from some European and Asian countries

I. Countries in Northern Europe

Countries in Northern Europe (Norway, Denmark, Ireland and the United Kingdom) have ambitious R&D programmes with regard to **fishing** technologies and the preservation/transformation of catches for their flottilla characterised by **large-scale factory ships**, more numerous than in the South of Europe, where traditional coastal ships are predominant and occupy both an economic and social role.

It should be noted than the majority of these projects are currently concentrating on **equipment** (fishing gear, propeller, etc.) or on **optimising a given compartment of the ship** (ram bow, preservation system, etc.). Few innovative design projects involve a small-scale (up to 24 m) ship in its entirety, whereas for large-scale ships (+40 m), the high sums at stake enable the financing of upstream R&D works.

Finland

Two support programmes coexist:

- **The shipbuilding innovation aid programme**

Boasting a budget of €18 M in 2008, support was concentrated on the "Oasis of the Seas" cruise ship, a passenger boat delivered in 2010 with the world's largest tonnage.

In 2010, €39 M was allocated to a dual fuel ferry (diesel/LNG) with €11 M allocated as an innovation aid and €28 M as investments for protecting the environment.

- **The "MERIKE" maritime R&D programme**

This programme, managed by the TEKES (financing agency for technology and innovation) has a budget of approximately €10 M/year.

Norway

Support for maritime research and innovation has greatly increased over the last few years to support the building and repair of specialised ships: chemical tankers, trawlers, reefers, supply barges for offshore facilities, ultrafast catamarans, cable layers and seismic exploration vessels.

- **The MAROFF maritime R&D programme (Maritime Activities & Offshore Operations)**

This programme, boasting a budget of €40 M from 2005 to 2009 and in collaboration with shipyards, equipment manufacturers, ports and ship owners, supports:

– reducing **emissions** in all segments of the naval industry, targeting zero sea and air emissions (gas, noise, etc.). Research is in particular based on the removal of NOx and renewable and alternative (LNG) energy sources.

– the sustainability of **offshore** marine operations, in particular in the arctic ocean: floating structures, LNG transport technologies, LNG storage terminal.

- **The SMARTRANS programme (Intelligent Freight Transport**

This programme, boasting a budget of €8 M/year, supports the industry, freight users and public authorities committed to

– reducing transport costs;

– transferring road transport to sea or rail transport;

– increasing loading/unloading speeds.

Furthermore, ship owners can allocate one third of their tonnage tax to environmental innovations.

Germany

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In addition to the programmes lead upon the initiative of the different states, three federal R&D support programmes are underway, financed by the Federal Ministry of the Economy and Technology (BMWi), which enables the optimal coordination and management of fundamental research works, applied research works and industrialisation works. The desire is to become a leader in the production of **complex ships**.

• The "Shipping and maritime technology for the 21st century" programme

This naval R&D support programme, launched in Germany in 2005, benefited from €153 M until the year 2010. It has been renewed for the period 2011-2016. The priorities are:

– **Environment**: energetic efficiency, reducing pollution, improving the full life cycle;

– **Shipping**: innovative transshipment technologies, ships adapted to suit river and coastal navigation for improved integration into multimodal transport chains, for use in shallow water and while limiting pollution and the degradation of shorelines;

– **Natural underwater resources**: developing technologies to explore, recover and transport underwater hydrocarbon deposits in an ecological manner.

• Support for innovation in shipbuilding

The support for innovation in shipbuilding programme set up in 2006 has been increased by 30%. The financial support (budget of €45 M between 2009 and 2012) aims at reducing the technological and financial risks connected to building prototypes which, in this field, must find a commercial use. The following are supported: new ship types or modules, new ship systems or components, new shipbuilding methods (mass production) to reduce costs and increase productivity.

Innovative character is measured in relation to the technological progress made in other EU countries.

Only shipyards with their head office and production site in Germany, processing orders or parts of orders involving eligible innovations within the scope of this programme in Germany, can claim this support. This support can cover, on the one hand part of the development and production costs, and on the other hand any subcontracting costs - if connected to the innovative aspect of the project. Support can total a maximum of 20% of these costs and is allocated in the form of a refundable grant under certain conditions. More particularly, it must be refunded if the innovation supported is reused, if it totals more than 200,000 euros and if it exceed 1% of the price defined in the order contract fort eh ship(s) (in the event of an innovative method: 3%).

• Isetec II support for port innovation

This R&D programme benefits from €30 M from 2008 to 2011.

The Netherlands

Specific programmes financed by the Ministry of Economic Affairs aim at stimulating R&D and innovations, encouraging exportations, promoting the link between fundamental research (universities, centres of research) and applied research (SMEs and large enterprises):

• Support for innovation in shipbuilding

This programme, boasting a budget of €20 M from 2007 to 2009, aims at improving industrial shipbuilding methods; innovative projects involving the industrial application of improved or new methods or products for shipbuilding or renovation.

• The sea transport innovation aid programme

Boasting a budget of €39.5 M from 2007 to 2011, this programme targets two niche markets:

– **the offshore industry** (production of gas and oil under extreme conditions): liquefied natural gas (LNG) supply chain, floating structures;

– **special complex ships**: dredging ships, patrol ships, short-distance ships and oversized yachts.

It is structured around an **integrated approach** (Clean Ship Concept) for sustainable solutions to the environmental problems connected to marine activities, i.e.:

– the involvement of all concerned **stakeholders**: marines, ship owners, shipbuilders, elected officials, etc.;

– combinations of different **support tools** (control, financial instruments, logistics solutions, training programmes, communication, etc.);

– the development of **new technologies**: ballast water treatment systems, silicon-based non-toxic anti-fouling paints, selective catalytic reduction systems for NOx, lubrication by air, solar power, etc.

• **The river transport innovation aid programme**

This river transport innovation aid programme boasts a budget of €10 M over 4 years.

The Netherlands are at the very top in terms of innovations, in particular with regard to **energy efficiency** and computer aided design, which are tested on showboats or marketed with spectacular results announced by manufacturers:

– The Dutch "EcoFlow" programme targets the launch of a **"show" boat** for alternative technologies in river navigation by the year 2012: navigation optimisation software (trajectory calculation, autopilot) and optimisation software for on-board energy consumption (energy saver), new blades for navigation in shallow waters, gas-electricity propulsion, composite materials, etc.

– Another programme targets the development of **narrow gauge, flexible, multi-purpose or specialised barges** (lightened units for bulk, self-unloading units, tankers, containers for fruits, etc.) adapted to suit the **medium-size** transborder water network and capable of being assembled into a train on broad gauge networks. The objective is also to reduce construction costs (in particular by removing the habitation module) and operating costs (long motor life, etc.). This programme corresponds to two projects, known as WATERTRUCK and INLANAV respectively, which are European projects (France, Belgium and the Netherlands) both financed by the Interreg programme. French businesses will probably take part in the planned tests.

– Tests are currently taking place in the Netherlands regarding the **use of LNG** for inland navigation. The "Argonon" project is preparing a tanker, which will probably represent the first river unit using LNG to enter into operation in September 2011. On-board storage shall be large enough to perform a Rotterdam-Basel return trip without any intermediary refuelling. As from its commissioning, it shall be compatible with the CCR IV regulations entering into effect as of 2016. This project, launched two years ago by a Dutch ship owner (with the collaboration of an energeticist, design office, province and the boatman syndicate) benefits from a European Interreg grant of €1.2 M in addition to aid from the Dutch Ministry of Transport within the scope of a support programme for innovation in river navigation. Furthermore, the Ministry of **infrastructures** and the environment has granted an allowance of €500,000 for the construction of an **LNG distribution network** for river navigation (5 refuelling stations are planned for the next 5 years).

2. Countries in Southern Europe

Italy

Several national R&D support programmes are underway, parts of which more particularly concern the naval industry. Three main markets are targeted: high-tech oceanographic boats, pleasure boats and sustainable fishing boats for the Mediterranean Sea.

• **The RITMARE research programme for sea transport**

Defined by the national platform grouping together all maritime stakeholders, consistent with the directions taken by the European WATERBORNE platform, the "Maritime technologies" programme represents an investment of 160 million euros (80 million euros of which originates from public financing), distributed over 5 fields of research:

– **Security, safety and survivability** (€25 M): preventing fires and accidents on-board; structural integrity of the ship; the ship's capacity to navigate under difficult conditions; feasibility assessment of on-board instruments; management of emergencies and ship evacuation.

– **Environmental sustainability** (€40 M): reducing air and sea emissions; reducing CO_2 production; reducing noise pollution into the air/water and waves generated; solutions for passing from traditional fossil fuels to liquefied gas and renewable energy sources and for the energetic transformation of on-board waste; "green" retrofitting techniques, clean destruction techniques.

– **Comfort** (€35 M): monitoring and predicting ship movements on choppy seas, integrated control of the ship's movements, position and route; predicting the noise and vibrations induced on the ship's structures; actively controlling structural vibrations and air noise; modelling the human perception of comfort factors; managing flow and the quality of air on-board; predicting and controlling electromagnetic emissions on-board.

– **Competitiveness** (€20 M): planning and reducing costs during the ship's life cycle; initial and further training for crews with regard to new technologies; optimising the logistics chain; optimising the ship-port interface and on-board loading environments; communication and decision aid instruments.

– **Innovative components, materials and methods** (€40 M): materials with high mechanical strength, fire resistance, sustainability and aesthetic properties; luxury materials (wood, leather, textiles, etc.); distortion phenomena caused by weld contractions and consequent re-work activities; complexity of the design and production method relating to the introduction of innovative components and materials; innovative materials and devices for personal and/or mutual protection for maintaining safety at sea; managing the end of life cycle of nautical and naval products so as to maximise their reuse and recycling.

• **The INDUSTRIA 2015 programme**

This R&D support programme concerns sustainable mobility for 2008-2010:

– **Innovation aid for competitive shipyards** (€27 M/year);

– **Energy-efficient, ecological ships**, both easy to maintain and equipped with navigation systems, automation systems and smart control systems (€4 M/year);

– **Managing intermodal transfer** for passengers and/or goods at connection points between "the last nautical mile" and the "first terrestrial mile" integrated with security systems for the port, ships, structures and means for moving passengers and/or goods (€25 M/year).

Spain

Shipyard innovation aid, boasting a budget of €20 M/year since 2006, has been extended until the year 2011.

The "PROFIT" R&D programme (national shipping) has a budget of approximately €7 M/year from the Ministry of Industry and Commerce.

A specific R&D programme has been in place since 2007 for fishing boats, with a budget of €37 M. An ambitious project has been launched entitled "Peixe Verde": a **demonstration and test fishing boat** for testing new technologies at sea (fishing gear, propulsion, life on-board, etc.).

3.Countries in Asia

Japan

Support for marine RDI is structured around the **"Cool Shipping" technology programme**. This programme of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) benefits from a budget of €7.3 M allocated in 2009. It aims at improving the energy efficiency of ships (target of reducing consumption by 30%), improving the competitiveness of the national industry, and reducing CO2 and NOx emissions in the field of shipping.

Several projects for ships of the future and floating structures have been launched by the National Maritime Research Institute (NMRI) in cooperation with Japanese industrialists:

– The **Mega-Float**, a vast floating structure capable of housing various facilities (e.g.:

floating airport, nautical base, port structure) while remaining resistant to earthquakes and being environmentally friendly. To this date, 5 such floating structures have been built in Japan.

- The **"Super Eco Ship 2030"**: the objective targeted is to reduce CO2 emissions by 69%, in particular via a lightened hull and a propulsion system using fuel cells and renewable energies (solar power, wind power), while simultaneously improving working conditions and on-board living conditions for crews. This ship can be connected to the land power grid when docked. A study is currently being conducted in the port of Osaka for building the infrastructures required for this connection.
- The design of a **cargo sailboat** measuring 300 metres in length, the diesel propulsion system of which will be assisted by nine sails made from carbon fibres that can be retracted for manoeuvres at port. This project should be completed within the next five years.
- The **"zero emission" ferry** measuring 30 m in length, capable of accommodating 800 passengers, will operate via rechargeable lithium-ion batteries. It should be brought into operation by the year 2015.

South Korea

As the world leader in shipbuilding, South Korea produces ships of all types, with the single exception of cruise ships, which are the speciality of European shipyards. South Korean shipyards are specialised in cargo ships, in particular container ships, ahead of their Japanese and Chinese competitors.

Priority is placed on developing green technologies and new "smart" ship concepts. Several promising sectors have been identified:

- in the short-term: ecological paint, equipment for treating ballast water, motors with reduced emissions, equipment for reducing pollution, the shape of the energy-saving ship, the ecologically-driven ship (LNG);
- in the long-term: convergence technologies (IT + ET), extreme ocean plant, the carbon capture and storage power plant (CCS plant).

China

China has a high-power marine industry comprised of shipyards for building and repair works and giant ports to cover the needs of its home market and for export. It mobilises public credit and foreign financing, in particular Japanese and Korean financing, to modernise and rationalise its industry and open marine academies. Civilians and military are closely intertwined.

The Chinese have encountered success in less sophisticated ships, where labour costs are not as high: petrol tankers, bulk carriers, container ships. Chinese shipyards are also becoming real competitors for passenger ships, roll-on/roll-off ships and very high-tech ships such as methane ships or offshore floating structures, by importing design methods and key equipment to complement their production chains, or by benefiting from technology transfers from joint ventures with Japanese and Korean companies, or by buying out foreign equipment suppliers (e.g.: the motor manufacturer Baudouin).

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