Indicator Report

Marine Research and Innovation 2018

Flanders Marine Institute (VLIZ)

Colophon

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1. Foreword

Why should we invest in marine research and innovation?

Over the last decade, man has increasingly turned to the sea for some of the major societal challenges such as food provision and energy supply. Indeed, the seas and ocean offer a plethora of resources and services. In this context, one immediately thinks of traditional maritime sectors such as fishing and shipping, however, in recent years a number of new sectors have emerged rapidly: large-scale aquaculture, seabed mining, the production of fresh water from the sea by desalination and offshore energy production. Still, the comprehensive expansion of activities at sea does not come without a price. The decline of fish stocks and the occurrence of marine litter in the most remote parts of our ocean are just two symptoms which indicate that man has encountered the limits of the marine system. One would almost forget that the seas and ocean also provide less tangible services that are nevertheless vital for life on earth: e.g. regulating the climate, buffering climate disruptions and oxygen production.

This 'blue (r)evolution' of recent years provides the marine research and innovation landscape with significant challenges. The required knowledge base must be established to allow the development of underpinned threshold values and efficient monitoring strategies for a sound policy and management of our marine environment. Intensive innovation is needed to achieve a more efficient and sustainable use of the seas and ocean. In terms of fundamental research, climate change is an important driver to further elucidate the interactions within the marine system. Moreover, scientists have a crucial role to play in training the next generation of marine and maritime experts. These experts will be essential to meet the increasing demand for such profiles on the labour market. These are just a few of the major challenges marine researchers and innovation actors are facing. In this regard we haven't even mentioned the steps that have to be taken to protect low-lying coastal areas against flooding. Hence, it is obvious that the role of marine research and innovation will only gain importance in our society in the future.

Belgium only disposes of a very small part of the North Sea. Can we make an international contribution to science with regard to coasts, seas and oceans?

It is true the Belgian sea area is the size of a thumbnail compared to the vastness of the world's oceans. However, the Belgian part of the North Sea is one of the best studied marine areas in the world. After all, we can rely on a very long marine research tradition that originated off our coast. As such, it is no coincidence that the *Laboratoire des Dunes* of professor Pierre-Joseph Van Beneden from Leuven (1809-1894), is considered to be the first marine station in the world.

However, it is a fallacy to deduce the size of the current marine research landscape from the size of our marine area. At present, 114 marine research groups associated with universities and scientific institutes are actively involved in this research, representing more than 1,600 people. Over the years, these groups have developed a very diverse expertise that is no longer restricted to the Belgian part of the North Sea. On the contrary, more than three quarters of the marine research currently takes place in foreign or international marine and coastal areas. The multitude of research topics is downright impressive. We hold expertise on mangrove areas in Asia and Africa, international legislation on underwater heritage as well as on ecosystem services in European estuaries. Moreover, our research contributes to the navigability of the Panama Canal. It is therefore not surprising that Belgian marine researchers score far above average in terms of international cooperation, with a robust anchoring in international networks such as IOC-UNESCO, ICES, OSPAR and the European Marine Board. The scientific output of the marine research groups is comparable to those of international maritime institutes, with a citation impact well above the global standard. Hence, it can be stated that the Belgian and Flemish marine research landscape is punching above its weight, with a strongly international focus.

Does it concern an artificial collection of marine research groups or do they constitute an integrated research and innovation community?

The 114 marine research groups in Flanders and Belgium are active in no less than 19 different research disciplines, ranging from biological and earth sciences to disciplines such as civil engineering and history and archaeology. As the coordination platform for marine research, Flanders Marine Institute (VLIZ) plays a central role in facilitating cooperation across the research fields. Of course, it would be a bridge too far to state that each of these groups can work together, but it is true that multidisciplinarity is embedded in marine research. This is partly due to the intrinsic coherence of the marine system. For example, the implementation of an offshore aquaculture project does not only

require a biological perspective, but also oceanographic (currents and waves), geological (seabed), physicochemical (temperature and seawater composition), engineering (mechanical load, anchoring of the structure) and even policy (maritime legislation) knowledge and information.

In addition, the multidisciplinary approach within the marine research community is also the result of a practical necessity. Oceanographic research is expensive and poses considerable challenges, both technological as in terms of health and safety. Consequently, there are only few research vessels that start multi-day campaigns with only one research group on board. The same sediment sample of the seabed is not only useful for a geologist to determine the sediment grain size, but can also provide information to the biologist about the benthic organisms present, to the engineer about geotechnical parameters or to the biochemist and microbiologist about bio-chemical processes in the pore water. Marine research is de facto a multidisciplinary matter and the collaboration within this landscape is also apparent from the figures about joint publications and joint projects of different research groups across various disciplines.

In recent years, the marine research community has grown steadily. Is there a risk of a decline in this landscape?

Since the first inventory of the marine research landscape in 2013, a significant growth was observed from 82 groups with almost 1,100 employees to 114 groups representing more than 1,600 people in 2018. It should be mentioned that this growth is partly artificial as we have gradually improved the methodology for mapping the marine research field. Still, we were also able to detect an actual increase of this community, including a so-called 'Blue Growth effect'. The latter is related to research groups that have expanded their expertise to the marine domain due to emerging maritime sectors such as the offshore wind energy. An illustrative example of this evolution is a group that initially developed its research on vibrations in aircrafts but successfully transposed this expertise to the structural monitoring of offshore wind turbines. In materials research, groups have also gradually entered the marine field due to the challenges related to large-scale projects at sea (corrosion, self-healing concrete, etc.).

Nevertheless, there are also research funding parameters which indicate that certain segments of the marine research landscape come under pressure. In the first place, this concerns funding channels for fundamental research at universities. As far as the federal research programme (BELSPO) is concerned, this decrease can be attributed to a policy choice to reduce the programmatic funding relevant to marine research. However, we cannot ignore the significant reduction in marine FWO-resources (Flemish funding instrument for fundamental research). One can assume that the downward trend in the overall success rate plays a role in this decline, but it is unclear to what extent other factors (excellence, policy choices of universities, an evolution towards applied research, etc.) also exert an influence. It is essential to continue investing in fundamental marine research in the long term. After all, this is the breeding ground from which new applications with valorisation potential emerge. Think, for example, of the research groups that have invested for years in fundamental deep-sea research and are now developing the knowledge base for a sound policy and management in the context of deep-sea mining. Blue skies research on the historical ecology of our coastal and marine areas could suddenly be valorised when threshold values had to be determined for the European Marine Strategy Framework Directive. The strengthening of the fundamental segment of the marine research field will possibly be the greatest challenge in the coming years. Hence, this will be particularly important as the university associations accommodate the majority of the marine research capacity in Flanders and Belgium.

Are we succeeding in valorising marine research in innovation projects and commercial applications?

Over the last 10 years an increase was observed in the funding for marine projects in channels focused on applied research and innovation. A growing share of this funding is taken up by projects involving private companies. At the European level, this evolution can be attributed to the policy choice to preferentially focus on emerging maritime sectors, the so-called Blue Growth Strategy (COM (2012) 494). The Government of Flanders also decided to invest in marine and maritime innovation, first by setting up an innovative business network Offshore Energy and subsequently by establishing a fully-fledged maritime spearhead cluster, the Blue Cluster.

A clear success story can be distilled from the funding time series of marine research and innovation projects. About 10 years ago, the first Blue Energy projects were mainly financed by Flemish resources. Between 2007 and 2013, European FP7-funding for Blue Energy remained limited to 'only' 2.5 million euro in Belgian partner budgets. However, the efforts at the regional level resulted in a multiplier effect in the Horizon 2020-programme (2014-2020), where over 20 million euro of the Blue Energy budget was allocated to Belgian and Flemish partners in only three years' time. Moreover, at the same time a full-fledged offshore sector developed within Flanders which, according to a recent study, will lead to an employment of 15,000 to 16,000 jobs by 2020.

With the advent of the Blue Cluster, it will be important to consolidate these strengths, but also to develop new success stories. In this context, obvious opportunities are present to match the considerable scientific knowledge in the field of hydraulic engineering and coastal ecosystems with the extensive industrial expertise of Flemish dredging companies. In addition, emerging fields such as marine biotechnology, the development of innovative sensors, autonomous vessels and robotics also hold a promise of valorisation. It is to be expected that in the coming years a further alignment will occur between the marine research field and the maritime business community, not only at the level of research and innovation but also with regard to marine and maritime training. The latter aspect will be essential in order to ensure the inflow of specialised profiles, required by the maritime sector.

What does the future hold for the marine research and innovation field?

It is generally accepted that the importance of marine research and innovation will increase significantly worldwide. The UN is currently preparing a Decade of Ocean Science for Sustainable Development that will run from 2021 to 2030. A maritime region such as Flanders cannot miss this opportunity. As such, it will be important to sufficiently strengthen the Flemish marine research and innovation field in order to be prepared for the challenges and opportunities that lie ahead. In this context, the establishment of the Blue Cluster is already a game changer for applied research and business-driven innovation with regard to the coast and sea.

However, the figures with regard to marine R&D-funding also indicate the need for a comparable reinforcement of marine fundamental research. A quantum leap could be made by investing in earmarked marine research funding linked with a coherent research strategy and vision. It should be clear that this would not be an empty investment but a long-term guarantee of continued excellent marine research and innovation push from knowledge institutes. This strategy will also ensure that we will continue to excel at international and European level, also with regard to participation in projects and the acquisition of project funding. Finally, this approach fully valorises the investments already made in large-scale marine research infrastructure.

If the government continues to invest in marine research and innovation, we may cherish the ambition to further evolve into an absolute spearhead of the Flemish knowledge economy.

Prof. Dr. Jan Mees
Flanders Marine Institute (VLIZ)

2. Policy context marine[1] research and innovation

The policy with regard to marine research and innovation is developed on different levels. In the following section, a concise overview is given of the most relevant actors on the international, European, Belgian and Flemish level.

2.1 International

The global dimension of the seas and ocean requires international coordination and a strategy in order to understand large-scale marine processes and phenomena. Therefore, the Intergovernmental Oceanographic Commission (*IOC*) was established within the United Nations Educational, Scientific and Cultural Organisation (*UNESCO*) as the competent organisation for marine science. IOC has the mission to promote international cooperation and to coordinate research programmes in research, services and capacity-building, in order to learn more about the nature and resources of the ocean and coastal areas. This knowledge should also be applied for the improvement of sustainable management and, sustainable development, the protection of the marine environment, and the support of the decision-making processes of its Member States.

The Ocean Sciences Section of IOC includes several programmes and initiatives (see *overview*), including the Global Ocean Science Report (*GOSR*), which provides an overview of the current status of the ocean sciences worldwide (*UNESCO 2017*). Furthermore, IOC also comprises sections with regard to *Capacity development*, *Tsunami warning* and *Oceans observations and services* which *inter alia* include the Global Ocean Observing System (*GOOS*) and International Oceanographic Data and Information Exchange Programme (*IODE*). IOC is also responsible for the development and coordination of the *Decade of Ocean Science for Sustainable Development* which will run from 2021 to 2030.

In addition to IOC-UNESCO, there are several entities within the UN with ocean-related activities that directly or indirectly influence global marine research. These entities are clustered in the *UN-OCEANS-network*.

In September 2015, Member States of the UN agreed on a set of Sustainable Development Goals (*SDGs*) as part of the *2030 Agenda for Sustainable Development*. *SDG 14 – Life Below Water* specifically deals with the ocean and one of its objectives is to increase scientific knowledge, develop research capacity and transfer marine technology for the benefit of the ocean.

In addition, there are various international organisations outside the UN context which are directly or indirectly relevant for the global component of marine research. These organisations can be involved in different aspects ranging from policy, coordination, advice, funding to the actual execution of research in the marine domain (table 1, non-exhaustive list)

Table 1. Global marine research networks, organisations and programmes (non-exhaustive list).

Theme	Organisation	Role
Policy advice / fisheries / use of the sea	International Council for the Exploration of the Sea (*ICES*)	A global organisation developing science and advice on the sustainable management of the oceans.
Policy advice	Organisation for Economic Co-operation and Development (*OECD*)	This organisation *inter alia* works on global reviews of marine biotechnology (*OECD 2013* and *OECD 2017*) and the future use of our ocean (*The Ocean Economy in 2030*) and the associated innovation-aspect.
International coordination of marine research	Scientific Committee on Ocean Research (*SCOR*) of the International Science Council (*ICSU*)	This organisation attempts to answer interdisciplinary ocean-related scientific questions and is at the heart of a number of large-scale marine research projects (e.g. *IMBER*, *SOLAS*, *GEOTRACES*, *IOQE* and *IIOE-2*).
International coordination of marine research	Census of Marine Life (*CoML*)	An international initiative mapping the diversity, distribution and abundance of marine life.
Ocean observation	Partnership for Observation of the Global Oceans (*POGO*)	A world-wide cooperation for a sustainable, state-of-the-art global ocean observing system that serves the needs of science and society.
Coordination of marine research and education	World Association of Marine Stations (*WAMS*)	A global network which clusters existing marine stations to foster collaboration.

[1] Unless explicitly stated otherwise, the term 'marine' is used in this report in its broadest sense, including maritime, estuarine and coastal aspects.

2.2 Europe

EUROPEAN COMMISSION – GENERAL POLICY CONTEXT REGARDING RESEARCH AND INNOVATION

The Directorate General for Research and Innovation (*DG R&I*) of the European Commission (EC) is competent for the European research and innovation policy and is responsible for the coordination of these activities. Important concepts and strategies of this policy are *inter alia* Open Science and Open Innovation (*Open innovation, open science, open to the world – A vision for Europe, 2016*), the *Innovation Union* (a strategy to facilitate innovation), the *European Research Area* (coordination of research programmes) and the establishment of a European Innovation Council (*EIC*) pilot. In addition, DG R&I is also responsible for the *funding* of research and innovation, *inter alia* by means of European framework programmes such as the current *Horizon 2020* (2014-2020) and the upcoming *Horizon Europe* (2021-2027) which is currently being conceived (see **European funding instruments for marine research**).

For the implementation of its policy, DG R&I collaborates with various departments of the EC and agencies such as the European Research Council Executive Agency (*ERCEA*), Research Executive Agency (*REA*), Executive Agency for Small and Medium-sized Enterprises (*EASME*), Innovation and Networks Executive Agency (*INEA*), Joint Research Centre (*JRC*), etc.

RESEARCH AND INNOVATION WITHIN THE EU INTEGRATED MARITIME POLICY – BLUE GROWTH STRATEGY

Within the EC, the Directorate General for Maritime Affairs and Fisheries (*DG MARE*) is responsible for the development and implementation of the European policy with regard to the maritime domain and fisheries. An important policy line within this Directorate General concerns the so-called *Blue Growth Strategy* (COM (2012) 494) which is part of the Integrated Maritime Policy (*IMP*) (COM (2007) 575). Blue Growth is the long term strategy to support sustainable growth in the marine and maritime sectors as a whole. Research and innovation are key drivers within this policy and were further developed in the following communications: A European strategy for marine and maritime research (COM (2008) 534) and Innovation in the Blue Economy (COM (2014) 254). In the Blue Growth calls, as well as in other parts of Horizon 2020, funding for marine research and innovation is distributed in cooperation with DG R&I.

In line with the so-called *Sea Basin Regional Strategies* of the IMP, a number of marine research and innovation strategies and initiatives are being developed, targeting a specific area:

- The *Galway Statement (2013)* on Atlantic Ocean cooperation has led to the establishment of the Atlantic Ocean Research Alliance (*AORA*);
- The *Belém Statement (2017)* builds on the Galway Statement (2013) and initiates collaboration on ocean research and innovation between the European Union, Brazil and South Africa;
- *BLUEMED* is a research and innovation initiative that aims at stimulating the Blue Economy in the Mediterranean Sea by enhanced collaboration;
- *BONUS* is an article 185-initiative of the EU Convention (TFEU) which elaborates a research and innovation programme for the Baltic Sea. At present, preparations are being made in the BANOS CSA to extend this programme to the North Sea basin.

Marine Knowledge 2020 (COM (2010) 461) constitutes an important element within the IMP. This initiative aims at centralising and disclosing marine data and knowledge from different sources for end users. The European Marine Observation and Data network (*EMODnet*) uniformly discloses the fragmented marine data in a web portal. More recently, the European Ocean Observing System (*EOOS*) was established which takes on a coordinating role to streamline the different European initiatives on ocean observation. Besides the above mentioned initiatives, there are several other European marine data and observation portals. An overview is given in *McMeel and Calewaert (2016)* and *Holdsworth et al. (2017)*.

In 2014 the European council has approved a *Maritime Security Strategy*. Its primary objective is to improve the security at sea by creating a common framework for all involved national and EU entities. In this context an *action plan* was drafted which also addresses research and innovation (e.g. the elaboration of a joint civil-military research agenda for maritime security research).

EUROPEAN FUNDING INSTRUMENTS FOR MARINE RESEARCH

European Commission

The EC disposes of various instruments for the funding of research, depending on the objective, partnerships, budget, etc. (see overview in *Pirlet et al. 2015*). Important funding mechanisms for the current marine research community are:

- *Horizon 2020* (2014-2020), which included marine research as a transversal priority;
- The Structural Funds, including the European Regional Development Fund (*ERDF*) which finances the Interreg programme (III, IV, V);
- The European Maritime and Fisheries Fund (*EMFF*) (2014-2020), in support of the Common Fisheries Policy (CFP) and the IMP;
- The Programme for Competitiveness of Enterprises and SMEs (*COSME*) (2014-2020).

In addition, there are the so-called ERA-NET Cofunds which are (partly) funded within Horizon 2020, launching joint calls for transnational research and innovation in areas with significant added value for Europe. Several of these ERA-NET Cofunds address a marine theme (e.g. *Martera Cofund* on marine/maritime technologies, *OCEANERA-NET Cofund* on Ocean Energy, or the *ERA-Net Cofund on Blue Bioeconomy*). Finally, the European Investment Bank (*EIB*) *inter alia* also invests in large-scale research infrastructure.

JPI Oceans

Joint Programming Initiatives (JPI) are European initiatives which aim at coordinating national (or regional) research and innovation programmes and pooling national (or regional) funding to efficiently use the available resources. Since 2008, ten JPIs have been launched, including the JPI on Healthy and Productive Seas and Oceans (*JPI Oceans*), which has published its *Strategic Research and Innovation Agenda (2015-2020)* in 2015. Several joint actions with regard to marine themes have been identified, within which research projects are funded.

EUROPEAN COLLABORATION CONCERNING MARINE RESEARCH INFRASTRUCTURE

Marine research requires specific and often expensive infrastructure. Hence, several European initiatives facilitate collaboration with regard to marine research infrastructures in order to optimise their use. The European Strategy Forum on Research Infrastructure (*ESFRI*) supports a coherent and strategic approach to the European policy on this infrastructure. Within the ESFRI-context, several pan-European infrastructures have already been established, four of which are of particular importance for marine research in Flanders and Belgium: the Integrated Carbon Observation System (*ICOS*) and more specifically the Ocean Thematic Centre (OTC), the virtual laboratory for biodiversity research (*LifeWatch*), the European Marine Biological Resource Centre (*EMBRC*) and the European Plate Observing System (*EPOS*). In addition, there are a number of dedicated marine ESFRI-initiatives without Belgian or Flemish participation: e.g. *EMSO*, *Euro-Argo RI*, *KM3NET* and *Danubius-RI*. The Belgian Science Policy Office (*BELSPO*) covers the annual Belgian contribution for the ESFRI-infrastructures, as well as the federal participation. Since 2018, the Flemish participation in large-scale international research infrastructure is facilitated by the FWO-call '*International Research Infrastructure*'.

In addition to the aforementioned collaboration in an ESFRI-context, several European initiatives exists to stimulate cooperation with regard to marine research infrastructure. In this regard, *ERVO* unites the operators of European research vessels. Within the projects Eurofleets and *Eurofleets 2* a common framework was established to coordinate the transnational exchange of ship time (and the associated infrastructure). Furthermore, initiatives such as *EMODnet*, *EOOS* and *Copernicus Marine Environment Monitoring Service* ensure the alignment on the European level with regard to marine observation and data infrastructure (see also above). This coordination is further elaborated in EU projects such as *JERICO-NEXT* (collaboration with regard to coastal observatories), *Atlantos* (Optimising and Enhancing the Integrated Atlantic Ocean Observing Systems), *Hydralab+* (adaptation for climate change) and *Seadatanet*/*Seadatacloud*.

An overview of the available marine research infrastructure in Europe is given in the *infrastructure database* of EurOcean.

EUROPEAN NETWORKS WITH REGARD TO MARINE RESEARCH AND INNOVATION

In addition to the organisations, entities and initiatives mentioned above, there are several consortia and networks representing (parts of) the European marine research and innovation community. The European Marine Board (*EMB*) works at the interface between marine research and marine-maritime policy, developing common positions on research priorities and strategies for European marine research, by means of amongst other *Position Papers* and the so-called *Navigating the Future* series. The *EurOCEAN conferences* provide a forum for the marine and maritime research community and wider stakeholders to interface with European and Member State policymakers and strategic planners. In the context of these conferences, the European research community has contributed to shaping the European vision for marine research through various declarations such as the *Rome Declaration 2014* on the relationship between Ocean Sciences and Blue Growth.

Furthermore, there are several examples of (thematic) partnerships between innovation and research institutes of which the European Marine Research Network (*EUROMARINE*), the European Fisheries and Aquaculture Research Organisation (*EFARO*), the European Aquaculture Technology and Innovation Platform (*EATIP*), the European Global Ocean Observing System (*EuroGOOS*), the European Network of Marine Research Institutes and Stations (*MARS*), the *EU Technology Platform Waterborne* and *EurOcean* are just a few.

2.3 Belgium/Flanders

DIVISION OF COMPETENCES REGARDING SCIENTIFIC RESEARCH AND INNOVATION

The division of competences with regard to the scientific research and innovation in Belgium is stipulated in the law of 8 August 1980 (*bijzondere wet tot hervorming der instellingen*). Article 6bis of this law defines that the communities and the regions are competent for scientific research within the scope of their respective powers, including research carried out in the context of international or supranational agreements or acts. Furthermore, this law also stipulates the competences of the federal government with regard to this matter. The primary competence for scientific research and innovation lies with the communities and regions. The communities are responsible for all personal matters, cultural matters and education and training. The regions are competent for matters related to the fields of economy, energy, public works, the environment and transport. Contrary to the other regions, Flanders has opted to combine the communal and regional competences (see **The Flemish policy context for science and innovation**).

The coordination of the cooperation between the different policy levels is carried out by the Interministerial Conference on Science Policy (*IMCWB*).

FEDERAL SCIENCE POLICY

The Belgian Science Policy Office (*BELSPO*) supports the science policy of the federal government. BELSPO is responsible for the management of *research programmes* in support of policies with regard to sustainable development, combating climate change, biodiversity, energy, health, mobility and the information society. The Belgian Research Action through Interdisciplinary Networks (*BRAIN-be*) and the Interuniversity Attraction Poles (*IUAP*) (in 2017 replaced by the Excellence of Science (*EOS*) programme of FWO and FNRS) are of primary importance for the funding of marine research.

In addition, the federal science policy manages the Belgian contribution to the European Space Agency (*ESA*). Furthermore *10 federal scientific institutes* are part of BELSPO. In this regard, the Royal Belgian Institute of Natural Sciences (*RBINS*), the Royal Museum for Central Africa (*RMCA*), the Royal Meteorological Institute (*RMI*) and the *Royal Observatory of Belgium* contribute to marine research.

THE FLEMISH POLICY CONTEXT FOR RESEARCH AND INNOVATION

In Flanders, the policy domain Economy, Science and Innovation (*ESI*) is the entity that is responsible for the development and implementation of the science and innovation policy. In addition, the other policy domains can also (albeit to a much lesser extent) take initiatives in the field of science and innovation in order to support and underpin their policy. The policy area of ESI comprises the Department of Economy, Science and Innovation and several agencies. The entities listed below are specifically relevant for the science and innovation policy (see also *Speurgids Ondernemen & Innoveren 2018*):

- The Department of Economy, Science and Innovation (*ESI*) is responsible for the preparation, monitoring and evaluation of the economic, science and innovation policy.

The execution of this policy is carried out by various agencies, including:

- Flanders Innovation and Entrepreneurship (*VLAIO*) is the contact point of the Government of Flanders for all entrepreneurs in Flanders and provides stimulation and support for innovation and entrepreneurship in a favourable business climate;
- The Research Foundation - Flanders (*FWO*) is responsible for supporting fundamental and strategic research;
- (Botanic Garden Meise);
- The Flemish Advisory Council for Innovation and Enterprise (*VARIO*) advises the Government of Flanders and the Flemish Parliament on its science, innovation, industry and entrepreneurship policy.

The research is carried out primarily by the five university associations (*KU Leuven Association*, *Ghent University Association*, *Antwerp University Association*, *Brussels University Association* and *University Association and Graduate Schools Limburg*), the Strategic Research Centres (SRCs) (*VITO*, *IMEC*, *VIB*, *Flanders Make*) and a number of other research institutes in specific fields of expertise such as agriculture and fisheries (*ILVO*), nature and forest research (*INBO*), marine sciences (*VLIZ*), tropical medicine (*ITG*), etc. (More information: *STI in Flanders, policy and key figures 2017*). In the context of the current report, it should be mentioned that Flanders Marine Institute (*VLIZ*) acts as the coordination platform for marine research in Flanders.

In the context of innovation, Flanders conducts a *cluster policy*. These cluster organisations are set up to facilitate a network of companies which are active in a certain domain in order to increase their competitiveness through mutual cooperation and collaboration with knowledge institutes. Two types of clusters are distinguished: *spearhead clusters* and *innovative business networks*. The spearhead clusters are large-scale initiatives (funding for a maximum period of 10 years) that are in line with important strategic domains for Flanders. The innovative business networks are typically smaller initiatives that often arise bottom-up from companies that want to invest in a specific domain that has the opportunity to increase their competitiveness. Specifically for the marine/maritime innovation field, the innovative business network *Offshore Energy* and the spearhead cluster *Blue Cluster* are relevant.

PROVINCE OF WEST FLANDERS

At the level of the Province of West Flanders, a number of locally-anchored initiatives have been set up that have a direct relation with marine science and innovation:

- *TUA West* (Technical Knowledge Alliance West Flanders), an external agency of the Province of West Flanders, has a liaison function and brings together companies, knowledge institutes and governments in a triple helix configuration. TUA West focuses on a number of knowledge priorities within West Flanders, namely Blue Energy, Mechatronics, Advanced Materials, Food and Care Economics;
- Within the POM West Flanders, the so-called Factories for the Future (FvT) were established to foster close cooperation between companies, knowledge institutions and government. The *FvT Blue Energy* is of particular importance for the marine domain.

3. Marine research and innovation in Flanders/Belgium: figures and indicators

The covenant between the Government of Flanders and Flanders Marine Institute (VLIZ) (2017-2021) stipulates that VLIZ must guarantee "An annual update of the inventory of the marine research landscape in Flanders" (KPI 11). Hence, every year a state of the marine research in Flanders and Belgium is drawn up, based on a replicable methodology (see e.g. *Pirlet et al. 2017*). The current publication expands this annual inventory with additional figures on the marine research and innovation landscape (e.g. funding, training, technometrics, etc.).

For more information about the historical context and evolution of the marine research landscape in Flanders and Belgium, reference is made to *Mees et al. (2015)*.

3.1 Methodology – Mapping of the Flemish/Belgian marine research landscape

This inventory focuses on the period 2008-2017. In order to trace evolutions on a longer term, clear definitions, preconditions and a replicable working method are used (more information: *Pirlet et al. 2017*). A central concept in this inventory is the definition of the Marine Research Group (MRG) (table 2).

Table 2. Definition of Marine Research Group (MRG).

Definition Marine Research Group (MRG)	
An MRG simultaneously meets the following four criteria	The research group is located in Flanders or in Belgium.
	The research group periodically receives government funding or subsidies embedded in policy agreements, covenants or other legal agreements.
	Groups which do not belong to a university association are included in the list of institutes recognised for scientific research, as established in the royal decree of 22 August 2006 and the subsequent modifications of this royal decree.
	The research group focuses on marine research, or research which is relevant for this topic. In case of doubt, the measurable marine research output of the group is checked over the last five years. This output is defined as 'more than one peer-reviewed or VABB-publication of which the first author is affiliated to the research group'.

The methodology of the inventory relies on the content of the Integrated Marine Information System (*IMIS*, VLIZ), supplemented by an annual systematic survey of literature databases. In the present inventory, these databases are Web of Science (through ISI-Web of Knowledge), the IEE-database and the Flemish Academic Bibliographic Database for the Social Sciences and Humanities (*VABB-SHW*)[2]. The selection of publications from these databases are checked on their marine[3] focus and affiliation with a Belgian research group. Next, the publications are added to the collection of the Belgian Marine Bibliography (BMB) in IMIS, and a link is made between the publication, the institute and the author(s). Based on these links, new or additional MRGs are identified, provided they have published more than one marine peer-reviewed or VABB-publication as a first author in the past five years. Since 2013, the inventory and the antecedent survey of the literature databases are conducted annually for the previous five years, on a fixed benchmark date in July. The benchmark date for the present inventory was 13 July 2018. The relationships that are established in IMIS between the publication, the institute and the author(s), allow quantitative measurements regarding the marine publications and the authors of the MRGs. However, the inventory of the staff of the MRGs is based on a direct survey of the research community (conducted in 2017-2018). Every MRG, as well as the researchers, authors and publications affiliated with the MRG, are linked to one or more research domains and disciplines. To enable benchmarking at an international level, the definition of research domains and the further division into research disciplines, are based on the international available typology (e.g. *Frascati Manual*).

The methodology followed, the preconditions and the limitations associated with this methodology and its results are described in detail in the annual report (*Pirlet et al. 2017*). Important remarks are:

- The inventory addresses MRGs at universities, graduate schools and scientific institutes in Flanders and Belgium. Marine research performed outside of these institutions is not systematically covered in the present inventory, although the report also contains some indicators on the marine innovation landscape;
- The results of this inventory are mainly focused on peer-reviewed publications and publications included in the Flemish Academic Bibliographic Database for the Social Sciences and Humanities (VABB-SHW). However, a

[2] VABB-SHW is a database containing scientific publications of researchers in the field of social and human sciences which are affiliated to a Flemish university.
[3] This theme covers marine, maritime, coastal and estuarine research activities within various research domains.

significant part of the scientific output is available in other types of publications (e.g. theses, books, scientific advices, project reports, etc.) that are disclosed and described in IMIS, but have not yet been included in the current inventory;

- The collection of publications included in the inventory is largely determined by the surveyed databases (Web of Science, IEEE and VABB-SHW), in which certain scientific fields are less represented. This implies a potential incompleteness or underestimation of the scientific output of the MRGs. In the future, the inventory may be expanded to new information sources, citable data sets and other scientific knowledge outputs (project deliverables, maps, models, etc.);
- In literature databases, new publications are included and described with a certain delay. Hence, in the current inventory the statistics for 2017 are incomplete with regard to publications from the Web of Science and IEEE-database. For VABB-SHW, the figures for 2017 were not available yet.

3.2 Marine research capacity in Flanders and Belgium

NUMBER OF MARINE RESEARCH GROUPS (MRGs)

A total of 114 MRGs were identified in Belgium on the benchmark date (July 2018). A gradual increase can be observed since the first inventory in 2013 (82 MRGs) towards 115 MRGs in 2017. The majority of the 'new' MRGs that were identified since 2013, are existing research groups (active in other research domains) in which a (limited) number of researchers have expanded their expertise to marine research topics and applications. Hence, the significant increase in the number of research groups does not necessarily translate into a corresponding increase in the research capacity (see below). An overview of the MRGs is available in *Mees et al. (2018)* and can also be consulted in an interactive manner on *http://www.vliz.be/en/institutes* and *www.compendiumcoastandsea.be*.

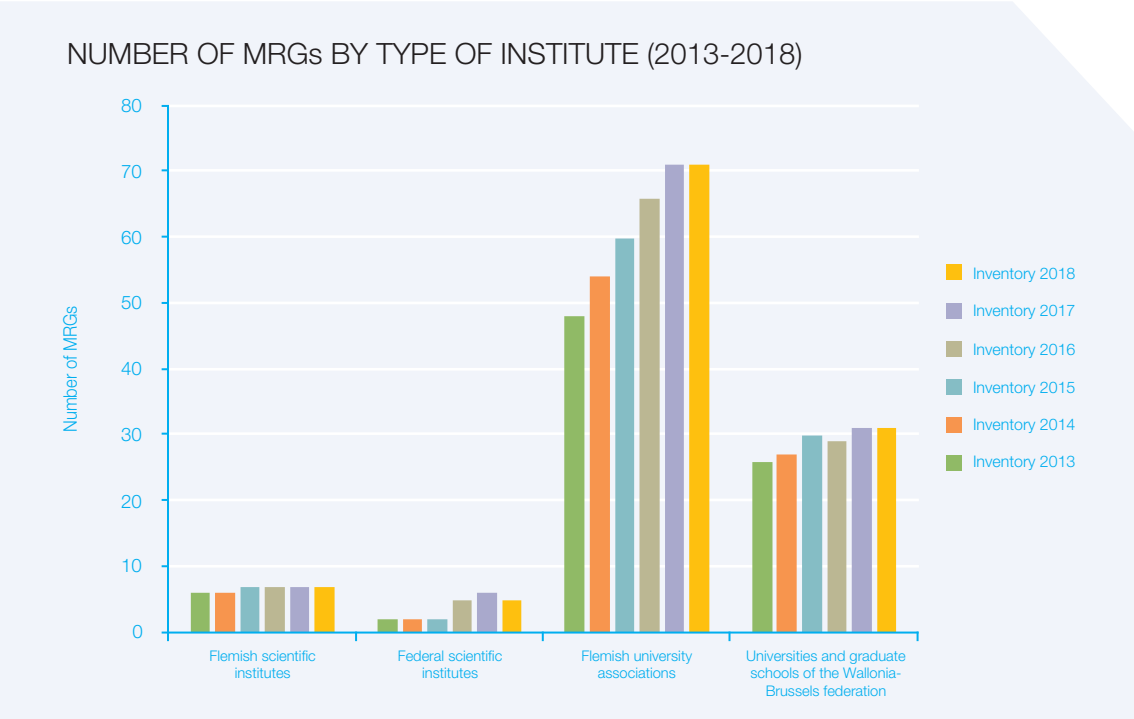

Figure 1. Number of MRGs according to the type of institute (2013-2018).

71 of the groups that were identified as an MRG in 2018 are affiliated with Flemish university associations, 31 with universities and graduate schools of the Wallonia-Brussels Federation (note: groups of university associations are counted at the level of laboratory, unit or research group) (figure 1). These MRGs can then be further classified according to the university / university association to which they belong (figure 2). The federal and Flemish scientific institutes are counted at the level of the institute and contain 5 and 7 MRGs respectively.

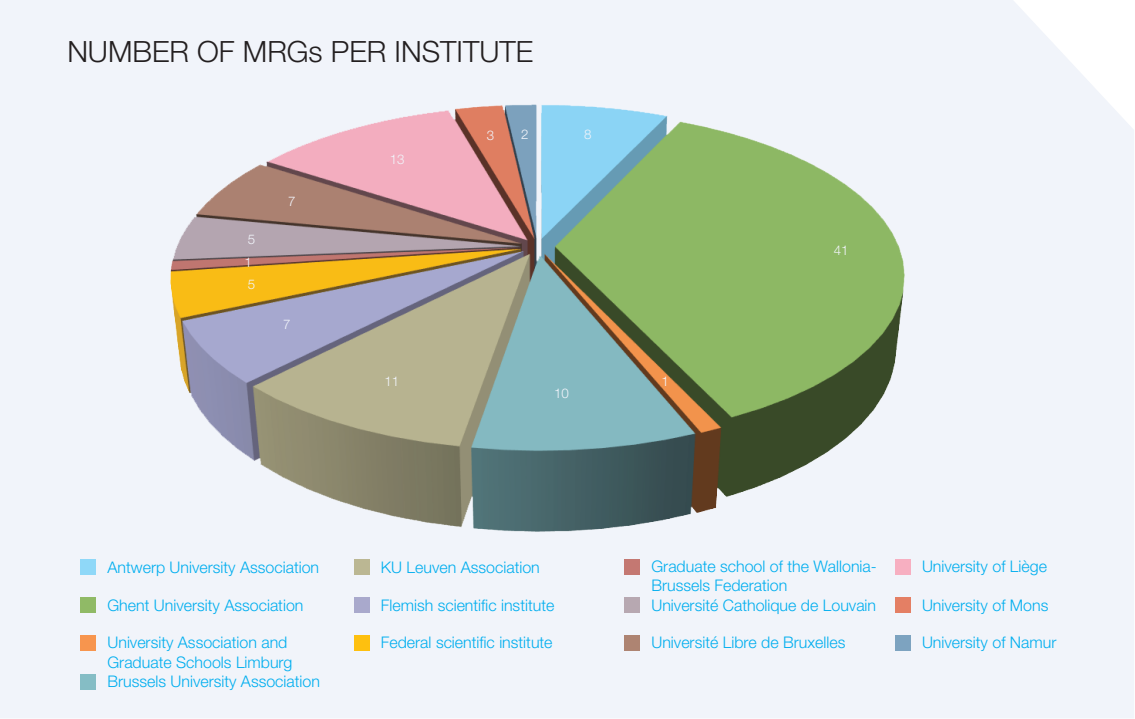

Figure 2. The number of MRGs according to the university / university association or scientific institute to which they belong (2018).

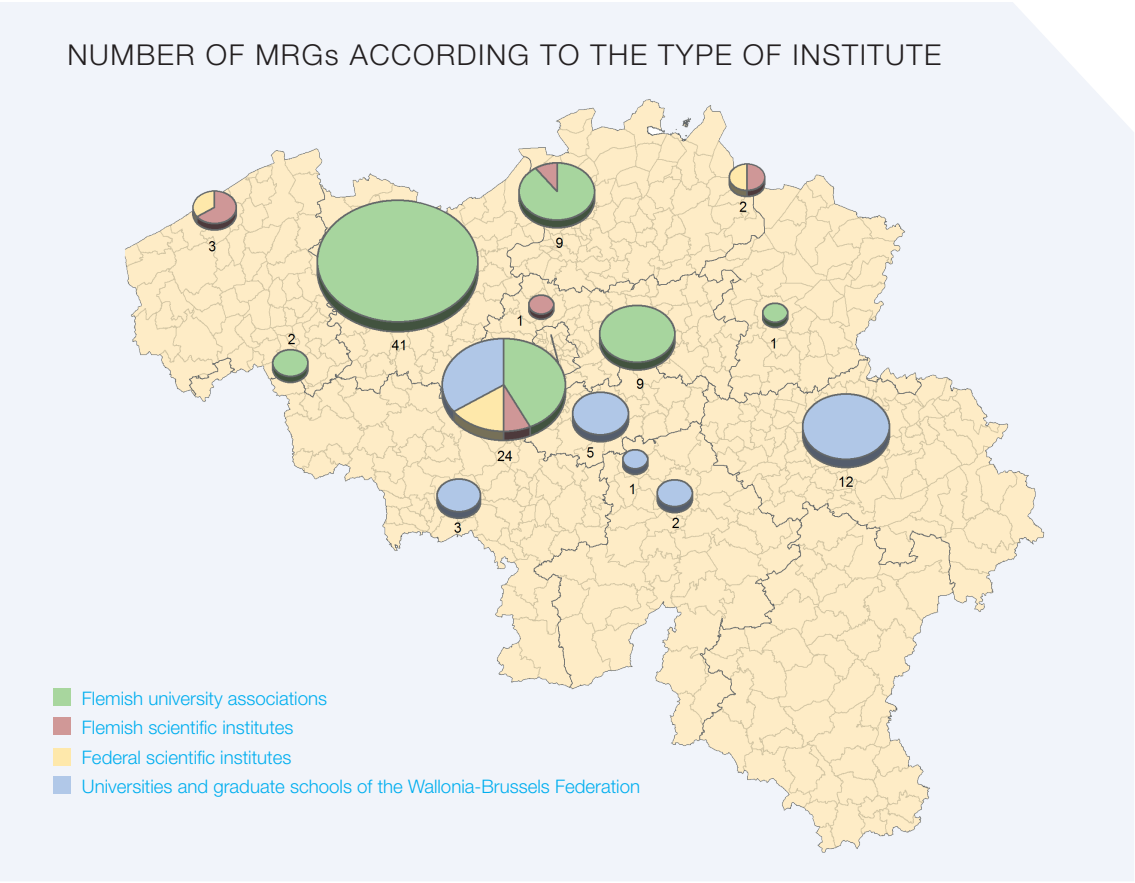

Figure 3. Number of MRGs, according to the type of institute and location (2018).

The largest share of the MRGs is situated in Ghent (36%) and Brussels (20%). A significant percentage of groups are also concentrated in Liège, Antwerp and Leuven. The MRGs affiliated with the scientific institutes are mainly situated in Brussels and Ostend (figure 3).

NUMBER OF MARINE RESEARCHERS

The number of staff active in marine research provides a better insight in the actual research capacity than the number of groups. On the benchmark date of 2018, 1,617 unique persons affiliated with an MRG were counted who are active in marine research on a full-time or part-time basis. This number is significantly higher than the benchmark in 2013 (1,075 persons) and 2015 (1,373 persons). This increase is on the one hand the result of the increase in the number of groups that also focus on marine research themes, but can also partly be explained by the improved response of the MRGs to survey. The Global Ocean Science Report (GOSR, *UNESCO 2017*) reported that Belgium takes the second place worldwide when considering the number of marine researchers per capita (after Norway).

The 1,617 unique staff members who were active in marine research in 2018 can be divided into several categories: professors and heads of departments (278 staff members), researchers in PhD programmes or continued research (901) and specialised, research-supporting employees (438) (figure 4). It should be noted that not all persons work as full-time equivalents (FTEs) and/or are fully engaged in marine research domains.

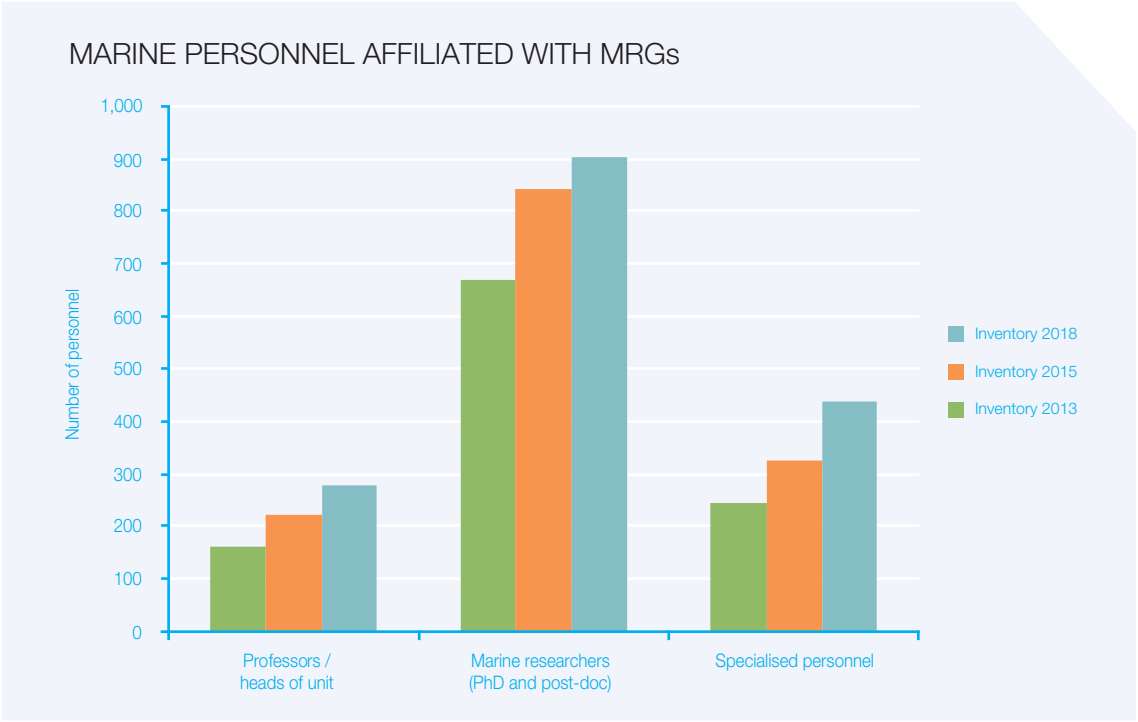

Figure 4. Number of staff members active in marine research, affiliated with MRGs (2013-2015-2018) according to the different categories to which they belong.

The Flemish university associations employ 856 marine staff members which constitute about half of the marine researchers and specialised staff in Belgium. The Flemish scientific institutes (348 marine staff members) and the Universities and graduate schools of the Wallonia-Brussels Federation (274 marine staff members) are followed by the federal scientific institutes (172 marine staff members). Please note that, in contrast to the figures above, these are not always unique persons, as some persons are affiliated with several entities.

The Flemish MRGs (1,204 persons) account for 6.4% of the R&D personnel in higher education and the public sector in Flanders, based on the figures of 2015 (*Viaene 2017*). However, it should be noted that this share may change when more recent figures with regard to the Flemish R&D personnel will be available. Moreover, the assumption was made that the 1,204 persons affiliated with the MRGs are FTEs.

The majority of the marine staff is male (63.8%, compared to 36.2% female). The percentage of women in marine research amounts to 45.2% in the category 'specialised personnel', but drops to 37.2% among marine scientists ((post)docs and PhD students) and even to 18.7% among heads of departments and professors. For comparison: the share of women in marine research worldwide equalled 38% in 2013 (Global Ocean Science Report, *UNESCO 2017*). At the Flemish universities, the proportion of women among the new junior researchers fluctuates between 45 and 50% in recent years. The percentage of female post-docs amounts to 40%. In the higher hierarchical positions, the share of women is gradually decreasing from the category of (tenure track) professors (35%) to (external) associate professors (14%) (figures of 2016) (*Vandevelde 2017*).

The median of the number of 'marine employees' (marine researchers and specialised personnel) per research group amounts to 9 persons per MRG. Only 10 of the 114 MRGs have more than 30 marine staff members. This mainly concerns the scientific institutes. Note that the staff members can be affiliated with several MRGs.

MARINE RESEARCH CAPACITY BY RESEARCH DOMAIN AND DISCIPLINE

Figure 5 shows the marine research capacity according to the research domain and discipline. The bulk of the marine research at the MRGs is carried out within the research domain of natural sciences: 76 research groups out of the 114 inventoried MRGs (with more than 1,300 associated marine staff members) focus completely or partially on biological, chemical or earth sciences or mathematics. In addition, 33 research groups are active in the domain of engineering and technology. The research domains can be further divided into several research disciplines (figure 5), in which the share of biological sciences (48 MRGs, 841 marine staff members) and earth sciences (27 MRGs, 650 marine staff members) stands out. In addition, research is carried out in no less than 17 other research disciplines ranging from fisheries and aquaculture sciences (10 MRGs), civil engineering (10 MRGs), history and archaeology (5 MRGs), economics and business (3 MRGs) to law and legal studies (2 MRGs). Note that an MRG (as well as the affiliated members) can be allocated to several disciplines.

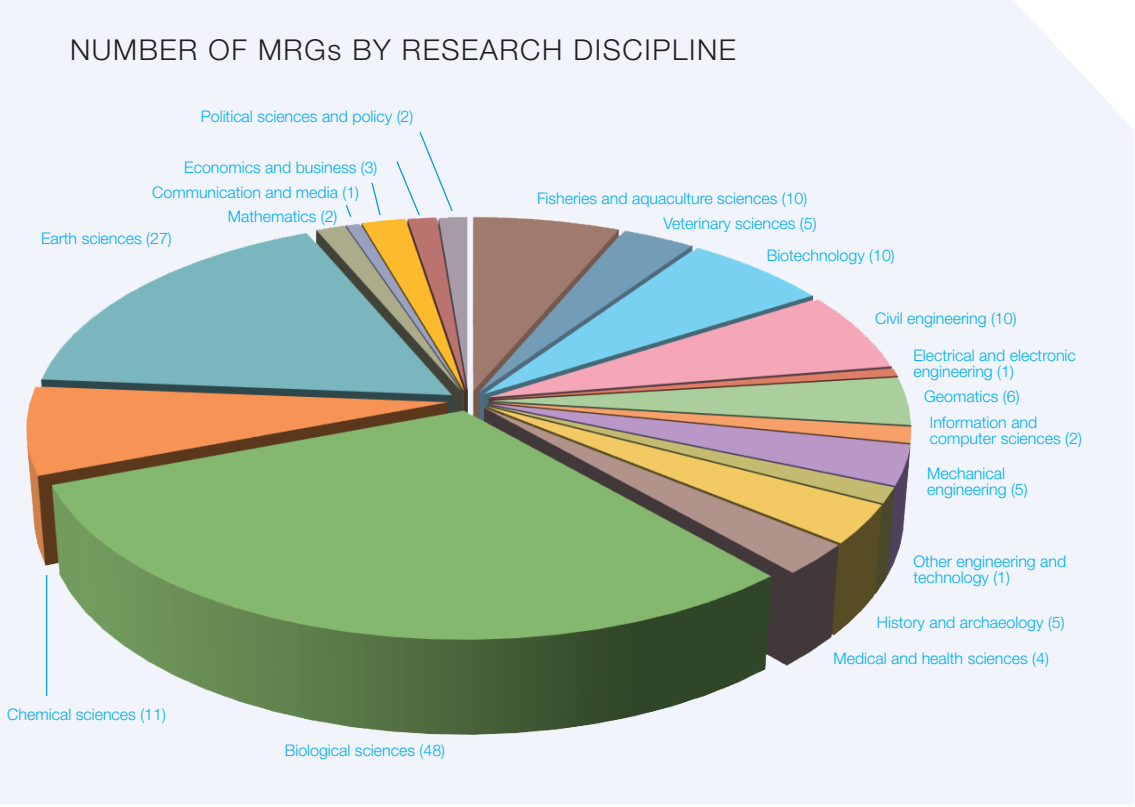

Figure 5. Share of MRGs by research discipline (2018). Note: MRGs can be allocated to several research domains and disciplines.

3.3 Bibliometric analysis of the marine research landscape

The scientific output of MRGs is diverse and includes peer-reviewed publications, books, (project) reports, proceedings, scientific advices, theses, multimedia, etc. In the figures below, only the output that can be collected in an exhaustive way is taken into account: peer-reviewed and VABB-publications. In the **Knowledge Guide Coast and Sea** of the Compendium for Coast and Sea (*Devriese et al. 2018*), other types of publications are disclosed, linked with the respective themes. Hence, it is not the intention to express a value judgement about the different types of publications in the current report. In the future the aim is to expand the inventory of scientific output towards other types of publications, as well as to research domains that are less focused on publishing in peer-reviewed journals.

NUMBER OF MARINE PEER-REVIEWED AND VABB-PUBLICATIONS

Between 2008 and 2016, the Belgian MRGs published on average more than 550 marine peer-reviewed publications every year, with an increase of 178 publications from 451 in 2008 to 629 in 2016[4] (figure 6). Hence, the annual scientific output of the MRGs is comparable with the output of the large marine research institutes in neighbouring countries (see e.g. *Pirlet et al. 2017*). In line with the research capacity (see above), the majority of the marine peer-reviewed and VABB-publications is published at the universities. In this regard, it is important to bear in mind that scientific institutes mainly concentrate on various types of policy-supporting or policy-preparing knowledge outputs, such as advices, project reports, monitoring or evaluations of policy objectives. Hence, these institutes are less focused on publishing their research in peer-reviewed articles.

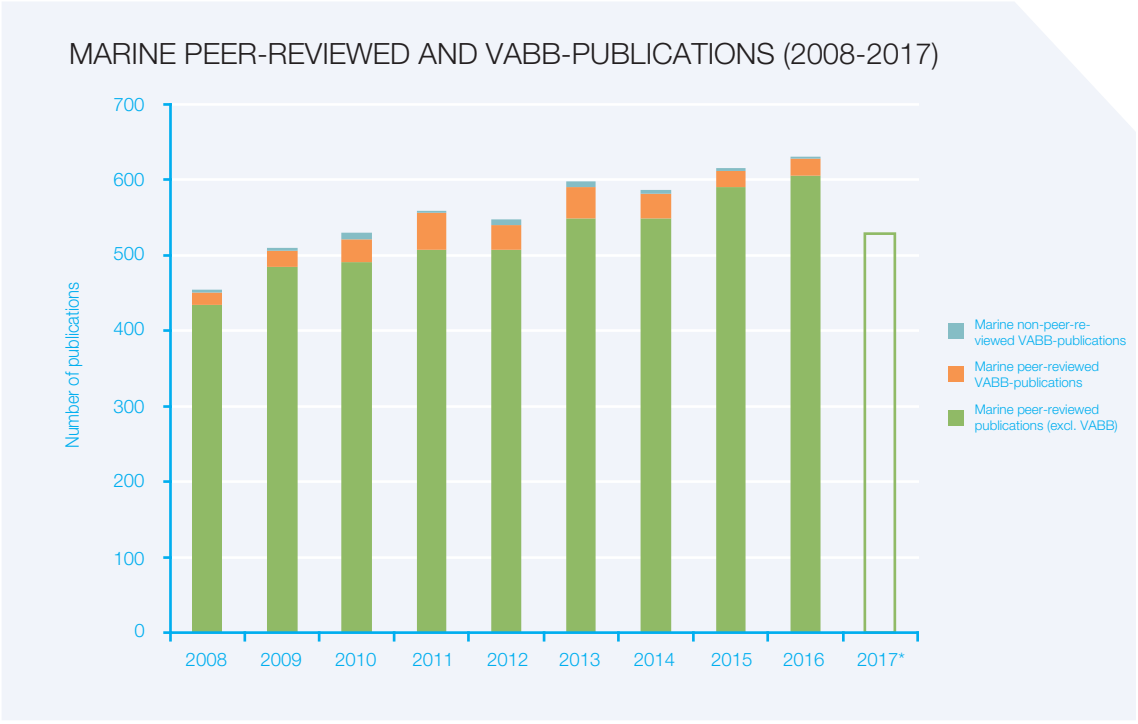

Figure 6. Number of marine peer-reviewed and VABB-publications affiliated with an MRG. *Note: the numbers of 2017 have a lower degree of completeness.

In the period between 2008 and 2017, a total of 2,921 unique authors were active (an average of 747 unique authors per year). These persons are affiliated with an MRG and act as (co-)authors of a marine peer-reviewed or VABB-publication. In line with the increase in personnel of the MRGs, a gradual growth of the number of authors can be noticed during recent years from 552 authors in 2008 to 897 authors in 2016. The majority of these authors were affiliated with Flemish university associations (57.4%) and an even larger part was working at a Belgian MRG in the research domain of natural sciences (62.5%).

[4] For comparison: the publication output of Flemish and Belgian researchers in 2015 amounted to respectively 28.16 and 23.05 publications/10,000 inhabitants (*Debackere et al. 2017*). For the MRGs this figure equalled 0.55 publications/10,000 inhabitants in 2015.

Between 2008 and 2017, the MRGs published in 1,092 different peer-reviewed journals which is a direct result of the very diverse expertise within the marine research landscape. A striking element is the rapid increase of the share of open access-journals from 28% in 2008 to 41% in 2016 (figure 7). This increase is also a retro-active phenomenon: over the last years more and more journals have switched to open access. This is also apparent from the figures in the inventory of 2015 in which the percentage of open access publications in 2008 amounted to only 6% (*Pirlet et al. 2015*).

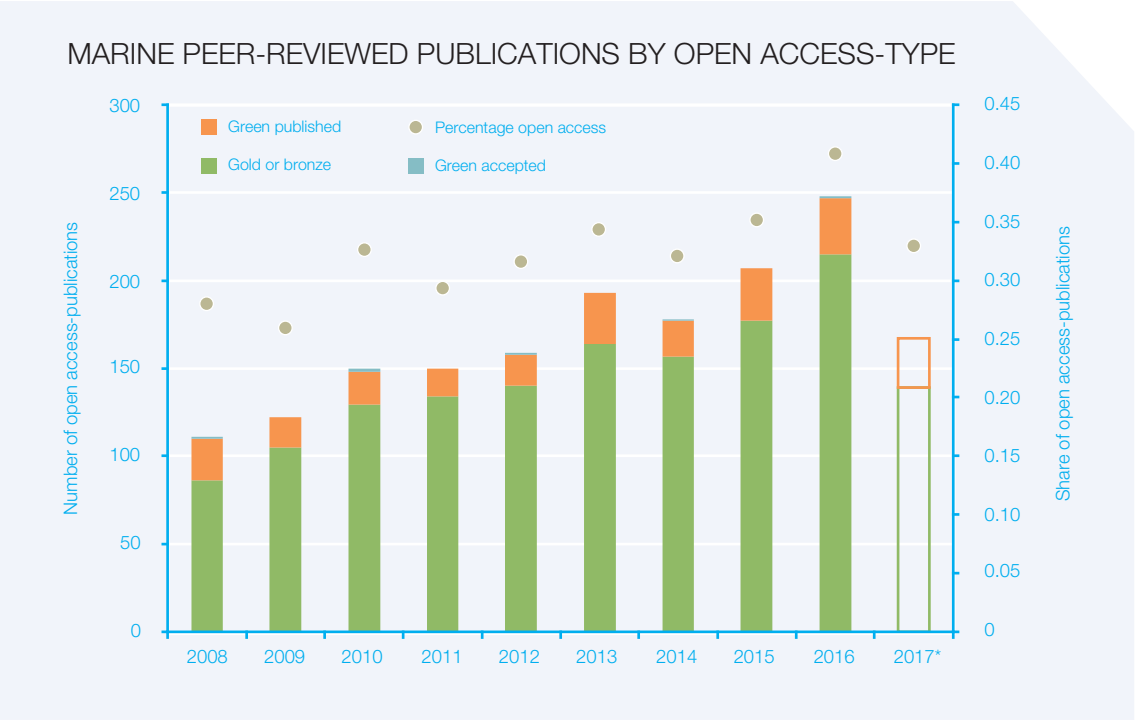

Figure 7. Number of marine peer-reviewed publication in open access journals. For the definition of the different types of open access (gold, bronze or green), reference is made to *Web of Science*. *Note: the numbers of 2017 have a lower degree of completeness.

The largest share of marine peer-reviewed and VABB-publications is published by MRGs in the research domain of natural sciences (66.8%) and the domain of engineering and technology (18.6%) (2008- 2017). This is in accordance with the research capacity (MRGs and staff members), but is also the result of the nature of the surveyed database (see **3.1 Methodology – Mapping of the Flemish/Belgian marine research landscape**) and the culture within the research field of natural sciences to publish in peer-reviewed journals.

RELATIVE CITATION INDICATORS OF MARINE PEER-REVIEWED PUBLICATIONS

Although relative citation indicators are no direct measure for the quality of the conducted research, they enable to benchmark according to an internationally accepted standard method. In cooperation with ECOOM (Bart Thijs, Wolfgang Glänzel and Koenraad Debackere), relative citation indicators were calculated for a list of 3,022 marine peer-reviewed publications affiliated with MRGs (2008-2014) (analysis based on the Accession Number (UT-codes) in Web of Science). A time frame of three years was used for these citations. This means the year of publication and the two following years. For more information on these relative citation indicators, reference is made to *Debackere et al. (2017)*.

An important parameter in this context is the Relative Citation Rate (RCR), which is defined as the ratio of the Mean Observed Citation Rate (MOCR) and the Mean Expected Citation Rate (MECR) (table 3). An RCR-value of more than 1 therefore means that the set of publications is cited more than can be expected based on the journals in which they have been published. For the list of marine peer-reviewed publications of the MRGs, the RCR is 1.15. The Normalised Mean Citation Rate (NMCR) of the publications of the MRGs also scores above the global average with a value of 1.34. This relative indicator is defined in the same way as the RCR, but the actual impact of the citation is implicitly compared with the expectations, based on the subdomains in which these publications have appeared. These relative citation indicators show that the publications of the MRGs rate above the global average with regard to citations (figure 8 and table 3).

Table 3. The relative citation indicators of the marine peer-reviewed publications of the MRGs.

Relative citation indicators	
MOCR (Mean Observed Citation Rate) = 6.55	The average number of citations per publication, calculated as the ratio of the number of observed citations in a three year time frame and the number of publications.
MECR (Mean Expected Citation Rate) = 5.69	The average number of expected citations per publication, calculated as the ratio of the number of expected citations and the number of publications.
RCR (Relative Citation Rate) = 1.15	The ratio of the MOCR and the MECR. An RCR-value of more than 1 means that the set of publications is cited more than can be expected based on the journals in which they have been published. An RCR value of 1 means that the observed value corresponds exactly with the global average.
NMCR (Normalised Mean Citation Rate) = 1.34	This relative indicator is defined in the same way as the RCR, but the actual impact of the citation is implicitly compared with the expectations, based on the subdomains in which these publications have appeared.
NMCR/RCR = 1.17	This indicator reveals to what extent the citation impact of the journals, in which the publications appeared, is in accordance with the field standard. An indicator value of less/more than 1 therefore means that the set of publications on average appeared in journals with a lower/higher impact than can be expected based on the fields to which the publication belongs.

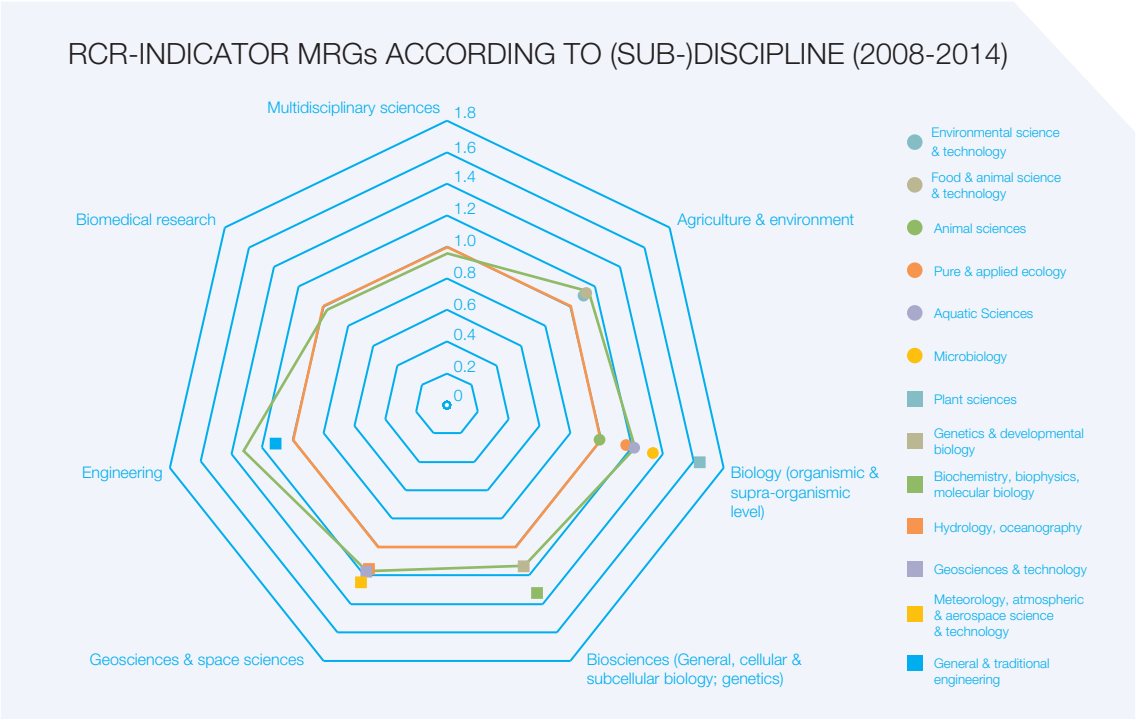

Figure 8. The relative citation frequency (RCR-indicator) according to the different disciplines and sub-disciplines in which MRGs have published in the period 2008-2014.

Relative citation frequency MRGs according to discipline

The marine research landscape is by nature multidisciplinary and therefore consists of different disciplines. Figure 8 shows the relative citation frequency for the various disciplines in which the MRGs have published in the period 2008-2014. Some of these disciplines can be divided into sub-disciplines. It should be noted that only (sub-)disciplines with more than 100 publications are included in this analysis. The relative citation frequency of the publications of the MRGs is higher than or (almost) equal to the global average for all reported disciplines (RCR => 1). A number of sub-disciplines even rate far above the global average with RCR-values up to 1.64.

A striking element is the large range of RCR-values of the sub-disciplines underlying the Biology discipline (Organismic and supra-organismic level) (1,280 publications). The other major discipline in which MRGs publish, Geosciences and space sciences (1,239 publications), reveals a much smaller distribution of the RCR-values of the sub-disciplines.

Relative citation frequency MRGs compared to other research disciplines in Flanders

In figure 9, the RCR-indicator of the marine research community is benchmarked with the RCR-values of the major research disciplines within Flanders (period 2010-2014). However, it should be explicitly noted that large differences exist between the citation practices in the different scientific (sub-)disciplines (*Debackere et al. 2017*).

Relative citation map of the MRGs, Flanders and twelve reference countries

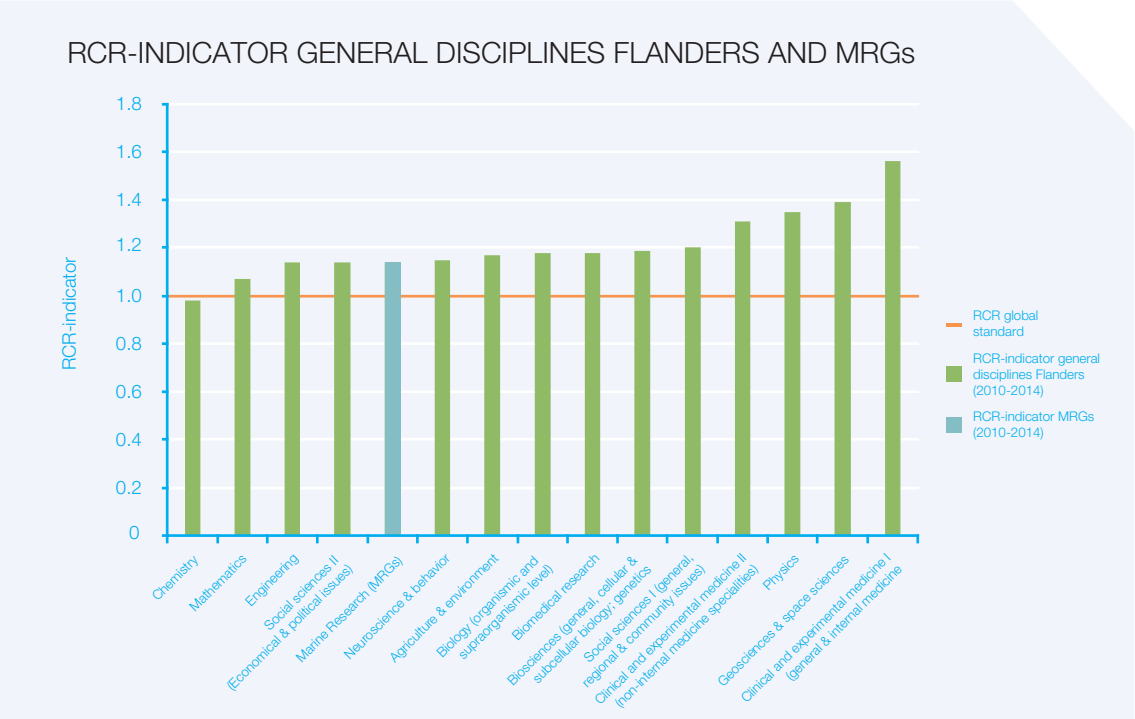

Figure 9. The relative citation frequency (RCR-indicator) of the major research disciplines within Flanders, compared to the RCR-indicator of the MRGs (2010-2014).

Figure 10 represents the mean observed citation rate (MOCR) and the mean expected citation rate (MECR) of the marine publications of the MRGs compared to the publications of Flanders, twelve reference countries (selected by ECOOM), as well as the global average in all disciplines combined (2010-2014). It should be noted that this kind of comparison can be misleading due to large differences between citation practices in the different scientific (sub-) disciplines (*Debackere et al. 2017*).

Within the relative citation map (figure 10), the two grid lines and the diagonal line constitute three standards that divide the diagram into six sectors. The vertical grid line indicates whether the mean expected citation rate (MECR) of a country is below (left) or above (right) the global average. The position relative to the horizontal line represents the mean observed citation rate (MOCR) of a country compared to the global average. Finally, the bisector corresponds to the RCR-value = 1 (*Debackere et al. 2017*). Hence, it can be stated that the MRGs and the majority of the reference countries are in the most favourable sector in terms of citation impact. Figure 10 also reveals that the MRGs are situated in the top group of the selected reference countries, although Flanders and Belgium (entire research community) score even better.

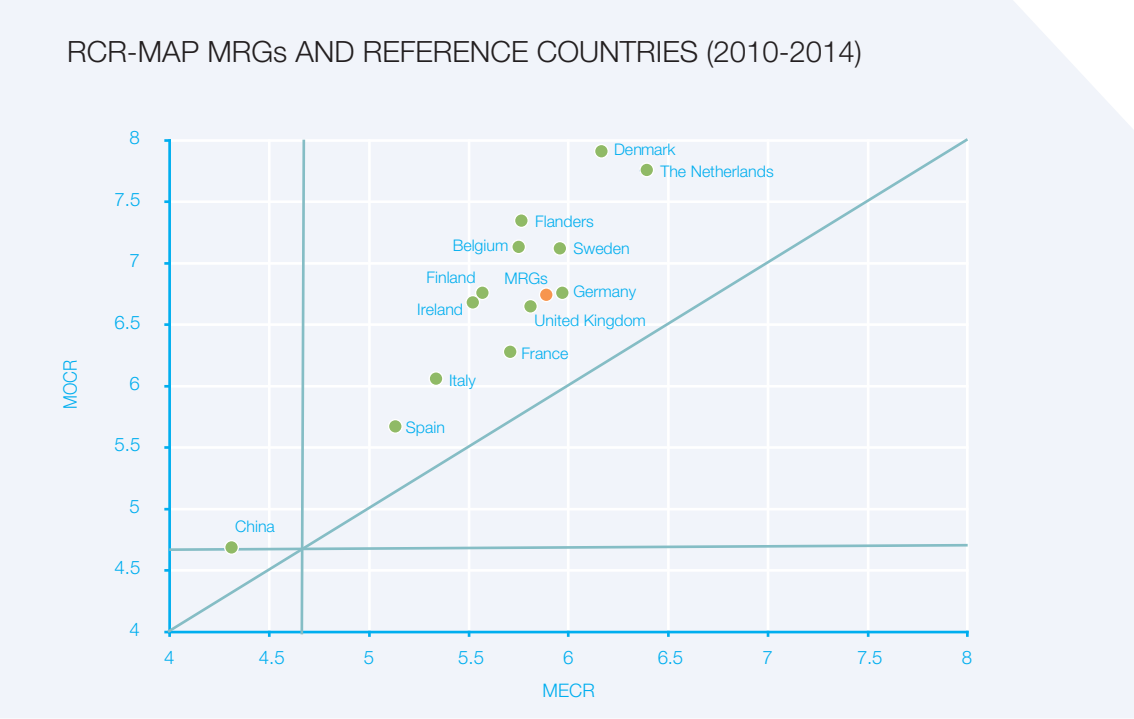

Figure 10. Relative citation map (MOCR relative to MECR) of the marine publications of the MRGs (orange), compared to the publications of Flanders, twelve reference countries and the world for all research disciplines combined (2010-2014) (modified after *Debackere et al. 2017*).

DETAILED ANALYSIS OF MARINE PEER-REVIEWED AND VABB-PUBLICATIONS

Geographical study areas of marine research

A detailed analysis of the study area of the marine peer-reviewed and VABB-publications (2008-2017) reveals the international character of the research performed by the MRGs. The share of publications (in which a study area could be identified[5]) that classifies as 'international research' (in terms of study areas) amounts to 78.9% (average 2008-2017). The five-yearly averages in this period range between 76.6% and 80.9%. The Atlantic region (15.9%) and Pacific region (11.7%) constitute the most important international study areas of the marine research landscape (figure 11).

The remaining 21.1% (average 2008-2017) can be considered as 'regional research' and includes the Belgian part of the North Sea (BNS), the Belgian coastal zone (beach, dunes and coastal polders), the Scheldt Estuary and the Southern Bight of the North Sea. The research that specifically addresses the BNS and the adjacent coastal zone amounts to respectively 5.1% and 3.6% of the publications. In this context, it is important to bear in mind that a significant part of the scientific knowledge about this area is published in types of publications that are not part of this analysis. The relative importance of the various geographic study areas remains relatively stable throughout the analysed period.

Collaboration between MRGs

Between 2008 and 2017, on average 32.5% of the peer-reviewed and VABB-publications resulted from a collaboration between at least two MRGs. This share varied between 29.6% in 2010 to more than 34% in four out of the five most recent years. The collaborations mainly occurred between MRGs affiliated with universities, both within the language regions (Flanders: 14.1%, Wallonia-Brussels Federation: 5.8% of the total number of MRG-publications) and across the language border (4.9%) (2008-2017). Additionally, a significant number of publications resulted from the cooperation of MRGs at Flemish universities with federal (5.8%) and Flemish scientific institutes (5.4%).

[5] In 36.4% of the marine peer-reviewed and VABB-publications affiliated with an MRG (2008-2017), no study area could be identified (lab experiment, modelling study, etc.). These publications were not included in the present analysis of the study areas.

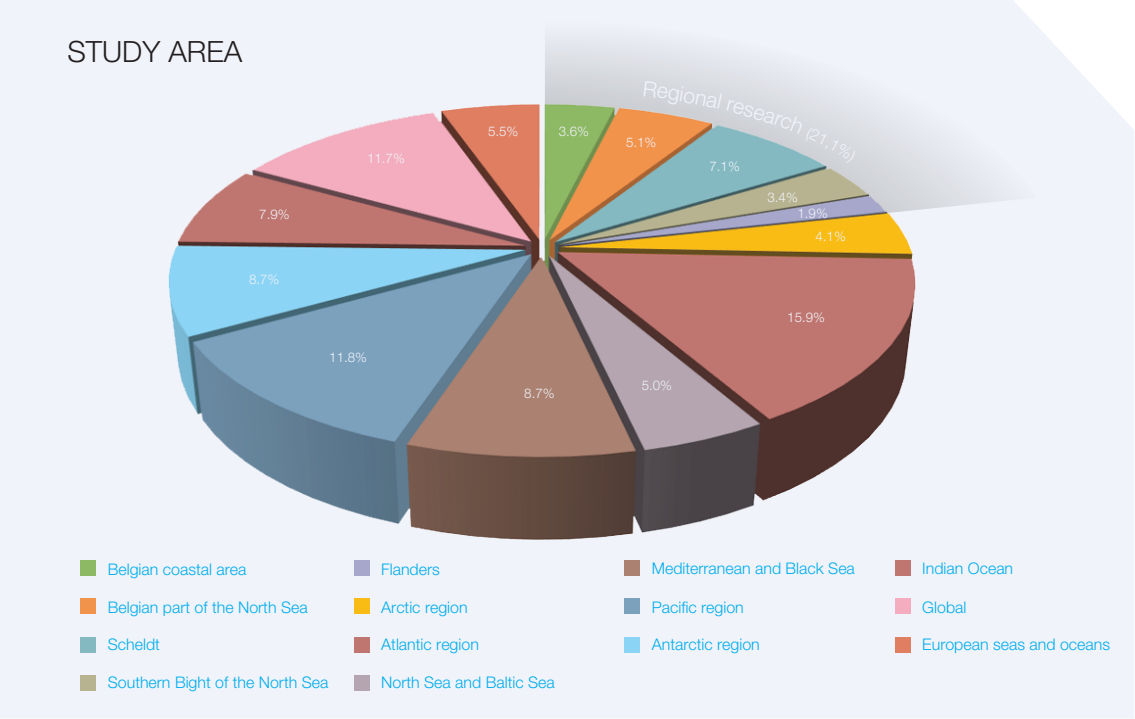

Figure 11. The share of marine peer-reviewed and VABB-publications affiliated with an MRG, according to the geographical study area (2008-2017). A publication is always assigned to one geographic area, unless multiple areas are explicitly mentioned. *Research assigned to the region 'Flanders' includes the coastal zone but is not restricted to this area.

Although the cooperation for these joint publications mainly occurred between MRGs within the research domain of natural sciences (26.1% of the total number of MRG-publications), 9.5% and 4.6% of the co-publications were also the result of collaborations between natural sciences and, respectively, the domain of engineering and technology and the domain of agricultural and veterinary sciences. These figures are, to a large extent, a reflection of the research capacity in the different types of institutes and research domains (see **3.2 Marine research capacity in Flanders and Belgium**).

It should be noted that the aforementioned figures only focus on collaboration with regard to the peer-reviewed and VABB-publications. In addition, there is also a range of partnerships in projects, education, monitoring, etc. which do not necessarily result in joint peer-reviewed publications.

International co-publications

International co-publications are publications in which at least one of the co-authors is affiliated with a foreign institute or organisation. Hence, the number of international co-publications are a proxy for the degree of international collaboration in the marine research field. Moreover, it is generally accepted that international co-publications receive on average more citations (*Debackere et al. 2017*).

In more than 72% of the marine peer-reviewed and VABB-publications of the MRGs (2008-2017), collaboration takes place with at least one foreign co-author. This share even amounted to 79.4% in 2017. In this context, the MRGs score significantly higher than the Belgian and Flemish average with regard to international peer-reviewed co-publications which amounted to respectively 67.7% and 66.5% in 2015 (*Debackere et al. 2017*)[6]. Between 2008 and 2017, the MRGs published with authors from 124 different countries (figure 12). It mainly concerns collaboration with neighboring countries (France, The Netherlands, Germany and the UK), as well as with researchers from the USA. This is also reflected in the institutes and organisations that collaborate most intensively with the MRGs (*Centre National de la Recherche Scientifique* (CNRS), Utrecht University, *Sorbonne Université*, Helmhotz Association, *Institut de Recherche pour le Développement* (IRD), *Muséum national d'histoire naturelle*, Natural Environment Research Council (NERC), Royal Netherlands Institute for Sea Research (NIOZ), etc.). In 60.4% of the marine peer-reviewed and

[6] It should be noted that this share may change when more recent figures become available.

VABB-publications of the MRGs (2008-2017) the first author is affiliated with a Belgian institute, followed by France (5.0%), Germany (4.0%) and The Netherlands (3.6%).

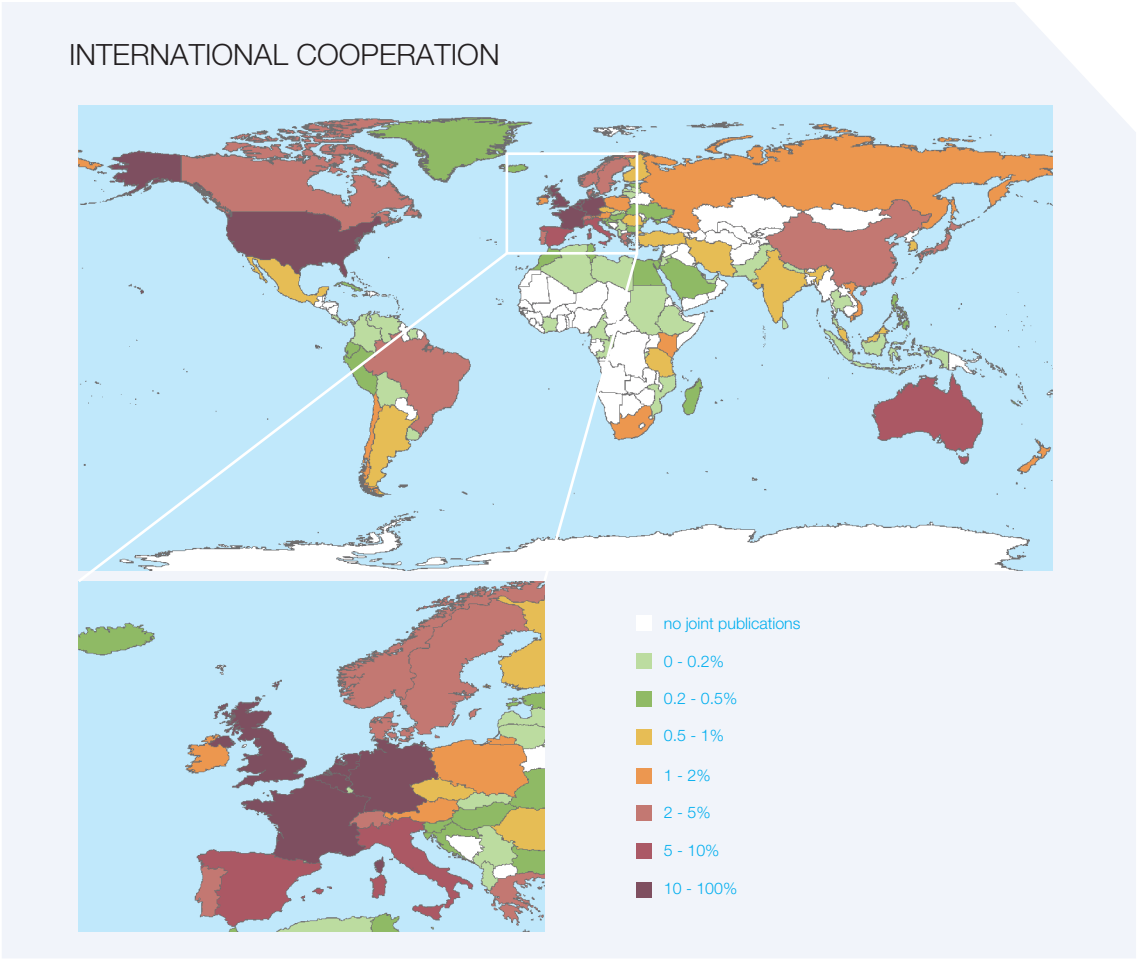

Figure 12. Geographical visualisation of international cooperation, based on the marine peer-reviewed and VABB-publications of MRGs, according to the country of affiliation of the authors (%) (2008-2017).

Use of research vessels

In 27.3% of the marine peer-reviewed and VABB-publications of the MRGs (2008-2017), a research vessel was used for sampling or data collection[7]. This share fluctuates between 19.4% (2008) and 36.9% (2009) without a clear trend. Hence, these publications constitute the sea-going research of the MRGs. The other publications mainly concern coastal and estuarine research, modelling studies, experimental research in laboratories, social and economic studies, historical research, etc. An unknown share of the aforementioned publications, however, indirectly relies on sea-going research (e.g. for the validation of models or experiments).

In 638 publications (11.5%), the research vessel is specifically mentioned by name (2008-2017). It concerns a total of 216 different vessels from 41 different countries, with the RV Belgica (Belgian, mentioned in 131 publications), RV Polarstern (German, 99 publications), RV Zeeleeuw (Belgian, 58 publications), RV Marion Dufresne (French, 44 publications) and RV Simon Stevin (Belgian, 35 publications) as the most frequently reported vessels. In addition to the Belgian research ships, the Belgian MRGs rely to a considerable degree on foreign vessels (German research vessels were reported in 173 publications, French vessels in 114 publications).

[7] This figure includes publications which specifically mention a research vessel by name, as well publications which have used a research vessel without including a reference.

3.4 Technometrics of the Flemish/Belgian marine innovation landscape

The analysis of patents provides an important insight into the process of technological progress, which in turn is an important factor in economic progress. These kind of indicators are internationally used to develop an understanding of the degree of innovation within an organisation, a region, a country, etc. It should be noted, however, that not all inventions are patented, or at least not all innovations are based on patented inventions (*Callaert et al. 2017*).

The current patent analysis was carried out by *ECOOM* (Mariëtte Du Plessis, Julie Callaert and Koenraad Debackere) in collaboration with VLIZ, in order to obtain an initial analysis of the patents in the Flemish/Belgian marine/maritime innovation landscape. In this regard the two major patent systems in the world were screened: the American patent system (based on data from the US Patent and Trademark Office, *USPTO*) and the European patent system (based on data from the European Patent Office, *EPO*). For more detailed information on these systems, reference is made to *Callaert et al. (2017)*.

The methodology which was used in this analysis, as well as the associated preconditions and restrictions are described below:

- The current patent analysis was carried out by *ECOOM* (in collaboration with VLIZ) and makes use of the PATSTAT 2017 (autumn version) database;
- Only companies and organisations based in Belgium are taken into account;
- The period 2008-2015 is analysed;
- The procedures within the American (*USPTO*) and European patent system (*EPO*) are somewhat different. As a consequence, the data for the applications within USPTO are incomplete and have therefore not been included in this technometric analysis;
- A direct extraction of marine/maritime patents from the USPTO- and EPO-databases or the querying of these databases for marine/maritime keywords was not possible. Therefore, a different approach needed to be developed: In a first phase the patents of all companies and organisations belonging to a marine/maritime cluster (Flanders' Maritime Cluster, Blue Cluster, Innovative Business Network Offshore Energy, Belgian Offshore Cluster, Belgian Offshore Platform, Factories for the Future – Blue Energy) were extracted, supplemented by the patents of the Belgian universities. Hence, this first extract mostly contains non-marine/maritime patents. Nevertheless, a number of IPC-technology classes (i.e. the International Patent Classification, Fraunhofer) can be selected that are specifically relevant for the marine field. This approach allows for an initial screening of the patents from the marine/maritime innovation landscape (see **Technometrics companies and organisations belonging to a marine/maritime cluster**);
- In a second stage, a sub-selection was made of companies and organisations belonging to a marine/maritime cluster (see above) and developing mainly marine/maritime activities. Hence, the majority of this selection contains marine/maritime patents but is by no means exhaustive (see **Technometrics companies and organisations mainly engaged in marine/maritime activities**).

Patents

A patent can be defined as a document that is published by a mandated governmental body which gives the right to prohibit any other person/institution from producing or using a specific new design, device or process for a number of years (Source: *ECOOM*).

The purpose of the patent system is to protect the inventor. The granting of a temporary monopoly will ensure that the inventor receives sufficient benefit from innovative efforts, which in turn may stimulate technological progress. However, in exchange for the granting of a monopoly, it is demanded that the information concerning the invention is made public. The public accessibility of information in patent documents leads to a wider dissemination of technological innovations and prevents useless duplication of R&D efforts. Finally, it can be stated that patent systems facilitate the trade of technological knowledge, due to the presence of clearly defined property rights (*Callaert et al. 2017*).

TECHNOMETRICS COMPANIES AND ORGANISATIONS BELONGING TO A MARINE/MARITIME CLUSTER

This first technometric analysis started from a list of 254 companies and organisations based in Belgium and belonging to a marine/maritime cluster (Flanders' Maritime Cluster, Blue Cluster, Innovative Business Network Offshore Energy, Belgian Offshore Cluster, Belgian Offshore Platform, Factories for the Future – Blue Energy). Based on this list, 26 companies and organisations were identified that have applied for a patent within EPO or that have been granted a patent within USPTO between 2008 and 2015. It concerns a total of 883 EPO-patent applications (277 EPO-patents

granted) and 352 patents granted by USPTO[8]. In addition, this selection was supplemented by patent applications and grants from Belgian universities. It should be noted that the majority of these are non-marine/maritime patents.

Based on this wide selection, 19 IPC-technology classes (i.e. the International Patent Classification, Fraunhofer) were selected that hold specific relevance for the marine field (figure 13 and table 4). Evidently, this does not mean that there are no marine/maritime patents in other (more general) technology classes. The selected classes should therefore be regarded as a first estimate of the strengths of the marine innovation landscape. Moreover, this approach enables the monitoring of future evolutions in this landscape. It is important to note that this first marine/maritime technometric analysis allows for an initial exploration that can be further refined in future analyses.

Table 4. Distribution of patent applications (EPO) and granted patents (USPTO) from companies and organisations that belong to a marine/maritime cluster, according to the 19 IPC-classes with specific marine/maritime relevance (2008-2015).

IPC-classes with specific marine/maritime relevance		EPO-patent applications	Granted USPTO-patents
Horticulture; Cultivation of vegetables, flowers, rice, fruit, vines, hops, or seaweed; Forestry; Watering	A01G	2	9
Animal husbandry; Care of birds, fishes, insects; Fishing; Rearing or breeding animals, not otherwise provided for; New breeds of animals	A01K	21	0
Cleaning in general; Prevention of fouling in general	B08B	3	3
Reclamation of contaminated soil	B09C	3	1
Ships or other waterborne vessels; Equipment for shipping	B63B	7	0
Marine propulsion or steering	B63H	1	0
Treatment of water, waste water, sewage, or sludge	C02F	5	2
Coating compositions, e.g. paints, varnishes or lacquers; Filling pastes; Chemical paint or ink removers; Inks; Correcting fluids; Woodstains; Pastes or solids for colouring or printing; Use of materials therefor	C09D	14	3
Cracking hydrocarbon oils; Production of liquid hydrocarbon mixtures, e.g. by destructive hydrogenation, oligomerisation, polymerisation; Recovery of hydrocarbon oils from oil-shale, oilsand, or gases; Refining mixtures mainly consisting of hydrocarbons; Reforming of naphtha; Mineral waxes	C10G	2	0
Hydraulic engineering	E02B	16	4
Foundations; Excavations; Embankments; Underground or underwater structures	E02D	19	7
Dredging; Soil-shifting	E02F	21	0
Earth or rock drilling; Obtaining oil, gas, water, soluble or meltable materials or a slurry of minerals from wells	E21B	4	1
Wind motors	F03D	20	7
Fluid dynamics, i.e. methods or means for influencing the flow of gases or liquids	F15D	1	0
Pipes; Joints or fittings for pipes; Supports for pipes, cables or protective tubing; Means for thermal insulation in general	F16L	5	0
Measuring distances, levels or bearings; Surveying; Navigation; Gyroscopic instruments; Photogrammetry or videogrammetry	G01C	4	2
Geophysics; Gravitational measurements; Detecting masses or objects; Tags	G01V	6	1
Cables; Conductors; Insulators; Selection of materials for their conductive, insulating, or dielectric properties	H01B	7	16

TECHNOMETRICS COMPANIES AND ORGANISATIONS MAINLY ENGAGED IN MARINE/MARITIME ACTIVITIES

Based on the technometric analysis above, which started from a wide selection of organisations and companies (based in Belgium) belonging to a marine/maritime cluster, a sub-selection of organisations and companies that are exclusively or to a large extent involved in marine/maritime activities was made. Based on this sub-selection, 9 companies and organisations were identified that had applied for an EPO-patent (59 applications / 27 granted patents) or that had been granted a patent from the USPTO (7 patents) in the period 2008-2015 (figure 14 and table 5).

[8] For comparison: the annual EPO-applications for Belgium vary between 2,000 and 2,500 (800-1,200 granted patents). For the USPTO-grants, this figure ranges between 1,200 and 1,500 (Source: *Callaert et al. 2017*).

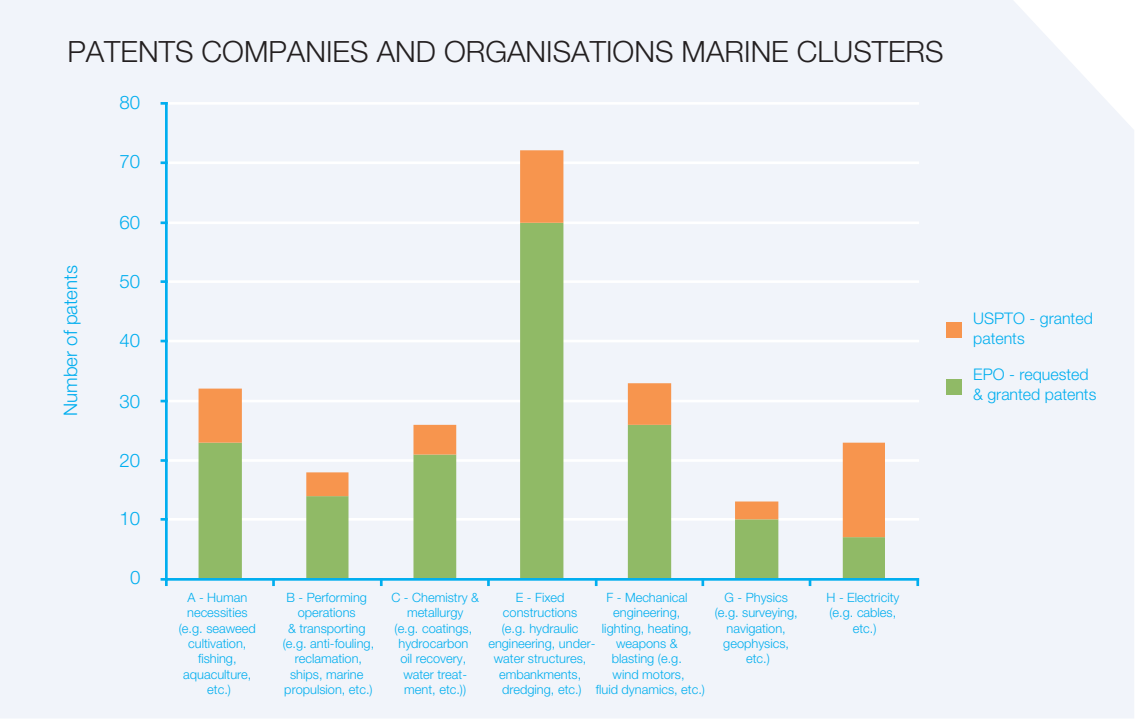

Figure 13. Distribution of patent applications (EPO) and granted patents (USPTO) from companies and organisations that belong to a marine/maritime cluster, according to the large domains which hold the 19 IPC-classes with specific marine/ maritime relevance (2008-2015).

The IPC-technology classes (i.e. the International Patent Classification, Fraunhofer) of these patents provide further insight into the strengths of the marine/maritime innovation landscape. In this regard, the classes Hydraulic engineering (20), Foundations; Excavations; Embankments; Underground or underwater structures (19) and Dredging; Soil-shifting (21) stand out (figure 14).

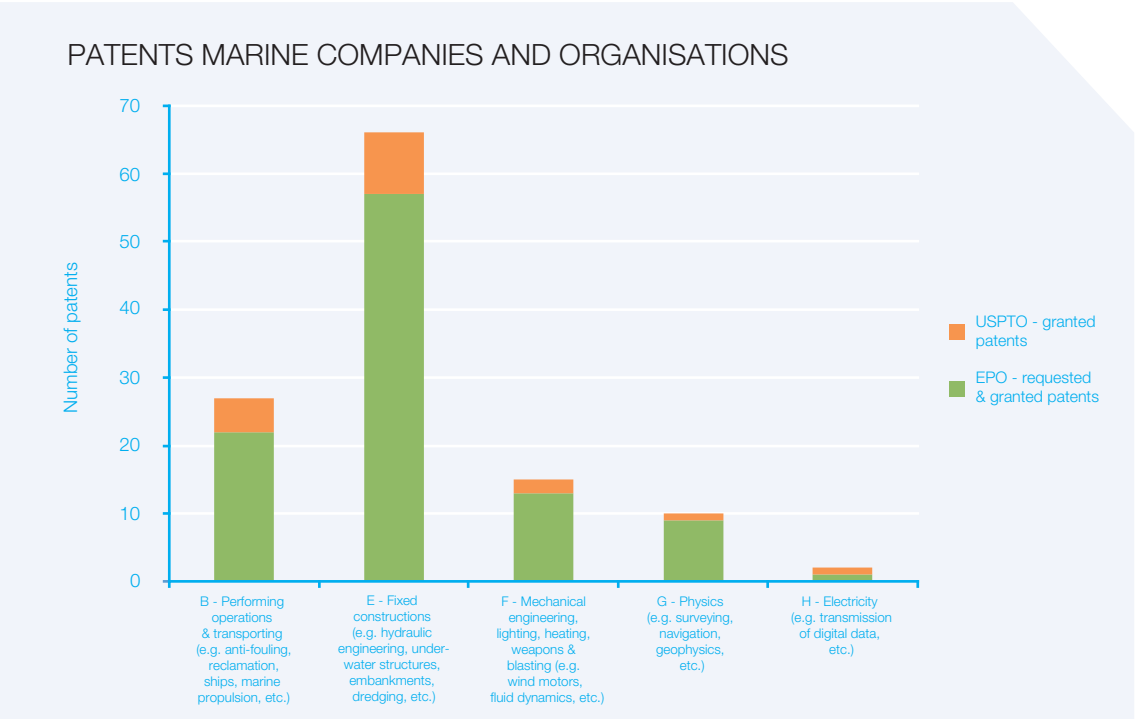

Figure 14. Distribution of patent applications (EPO) and granted patents (USPTO) from companies and organisations that are exclusively or to a large extent involved in mainly marine/maritime activities (2008-2015).

Table 5. Distribution of patent applications (EPO) and granted patents (USPTO) from companies and organisations that are exclusively or to a large extent involved in mainly marine/maritime activities, according to the IPC-classes (2008-2015).

IPC-classes		EPO-patent applications	Granted USPTO-patents
Cleaning in general; Prevention of fouling in general	B08B	1	
Reclamation of contaminated soil	B09C	1	
Working or processing of sheet metal or metal tubes, rods or profiles without essentially removing material; Punching	B21D		1
Making forged or pressed products, e.g. horseshoes, rivets, bolts, wheels	B21K		1
Other working of metal; Combined operations; Universal machine tools	B23P		2
Abrasive or related blasting with particulate material	B24C	1	
Tools or bench devices not otherwise provided for, for fastening, connecting, disengaging, or holding	B25B		1
Ships or other waterborne vessels; Equipment for shipping	B63B	7	
Marine propulsion or steering	B63H	1	
Transport or storage devices, e.g. conveyers for loading or tipping; Shop conveyer systems; Pneumatic tube conveyers	B65G	2	
Handling thin or filamentary material, e.g. sheets, webs, cables	B65H	1	
Cranes; Load-engaging elements or devices for cranes, capstans, winches, or tackles	B66C	8	
Hydraulic engineering	E02B	16	4
Foundations; Excavations; Embankments; Underground or underwater structures	E02D	15	4
Dredging; Soil-shifting	E02F	21	
General building constructions; Walls, e.g. partitions; Roofs; Floors; Ceilings; Insulation or other protection of buildings	E04B	1	
Earth or rock drilling; Obtaining oil, gas, water, soluble or meltable materials or a slurry of minerals from wells	E21B	3	1
Mining or quarrying	E21C	1	
Machines or engines for liquids	F03B	2	
Wind motors	F03D	7	2
Fluid dynamics, i.e. methods or means for influencing the flow of gases or liquids	F15D	1	
Springs; Shock-absorbers; Means for damping vibration	F16F	1	
Pipes; Joints or fittings for pipes; Supports for pipes, cables or protective tubing; Means for thermal insulation in general	F16L	2	
Measuring distances, levels or bearings; Surveying; Navigation; Gyroscopic instruments; Photogrammetry or videogrammetry	G01C	1	
Investigating or analysing materials by determining their chemical or physical properties	G01N	3	
Radio direction-finding; Radio navigation; Determining distance or velocity by use of radio waves; Locating or presence-detecting by use of the reflection or reradiation of radio waves; Analogous arrangements using other waves	G01S	2	
Geophysics; Gravitational measurements; Detecting masses or objects; Tags	G01V	1	
Control or regulating systems in general; Functional elements of such systems; Monitoring or testing arrangements for such systems or elements	G05B	1	
Electric digital data processing	G06F	1	1
Transmission of digital information, e.g. telegraphic communication	H04L	1	1

3.5 Marine and maritime education and training programmes

The development of knowledge and expertise constitutes a corner stone of the present economy. This is particularly the case when discussing innovation and economic growth. Hence, a good alignment between the educational programmes, the inflow and outflow of students and the needs from industry (and society) is of greatest importance (*De Kock 2017*). This section provides – for the first time – an insight in the importance of marine and maritime education and training programmes in Belgium.

The rapid development in the marine field with emerging blue sectors such as the offshore wind, has led to an increasing demand for high-quality marine training programmes in order to meet the needs form industry, science and policy. The challenges with regard to marine training were already mentioned in the communication of the European Commission concerning Innovation in the Blue Economy (COM (2014) 254) as well as in the *Rome Declaration (2014)* from the European marine research community. In this context, the European Commission has established in 2016 an expert group on the skills and career development in the Blue economy. The discussion within this expert group focuses on three main topics: education-industry cooperation, Ocean Literacy, and lifelong learning, mobility, education programmes. In 2018, the European Marine Board has published a Future Science Brief '*Training the 21st Century Marine Professional*' (*Vincx et al. 2018*). This publication emphasises the importance of a multidisciplinary approach to marine training and addresses the current mismatch between training programmes and the needs from policy and industry. Finally, the Future Science Brief formulates six recommendations to work towards a modern vision on marine training. This theme will also be addressed by the European *MATES*-project which started in 2018 and intends to develop a strategic plan to tackle the (future) needs for certain skills and training in the maritime industry.

On a European level, the EuroMarine-project (FP7) developed a first analysis of the marine training landscape (the project subsequently evolved into the *EuroMarine-network*). This analysis was further elaborated by the Belgian contribution to *EMBRC* (European Marine Biological Resource Centre, an ESFRI-ERIC), in which Ghent University developed the *European Marine Training Portal*. The Marine Training Portal contains more than 550 master programmes, doctoral training programmes and short-term trainings provided by institutes for graduate education and training. In order to be included in the portal, the title of the training is screened for marine topics, as well as the general content (more than 30% should be marine). It should be noted that certain training typologies (e.g. vocational training, specialized sectorial diplomas, certified courses, etc.) are not included in these numbers.

For the current report, all Belgian training programmes and courses which are included in the Marine Training Portal were contacted in order to obtain the annual enrollment numbers from 2013 onwards. It concerns a total of 22 different programmes and courses provided by Belgian universities and colleges. It is important to note again that this is by no means an exhaustive overview of marine and maritime training programmes in Belgium (see also the aforementioned criteria for inclusion in the Marine Training Portal). For example: only 2 programmes from *Antwerp Maritime Academy* are included in the Marine Training Portal (equaling 15-25 registrations per year), whereas the total amount of students that annually enroll in the academy amounts to 600-700 (*Economic impact study Belgian shipping cluster: Update 2017*). Also, marine training programmes and courses organised by institutes and organisations such as *Maritiem Instituut Mercator* (School for seafaring and technique), *Koninklijk Werk IBIS*, *De Scheepvaartschool*

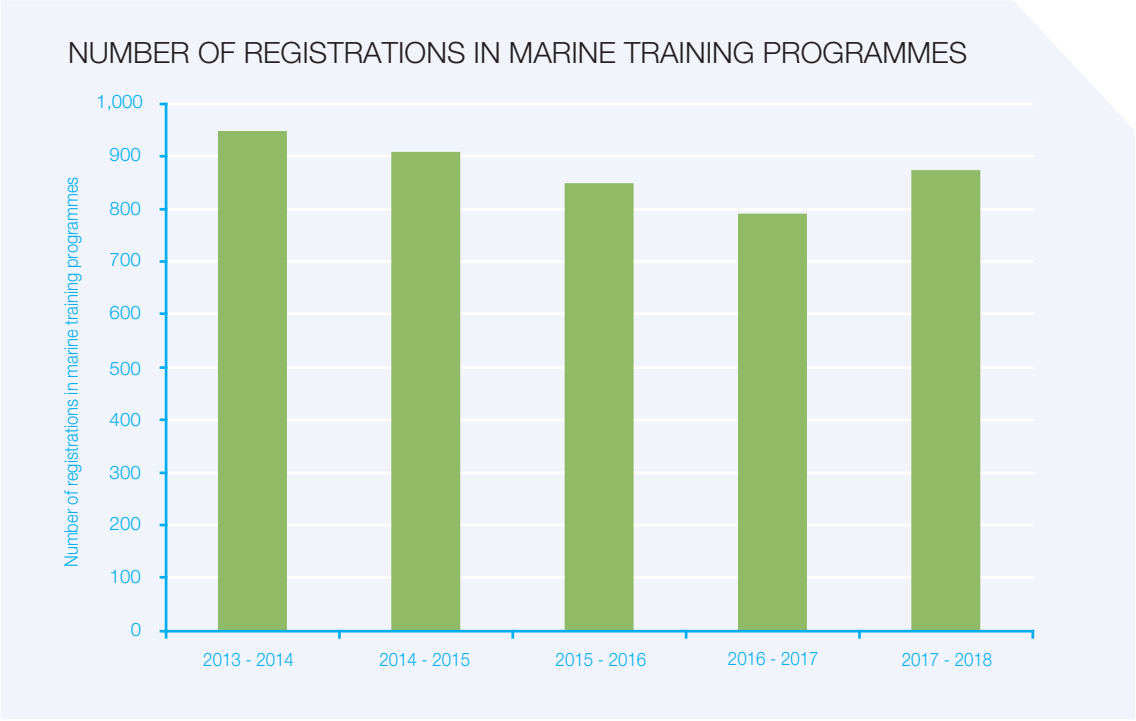

Figure 15. Number of registrations in marine training programmes and courses which are provided by Belgian universities and colleges (included in the Marine Training Portal) in the five scholastic years between 2013-2014 and 2017-2018.

(*Cenflumarin*), *Centrum voor Volwassenonderwijs* (*CVO – maritieme opleidingen*), *Syntra*, *VDAB maritieme opleidingen*, Falck (*training centre Ostend*), etc. are not included.

On average, 875 registrations per year were identified for the Belgian training programmes and courses which are included in the Marine Training Portal for the five scholastic years between 2013-2014 and 2017-2018[9] (figure 15). These registrations can be further classified in the different training typologies that were defined in *Vincx et al. (2018)* (table 6).

As mentioned above, these figures provide a first insight in the magnitude and importance of marine training programmes in Belgium. As such, this report gives information on the 'supply side'. It is the intention to further extend this exercise in the future with numbers about the demand for specialised personnel in the marine professional field. This will provide useful information about the alignment with regard to job qualifications between the marine training programmes and the corresponding job market (cf. the large demand for engineers in maritime companies).

Table 6. The different training typologies as defined in *Vincx et al. (2018)*. *The different marine training programmes and courses which are provided by Belgian universities and colleges sometimes meet the criteria of more than one category. In this situation, the typology was selected which best fits the concerned training programme/course (based on the criteria in the table below).

Training type	Training content	Training conducted by whom	Potential job market	Training format	Average number of registrations (2013-2014 – 2017-2018)*
Research-based University degree Courses (Bachelor, Masters, PhD)	Disciplinary and multidisciplinary scientific, curiosity-driven research training. Mostly requiring a research thesis.	University Staff with research and teaching duties	Scientific research, teaching, private sector, industry, science administration	Mostly full-time presence courses, incremented with e-learning	351
Maritime training for professionals, vocational diploma courses	Shipbuilding and repair, operation, pilotage, maritime law, management of shipping affairs	Universities and institutes of further education	Maritime traffic and all aspects of the shipping and offshore industry	Presence teaching and distance learning	123
Engineering and technology degrees (Bachelor and Masters)	Maritime engineering, ocean engineering, naval architecture, hydrodynamics, marine technology	Technical universities and polytechnics	Engineers and technicians	Mostly full-time presence, work-based training, online and distance learning	293
Specialised sectorial diplomas, certified courses, vocational training courses (Diploma, Bachelor, Masters)	Sector-specific e.g. tourism management, aquaculture and fishing technology, Marine Protected Areas, marine resource management, marine insurance, coastal management	Industry and certified teaching institutes, (technical) universities, NGOs, profit-seeking and non-profit enterprises	Mid- and high-level management in the corresponding sector	Work-based learning, part- and full-time, presence courses, distance learning, internships	107
In-house training of professionals diplomas and certificates	Technology, management and other skills defined per industry	External and internal professional trainers	Career-development within the industry, entry-level and add-on qualifications	Short, targeted offers	This category was not included in this exercise.

3.6 Marine research infrastructure

Ocean Science is 'Big Science' which requires expensive and sophisticated infrastructure (*UNESCO 2017*). Due to the challenging environment present in the seas, ocean and coastal areas and the multidisciplinary nature of marine research, a whole range of specialised marine research infrastructure exists: mobile platforms (research vessels, ships of opportunity), underwater platforms (submarines, Remotely Operated Vehicles (ROVs), etc.), autonomous platforms (Autonomous Underwater Vehicles (AUVs), gliders, etc.), fixed platforms and systems, (in situ) sensors (chemical, biological, geophysical, etc.), remote sensing (satellites, drones, airplanes, radar, etc.), specialised laboratories and analysis capacity, e-infrastructure (databases, models, etc.), collections, etc. (e.g. *EC Expert group on marine research infrastructures 2013*). On the one hand, the availability of the marine research infrastructure determines to a

[9] For comparison: in the scholastic year 2015-2016 47,457 students enrolled in the Flemish Higher Education (*De Kock 2017*).

large extent the marine research that can be carried out. On the other hand, the infrastructure must in turn be linked to the necessary technical and scientific expertise.

Flanders and Belgium dispose of a number of large marine research infrastructures that serve the research community. The marine research infrastructure which is present in the Flemish/Belgian research landscape, as well as in intermediary players in the innovation field such as *OWI-Lab* and *Greenbridge*, is listed in the **Catalogue Marine Research Infrastructure 2018** of the Compendium for Coast and Sea (*Dauwe et al. 2018*).

- The Belgian marine researchers have access to two complementary research vessels:
  - The Belgian Science Policy Office (*BELSPO*) is the owner of the oceanographic research vessel: *RV Belgica*, which carries out marine research in the Belgian part of the North Sea, as well as in the wider European waters. The ship is operated by OD Nature (RBINS) (scientific and budgetary management) and the Belgian Navy (operational aspects). BELSPO provides an annual budget of approximately 2.9 million euro for the operational costs of the RV Belgica. The federal government has taken the decision to replace the RV Belgica by a *new research vessel* by 2020 (see also website *BELSPO*), equaling an estimated investment of 54.45 million euro. Hence, the operational resources will be adapted to the wider range of the new ship.
  - The *RV Simon Stevin* is used for coastal oceanographic research in the Southern Bight of the North Sea and the eastern part of the Channel. The construction of the ship was commissioned by the Government of Flanders and came into service in 2012 (investment of 11.5 million euro + 1 million euro for scientific equipment). The vessel is operated by *VLOOT* (the shipowner of the Government of Flanders, responsible for the operational aspects of the vessel) and VLIZ (responsible for the scientific programme and the management of the research equipment). The Government of Flanders provides an average budget of 1.3 million euro per year for the operational cost of the vessel. An additional budget is reserved for the scientific and operational aspects.

  A cooperation agreement was concluded between the managing authorities of the two research vessels (VLIZ and RBINS) in order to optimally valorise their activities;
- The marine research community in Flanders and Belgium disposes of a satellite laboratory by the sea: the Ostend Marine Station Ostend (*MSO*). The station houses several facilities (storage for sediment cores; wet, dry and molecular laboratories; a cold room with three water tanks for marine organisms; technical workshop; etc.) several of which are used in the framework of European infrastructure networks (see below ESFRI). In 2017, the Government of Flanders decided to invest 3 million euro in the development of a *Marine Robotics Centre* (with various robotic platforms and a technical workshop) within the MSO. Since 1 January 2018 the concession of the MSO was extended to the adjacent site which enables an expansion of the station;
- Through the University of Liège (ULg), the research community disposes of a marine station at the Mediterranean Sea (Calvi, Corsica): *Station Sous-Marines et Océanographiques* (*STARESO*);
- In 2017, the groundbreaking of the *Flanders Maritime Laboratory* in the Science Park (Campus Ostend) was celebrated. This laboratory is an initiative of Ghent University, KU Leuven and Flanders Hydraulics Research and will be operational in 2020. It will house a wave basin (Coastal and Ocean Basin, COB) as well as a towing tank. Together with the involved universities, the Government of Flanders invests 28 million euro in this infrastructure.
- The Blue Accelerator project provides infrastructure (living labs) for marine research institutes and maritime companies to test innovative applications in a marine environment. It *inter alia* concerns an offshore test platform off the coast of Ostend. The project has a total budget of approximately 3.7 million euro, including co-funding from the Government of Flanders (735,400 euro), the Province of West Flanders, the European Regional Development Fund (ERDF, 1.5 million euro) and the partners concerned. (The final decision on this project is still pending);
- Belgium and Flanders participate in several so-called European Strategy Forum on Research Infrastructures (*ESFRI*). Several of these pan-European research infrastructures are of specific relevance to the marine research community: *ICOS* (Integrated Carbon Observation System), *LifeWatch* (virtual laboratory for biodiversity research), *EMBRC* (European Marine Biological Resource Centre) and *EPOS* (European Plate Observing System). The Government of Flanders allocates 2 million euro annually for the 'marine' infrastructures via the FWO (formerly: via the Hercules Foundation). Since 2018, the Flemish participation in these kind of research infrastructures is facilitated by the FWO-call '*International Research Infrastructure*'. The Belgian Science Policy Office (BELSPO) covers the annual Belgian contribution to the ESFRI-infrastructures, as well as the federal participation (equaling an annual contribution for the marine ESFRIs of 340,000 euro in 2018 and a total of 1.3 million euro for the federal participation between 2016 and 2019).

3.7 Funding of marine research and innovation

The marine research and innovation landscape in Flanders is funded by a multitude of channels. The present report provides an overview of the funding streams in the most relevant competitive funding channels for this landscape. This is by no means an exhaustive overview as a number of important funding sources are not included (direct funding of universities and scientific institutes, investments in research infrastructure (see above), etc.).

EUROPEAN FUNDING CHANNELS FOR MARINE RESEARCH AND INNOVATION

In this section, the funding of marine projects with Belgian participation in different European channels is discussed. The selection of European marine research and innovation projects with a Belgian partner was to a large extent made on the basis of the *Marine Knowledge Gate*, in collaboration with *EurOcean* (Cristina Costa, figures provided in April 2018). Data were provided for the following funding channels (period 2009-2017): 7th Framework Programme, Horizon 2020, Interreg IV and Interreg V. It should be noted that other European channels for marine research and innovation funding exist, but no data is currently available for them. Concerning the definition of a 'marine project', the criteria of the queried database was used:

- The project deals with marine and/or maritime research, either entirely or in certain component(s) of the project (for the definition of marine and maritime research reference is made to the *EU Strategy for Marine and Maritime Research*);
- The component(s) of marine/maritime research entail(s) a significant part/funding of the project;
- Projects strictly focused on freshwater are not included.

The reported figures concern partner budgets[10] of Belgian organisations[11]. These budgets are always allocated to the starting year of the project. Entities and organisations belonging to the European Commission and European/international (stakeholder) organisations which are housed in Brussels are excluded from the analysis as much as possible.

7th Framework Programme (FP7)

In the European 7th Framework Programme (FP7, 2007-2013), a total of 204 marine projects with a Belgian partner were funded, representing a total partner budget of 68.4 million euro. When excluding the European and international (stakeholder) organisations, it concerns 140 marine projects with a total partner budget of 46.2 million euro[12]. In 16 of these projects, a Belgian partner acted as the project coordinator.

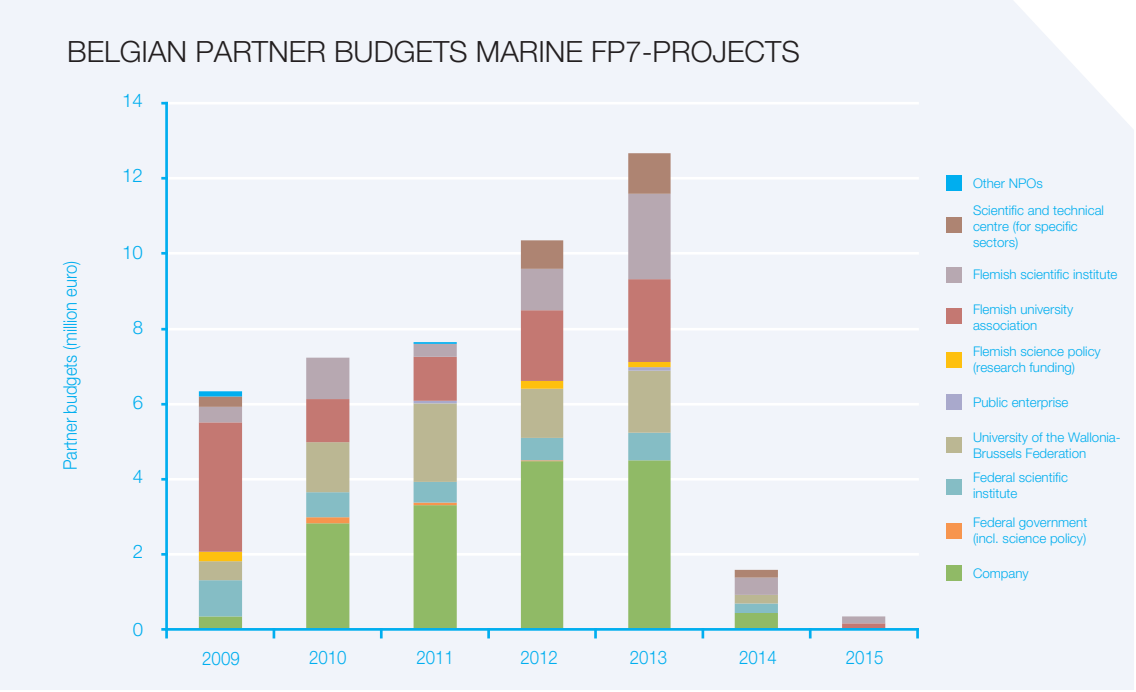

Figure 16. Evolution partner budgets (in million euro) for Belgian organisations (excl. international and European (stakeholder) organisations) in marine FP7-projects according to the type of organisation (budgets are allocated to the starting year of the project).

[10] The partner budget refers to the budget which is allocated to a specific partner within a project. Hence, this publication only deals with budgets for Belgian partners.
[11] Partner budgets which were missing in the European *CORDIS*-database were requested at the EWI Department.
[12] For comparison: The Belgian participation in FP7 equaled 3,652 projects and a budget of 1,814.9 million euro (including European and international (stakeholder) organisations based in Belgium) (*Van Langenhove and Dengis 2014*).

The evolution of the partner budgets of Belgian organisations (excl. international and European (stakeholder) organisations) in marine FP7-projects (figure 16) reveals a clear rising trend in the period 2009-2013 from 6.3 million euro in 2009 to 12.6 million euro in 2013 (with an annual average of 8.85 million euro). The sharp increase in partner budgets for Belgian companies from 0.37 million euro in 2009 to 4.52 million euro in 2013 (average 3.10 million euro per year) is striking. For the university associations and scientific institutes, including MRGs, the funding remains relatively stable with an average of 5.09 million euro/year (2009-2013). The decline in the budgets in 2014 and 2015 is related to the transition towards the next framework programme (Horizon 2020).

Figure 17 provides an overview of the Belgian partner budgets (excl. international and European (stakeholder) organisations) of marine projects, according to the FP7-theme (2009-2015). The main themes that stand out are 'KBBE – Food, agriculture and fisheries, and biotechnology' and 'ENVIRONMENT – Environment (including climate change)'.

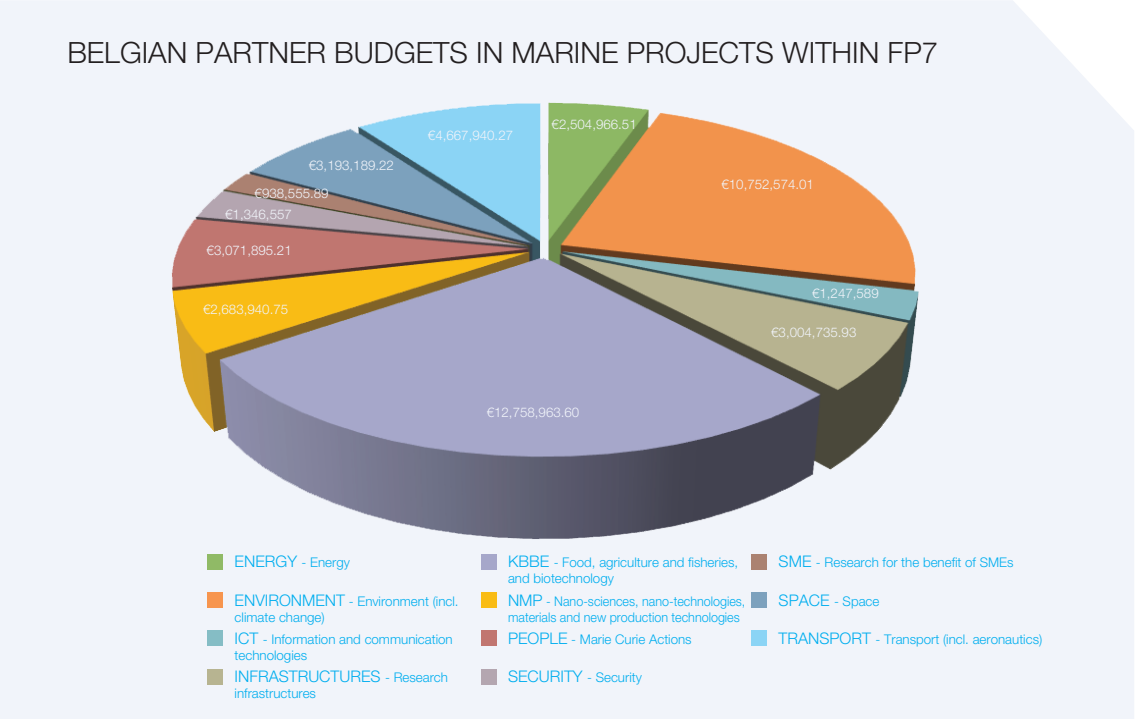

Figure 17. Partner budgets (euro) for Belgian organisations (excl. international and European (stakeholder) organisations) in marine projects, according to the theme within FP7 (2009-2015).

Horizon 2020

Horizon 2020 (2014-2020) united the (successors of) European research and innovation programmes, such as the 7th Framework Programme (FP7, see above), the Competitiveness and Innovation Framework Programme (CIP) and the European Institute of Innovation and Technology (EIT), into one programme. Currently, Horizon 2020 is still ongoing and in the present report budgets are included from 2014-2017. During this period, a total of 68 marine projects were identified with a Belgian partner representing a total partner budget of 52.4 million euro. When the international and European (stakeholder) organisations are excluded, it concerns 59 projects with a total Belgian partner budget of 46.2 million euro. A striking evolution compared to FP7 is that fewer projects have been identified, but they generally have a significantly higher budget. In 9 marine Horizon 2020 projects, a Belgian organisation (excl. international and European (stakeholder) organisations) acted as a project coordinator.

Figure 18 shows the evolution of the partner budgets of Belgian organisations (excl. international and European (stakeholders) organisations) in marine Horizon 2020-projects according to the type of institute (2014-2017). Between 2015 and 2017, this partner budget amounted to an average of 15.4 million euro per year[13], with the largest share

[13] For comparison: The total Belgian Horizon 2020-subsidy amounted to an average of approximately 400 million euro/year (2014-2016) (including international and European stakeholder organisations which are based in Belgium) (*Horizon 2020 in full swing – Three years on – Key facts and figures 2014-2016*).

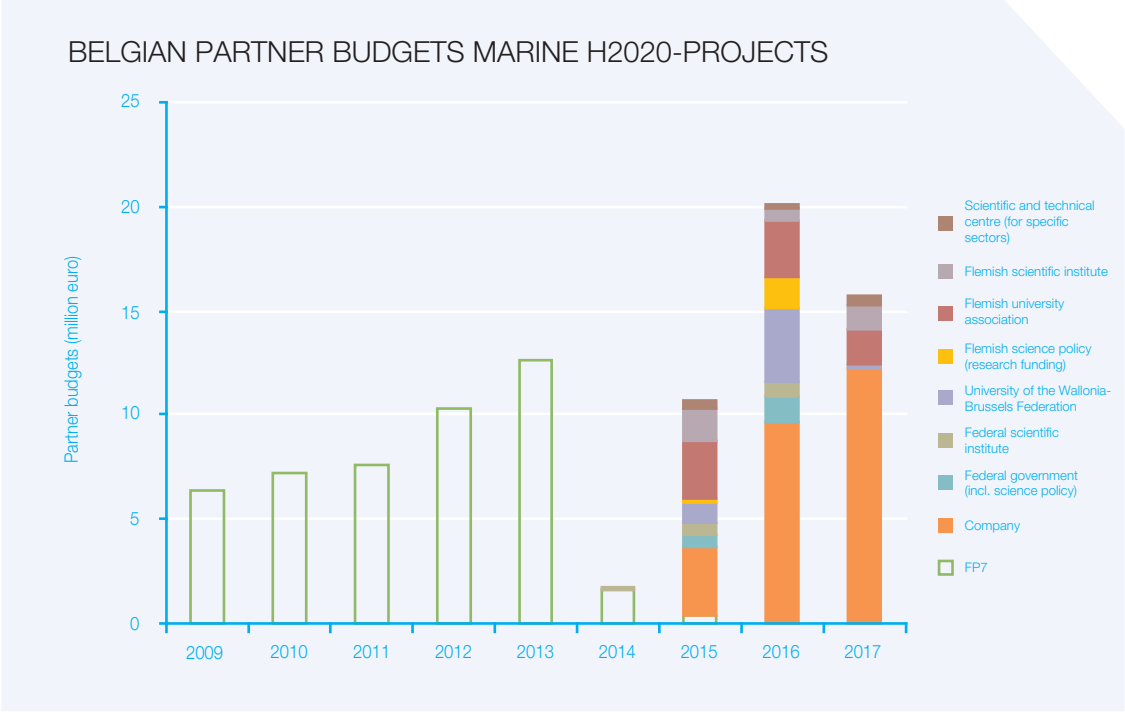

Figure 18. Evolution of partner budgets (in million euro) for Belgian organisations (excl. international and European (stakeholder) organisations) in marine Horizon 2020-projects according to the type of organisation (budgets are allocated to the starting year of the project). For the sake of completeness, the evolution of FP7-funding is also included.

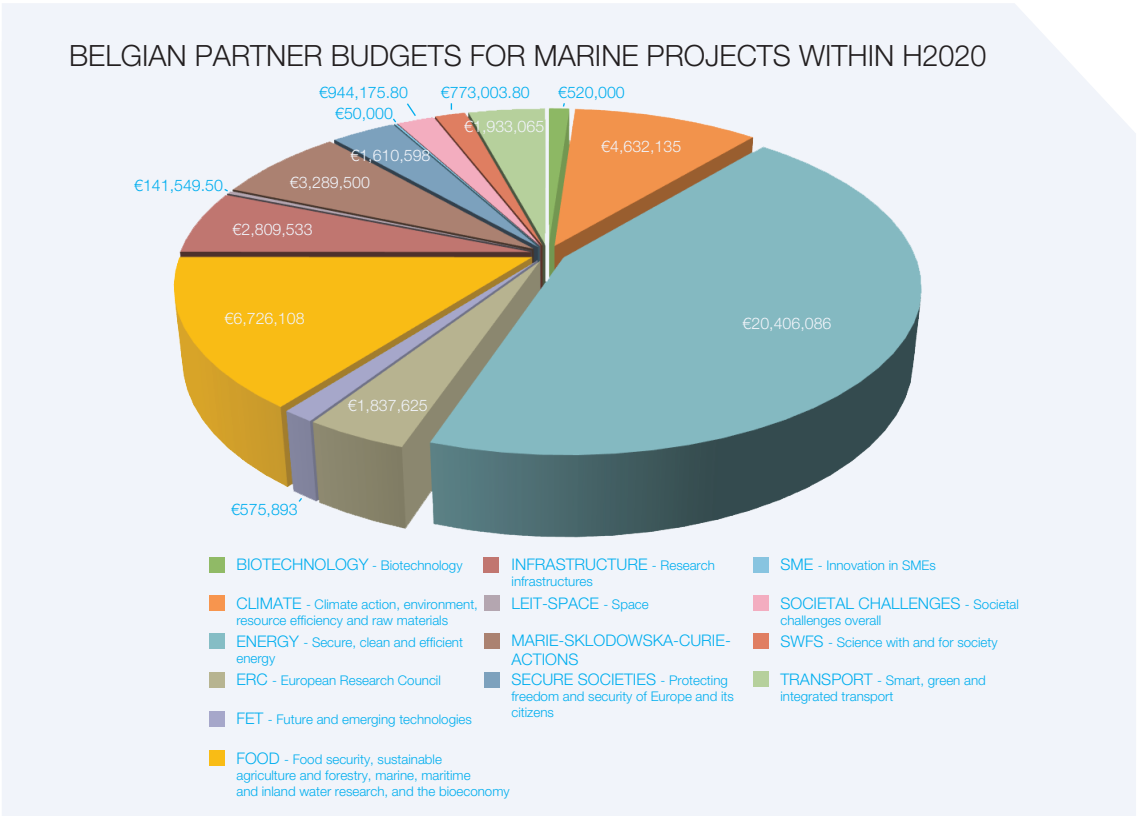

Figure 19. Partner budgets (euro) for Belgian organisations (excl. international and European (stakeholder) organisations) in marine projects, according to the theme within Horizon 2020 (2014-2017).

being taken by companies with an average of 8.4 million euro per year. This is a significant increase compared to FP7 which can be related to changes in the framework programme (integration with CIP, EIT, etc., see above). It is therefore not surprising that two maritime companies are in the top three of Flemish companies when it comes to Horizon 2020-fundraising (*Speurgids Ondernemen & Innoveren 2018*). Horizon 2020-funding for Belgian university associations and scientific institutions, including MRGs, averaged 5.5 million per year (2015-2017), which is a slight increase compared to the average in FP7.

Figure 19 provides an overview of the Belgian partner budgets (excl. international and European (stakeholder) organisations) of marine projects, according to the theme within Horizon 2020 (2014-2017). The lion's share is taken up by the theme 'ENERGY-Secure, clean and efficient energy', which reveals a strong increasing trend compared to FP7. Furthermore, other themes such as 'CLIMATE-Climate action, environment, resource efficiency and raw materials' and 'FOOD-Food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the bioeconomy' account for a significant budget as well.

European Fisheries Fund (EFF) and European Maritime and Fisheries Fund (EMFF)

The European Fisheries Fund (EFF, 2007-2013) and its successor the European Maritime and Fisheries Fund (EMFF, 2014-2020) support the fisheries and aquaculture sector in the Member States in order to achieve the objectives of the European Common Fisheries Policy (CFP). One of the central pillars of this policy is to stimulate innovation in these sectors. The largest part of the fund is distributed by a national government (shared management) on the basis of a national operational programme (*website Agriculture and Fisheries Department*). For the budgets reported below, it should be noted that the amounts of the EFF are listed by year of disbursement (and not by year of approval). Moreover, the scrapping subsidies paid by the EFF in 2009 and 2010 were not included in the figures as they are not related to innovation and cause a significant bias. Finally, it should be noted that the part of the EMFF responsible for promoting and implementing the EU Integrated Maritime Policy is not included in the reported budgets.

Between 2009 and 2017, more than 22 million euro of subsidies were distributed by the EFF (excluding scrapping subsidies) and the EMFF, representing an average of 2.4 million euro per year (figure 20). The EFF and EMFF grants were mainly allocated to companies (average of 1.4 million euro per year), followed by public authorities (average of more than 0.4 million euro per year) and Flemish scientific institutes (average of more than 0.3 million euro per year).

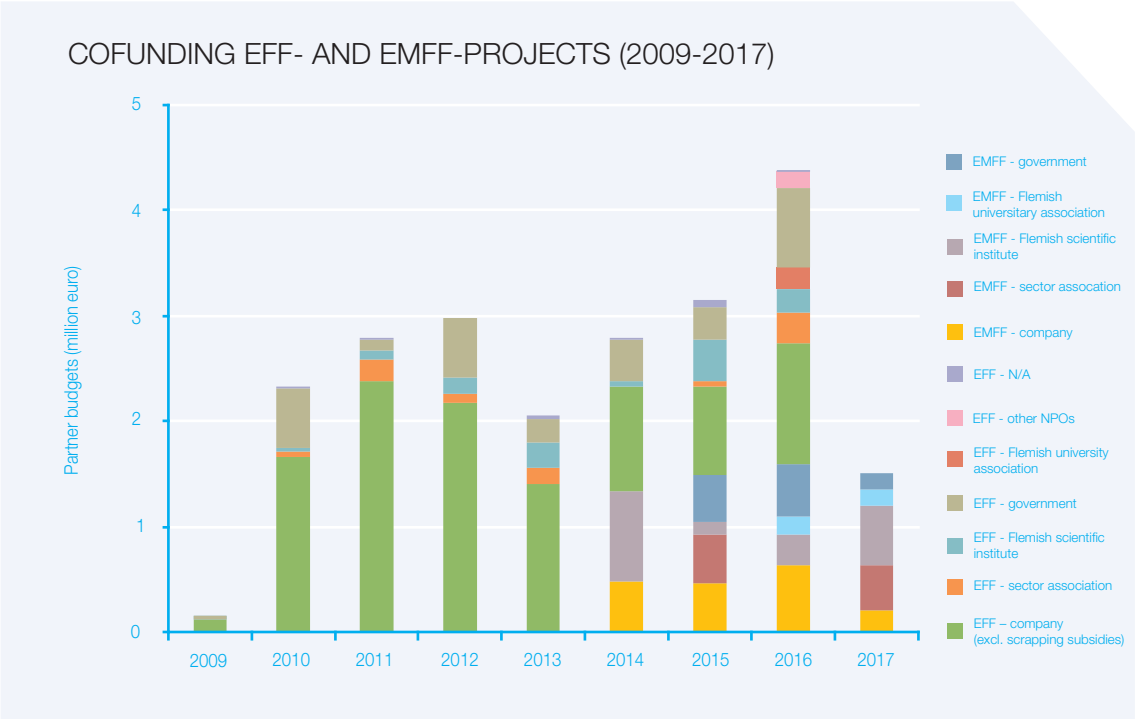

Figure 20. Evolution of the co-funding (in million euro) of EFF- and EMFF-projects for the period 2009-2017 according to type of organisation. Please note that the budgets of EMFF are presented according to the starting year of the project, the EFF-budgets according to the year of disbursement.

European Fund for Regional Development (EFRD) – Interreg programme

The Interreg programme is funded by Europe to promote cooperation between regional areas in different countries. In order to identify the marine Interreg projects, all approved projects of Interreg V (2014-2020) were screened by VLIZ with regard to their (potential) marine theme. Subsequently, the partner budgets of the marine Interreg project were provided by VLAIO. With regard to Interreg IV (2007-2013), the selection of marine projects with a Belgian partner was based on the inclusion in the Marine Knowledge Gate of EurOcean. Due to the different approach, the marine Interreg IV projects with Belgian participation have a lower degree of completeness than Interreg V. Hence, only the marine Interreg V projects will be discussed in more detail.

The Interreg V programme is currently still ongoing. Between 2015 and 2017, a total of 30 projects have started, equaling a total ERDF-subsidy of 23.6 million euro. The largest part of this subsidy was attributed to public authorities (7.5 million euro) and Flemish university associations (5.3 million euro) (figure 21). Companies, public enterprises and business clusters together raised 4.3 million euro in Interreg V subsidies. A striking element is that there is a fairly large gap between the various Interreg programmes (IV and V). This calls for caution when calculating averages.

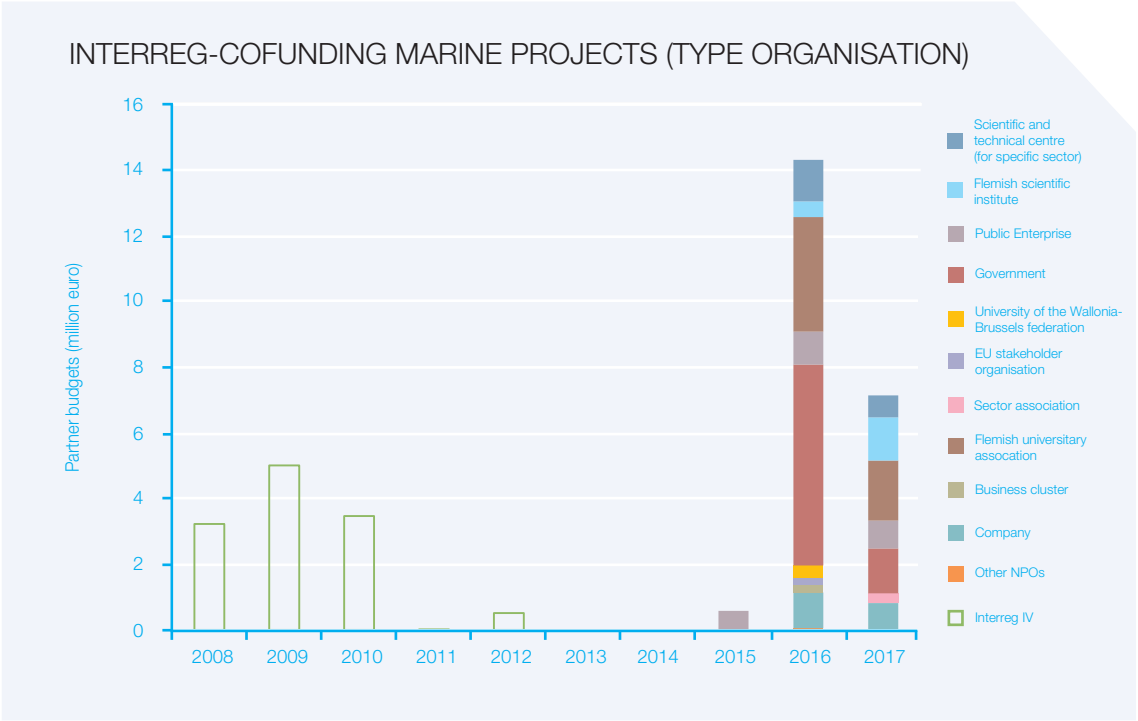

Figure 21. Evolution of the cofunding (in million euro) of marine Interreg projects according to the type of organisation (budgets are allocated to the starting year of the project). It should be noted that Interreg IV has a lower degree of completeness than Interreg V.

Figure 22 shows that most marine projects in Interreg V (period 2015-2017) were funded within the Flanders-Netherlands programme (6.3 million euro), followed by Interreg 2 Seas (6.0 million euro) and France-Wallonia-Flanders (4.5 million euro).

FEDERAL FUNDING OF MARINE RESEARCH - BELSPO

On the basis of the information available on the BELSPO-website and the Fedra-database, a selection of marine BELSPO-projects was made. After validation by BELSPO, a final list was obtained of 65 marine BELSPO-projects funded by different programmes with a starting date between 2008 and 2017 (different phases of a project are not counted separately). With the exception of one project, at least one MRG was involved in each of the selected projects.

Figure 23 shows the evolution of the budgets for the marine BELSPO-projects (2008-2017) according to the type of organisation. This figure also includes the budget which was attributed to an MRG. The decline in the budget in 2011

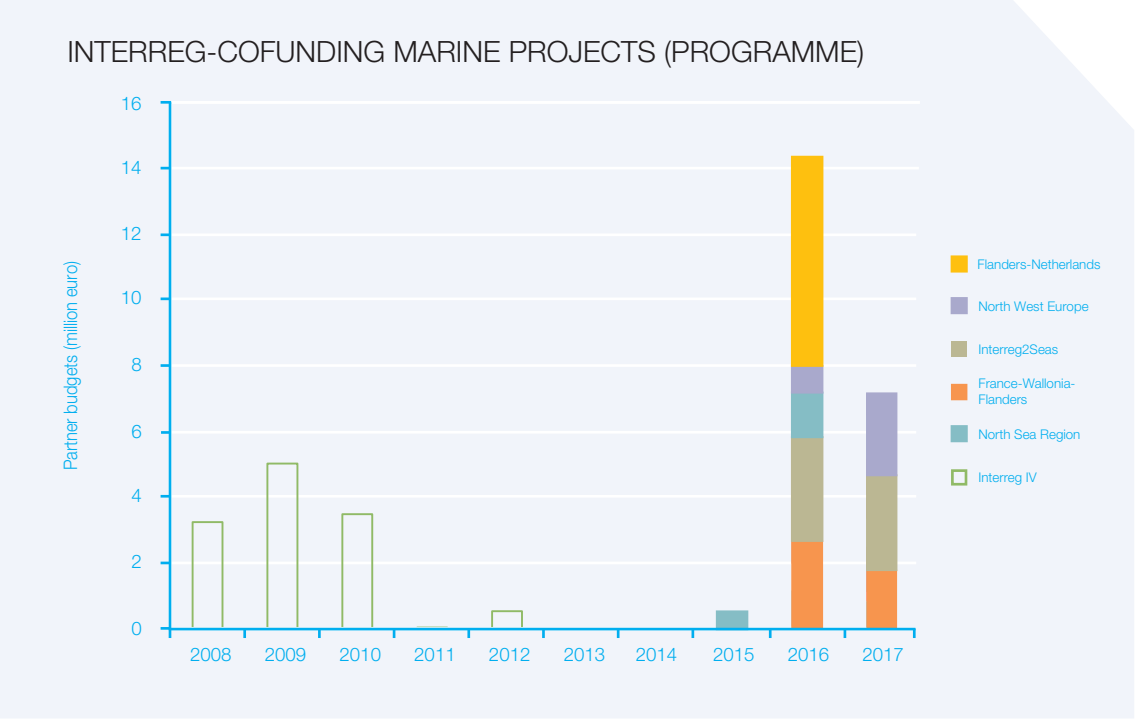

Figure 22. Evolution of the cofunding (in million euro) of marine Interreg projects according to the various programmes (budgets are allocated to the starting year of the project). It should be noted that Interreg IV has a lower degree of completeness than Interreg V.

can be attributed to the crisis of the federal government. After 2012, a clear downward trend in the funding of marine projects can be observed from 6.6 million euro in 2012 to 1.8 million euro in 2017, equaling an average of 3.9 million euro per year (2012-2017). For the MRGs, the average amounted to 3.4 million euro per year in this period.

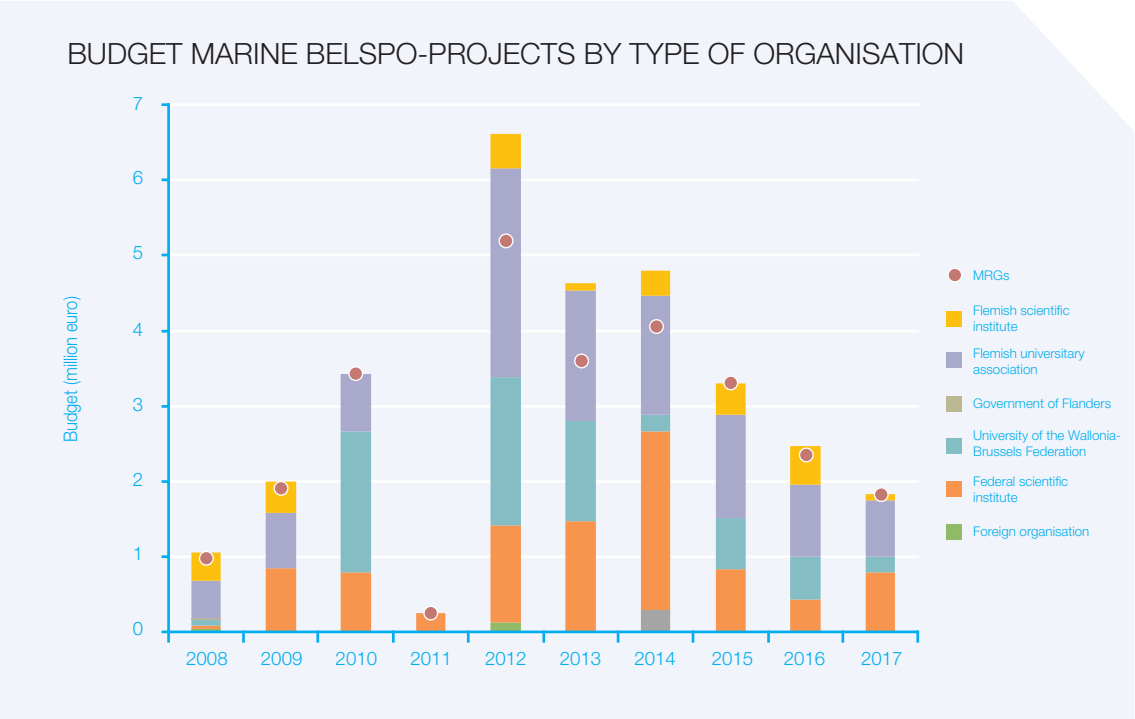

Figure 23. Evolution of the annual BELSPO-budget (in million euro) for marine projects according to the type of organisation (budgets are allocated to the starting year of the project).

The evolution of the BELSPO-funding of marine projects according to the programme is shown in figure 24. This graph reveals the large share of marine projects funded by the BRAIN-be (Belgian Research Action Through Interdisciplinary Networks) programme in the period 2012-2017 (average 2.7 million euro per year).

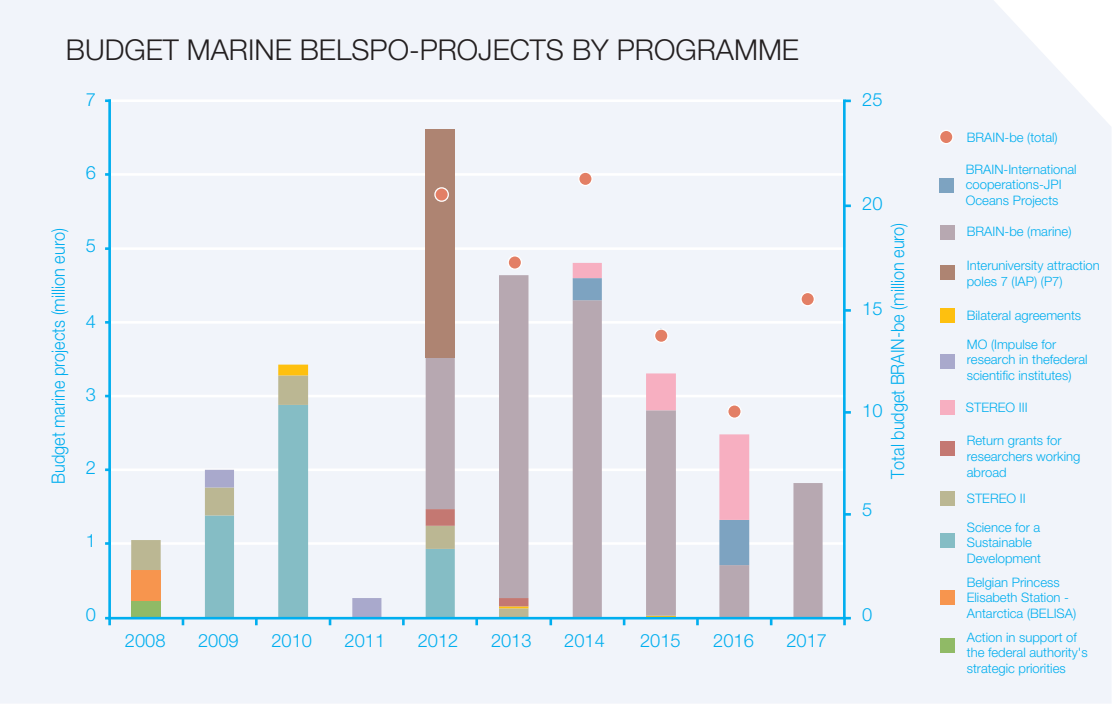

Figure 24. Evolution of the annual BELSPO-budget (in million euro) for marine projects according to the funding programme (budgets are allocated to the starting year of the project). The figure also shows the total annual budget of the BRAIN-be-programme (for all axes).

FLEMISH FUNDING CHANNELS FOR MARINE RESEARCH AND INNOVATION

The text below provides an overview of the funding of marine research and innovation projects through the following Flemish channels: Research Foundation - Flanders (FWO), Special Research Fund (*Bijzonder Onderzoeksfonds*) (BOF), Flanders Innovation & Entrepreneurship (VLAIO, and IWT) and VLIR-UOS.

Research Foundation – Flanders (FWO)

In order to map out marine FWO-projects and mandates, the following approach was used: based on a list of (potential) project promoters affiliated with the marine research groups (MRGs, 2008-2017) (provided by VLIZ in the spring of 2018), FWO was able to generate a broad selection of projects and mandates with a possible marine theme. Subsequently, this broad list was carefully screened by VLIZ to select projects and mandates with a marine topic.

In the period 2008-2017, a total of 118 marine FWO-projects were identified (with a promoter affiliated with an MRG), representing a total amount of 24.9 million euro or an average of 2.5 million euro per year[14]. A downward trend can be observed with a peak of 6.1 million euro (27 projects) in 2009 to less than 1 million euro (3 projects) in 2017 (figure 25). This decrease shows a correlation with the decline in the overall success rate of FWO-research projects (Source: *FWO bestedingsanalyse*).

With regard to the FWO-mandates, 174 marine mandates (with a supervisor affiliated with an MRG) were counted between 2008 and 2017, representing a total budget of 25.0 million euro. The mandates can be further divided into aspirant mandates (8.7 million euro) and post-doc mandates (16.4 million euro). It should be noted that the renewal of a mandate is counted separately. After a peak in the marine FWO-mandates in 2009 equaling 4.2 million euro in

[14] For comparison: Within the pillar 'Fundamental Research' of FWO, a total of 117 million euro (and after budget adjustment 129 million euro) was provided for research projects in 2017 (*Speurgids Ondernemen & Innoveren 2018*).

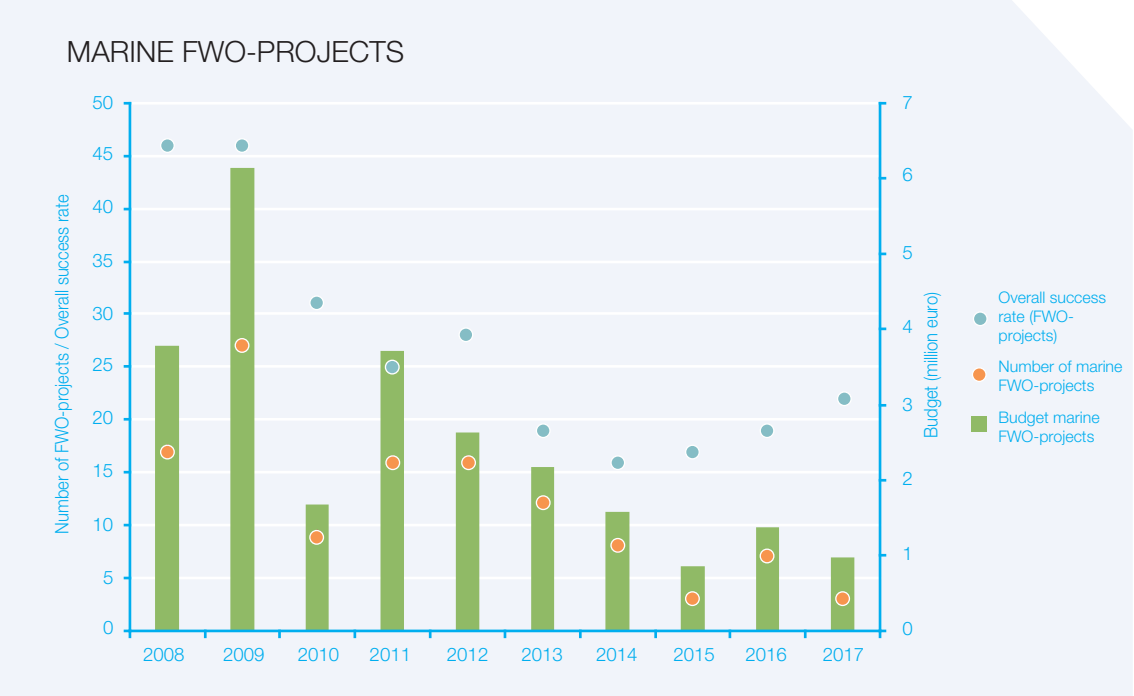

Figure 25. Evolution of the annual budget (in million euro) for marine FWO-projects (with a promoter affiliated with an MRG) (budgets are allocated to the starting year of the project). The figure also shows the number of marine FWO-projects funded per year, as well as the overall success rate for FWO-research projects (number) (Source: FWO bestedingsanalyse).

funding, a rather downward trend can be observed to 1.2 million euro in 2016 (figure 26). This corresponds to an average annual budget of 2.5 million euro in the period 2008-2017[15]. In contrast to the FWO-projects, there is no or only a limited correlation with the overall success rate of FWO-mandates (Source: *FWO bestedingsanalyse*).

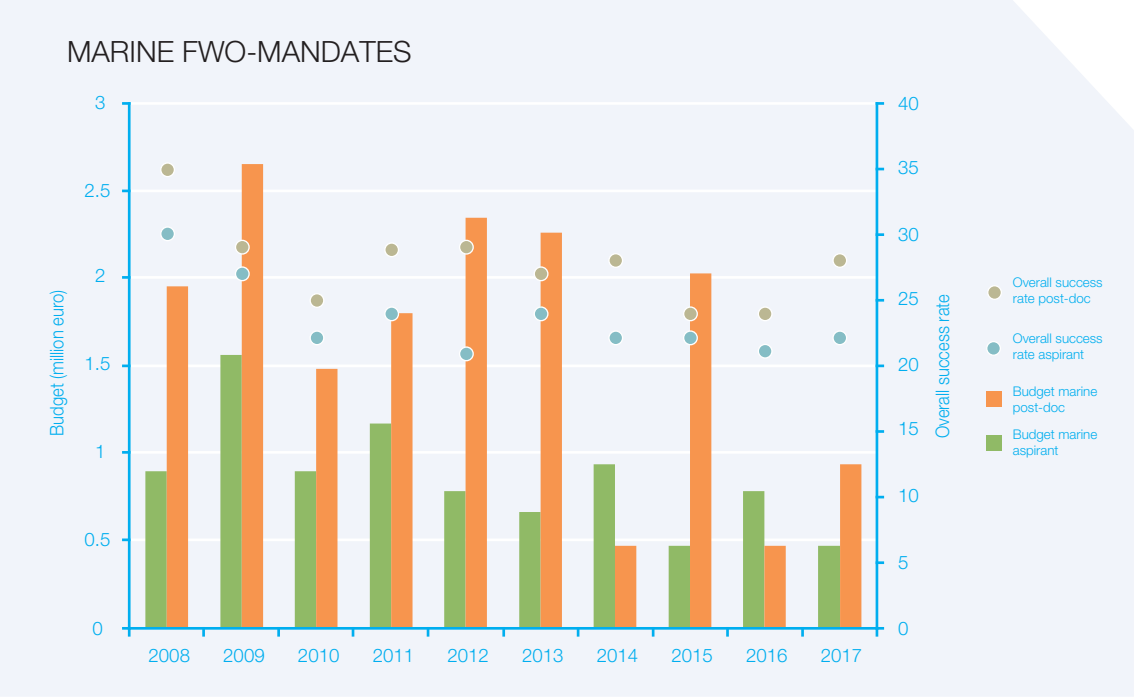

Figure 26. Evolution of the annual budget (in million euro) for marine FWO-mandates (with a promoter affiliated with an MRG) (budgets are allocated to the starting year of the project). The figure also shows the general success rate for FWO-mandates (Aspirant and Post-doc) (Source: FWO bestedingsanalyse).

[15] For comparison: Within the pillar 'Fundamental Research' of FWO, a total of 66 million euro (and after budget adjustment 60 million euro) was provided for mandates in 2017 (*Speurgids Ondernemen & Innoveren 2018*).

Special Research Fund (Bijzonder Onderzoeksfonds, BOF)

For the inventory of marine BOF-projects and -mandates, the following method was used: based on a list of (potential) project promoters affiliated with a marine research group (MRG, 2008-2017) (provided by VLIZ in the spring of 2018), a large selection of BOF-projects and -mandates with a possible marine theme was extracted from the *FRIS research portal* (ESI Department). Subsequently, this broad list was carefully screened by VLIZ for projects and mandates with a marine topic.

A total of 156 marine BOF-projects and -mandates (with a promoter affiliated with an MRG) were identified. This corresponds to a total budget of 43.2 million euro or an average of 4.3 million euro per year[16]. The numbers fluctuate considerably without a clear trend, although it can be noted that the years with outliers in funding are characterised by the approval of one or more Concerted Research Actions (GOAs) that have a duration of several years (figure 27).

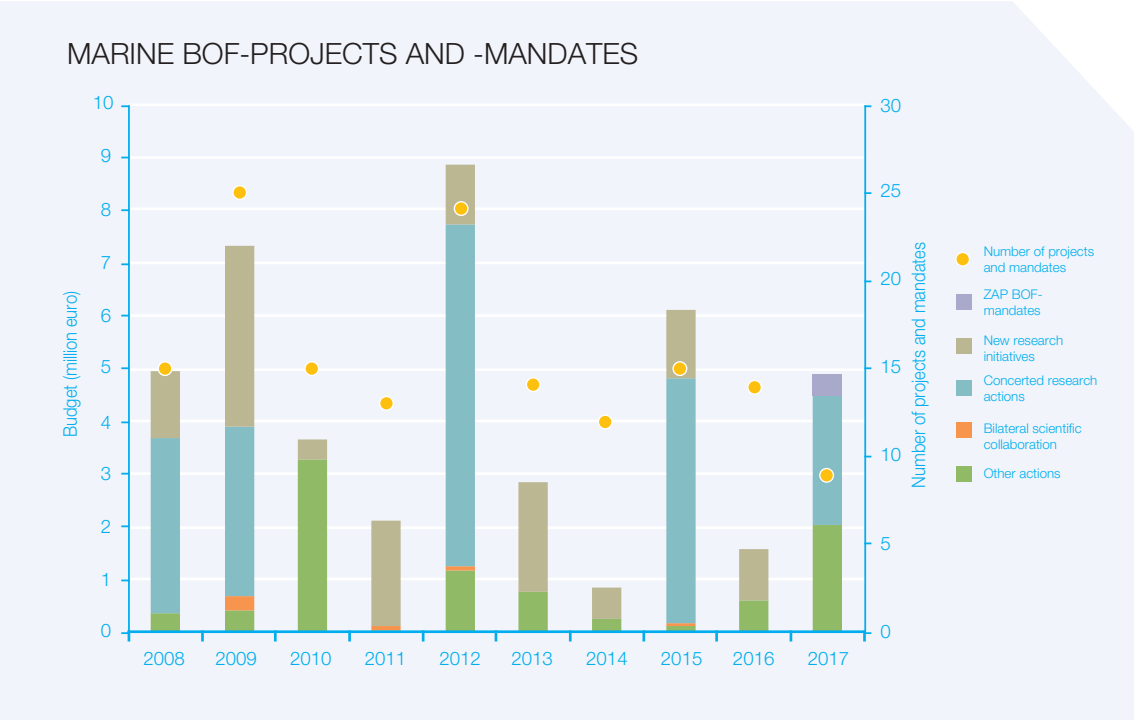

Figure 27. Evolution of the annual BOF-budget (in million euro) for marine projects and mandates (with a promoter affiliated with an MRG) according to the funding programme (budgets are allocated to the starting year of the project). The figure also shows the number of marine BOF-projects and –mandates which are funded per year.

Flanders Innovation & Entrepreneurship (VLAIO, and IWT)

For the mapping of marine VLAIO (and IWT) -projects and -mandates, the following approach was used: based on a list of key words, a broad selection of potential marine projects and mandates that were funded by IWT (until 2015) and subsequently by VLAIO[17] was made. This list was carefully screened by VLIZ for initiatives with a marine finality. It should be noted that in 2016 the Strategic Basic Research (SBO) section of IWT has been transferred to FWO.

A total of 147 marine projects and mandates were identified that were funded by VLAIO or IWT between 2008 and 2017 (figures 28 and 29). This corresponds to a total budget of 59.0 million euro or an average of 5.9 million euro per year. This annual average can be further divided into 1.7 million euro for projects with companies only, 1.9 million euro for joint projects with companies and knowledge institutes and 2.4 million euro for projects with only knowledge institutes. Within the latter two categories, projects with a participation of an MRG represent an average of 3.7 million euro per year.

[16] For comparison: in 2017 and 2018, the Flemish universities received a total of more than 170 million euro annually (156 million euro in 2016) (*Speurgids Ondernemen & Innoveren 2018*).
[17] VLAIO was established in 2016 as an integration of Enterprise Flanders (AO) and the business-oriented services of the Agency for Innovation by Science and Technology (IWT).

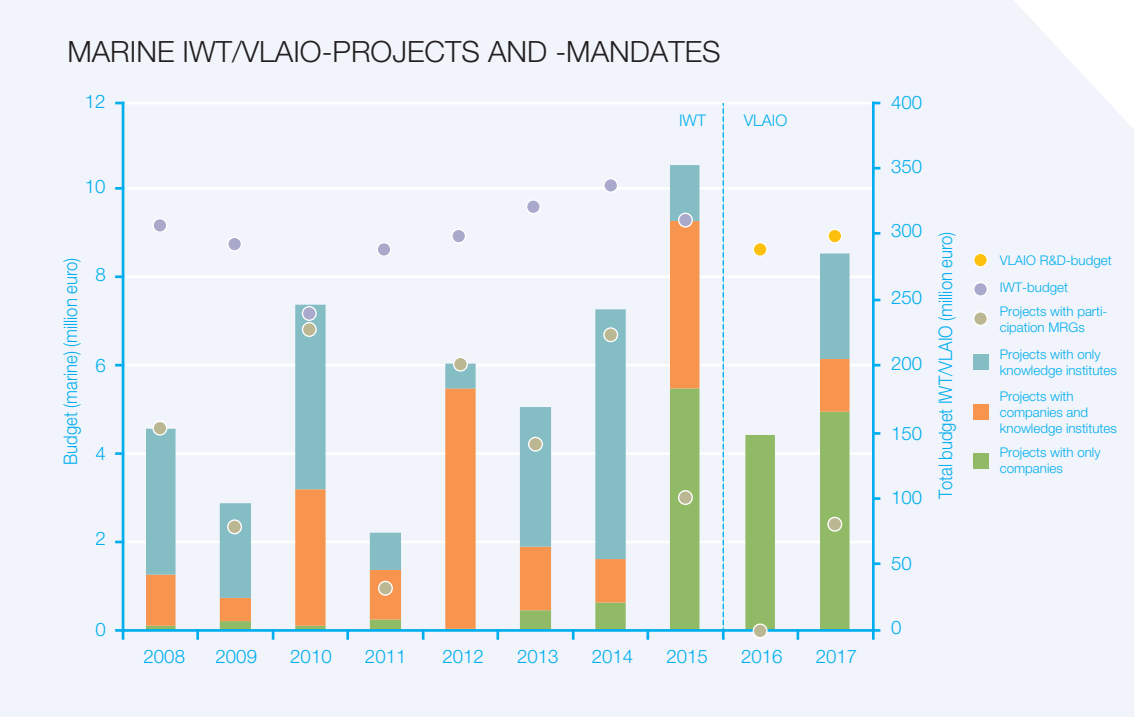

Figure 28. Evolution of the annual IWT/VLAIO-budget (in million euro) for marine projects and mandates according to the participation of companies, knowledge institutes and MRGs (total project budgets are allocated to the starting year of the project). The figure also shows the evolution of the total IWT-budget (million euro) and the science and innovation resources of VLAIO (million euro) (Source: annual reports IWT and Speurgids Innoveren en Ondernemen).

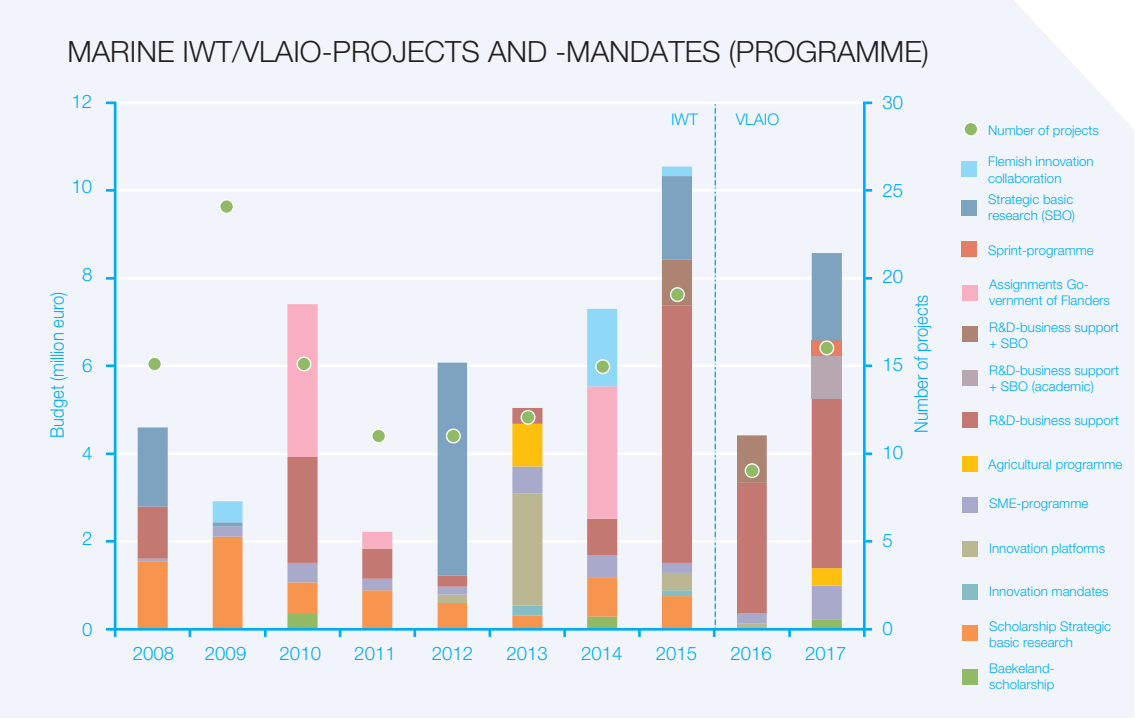

Figure 29. Evolution of the annual IWT/VLAIO-budget (in million euro) for marine projects and mandates according to the funding programme (total project budgets are allocated to the starting year of the project).

The transition from IWT to VLAIO is marked by a clear increase in the number of projects in which only companies participate and an associated increase in funding through the R&D-business support programme. There seems to be a (slight) decrease in the funding for knowledge institutes and MRGs since VLAIO was founded. It should be noted however, that for VLAIO and IWT we only dispose of the full project budgets (and not the partner budgets), which prohibits a detailed analysis. Nevertheless, the possible decrease could be attributed to the extinction of channels such as SBO-projects and -scholarships (strategic basic research, now included in FWO) that specifically serve knowledge institutes. In general, little or no correlation is observed between the evolution of marine IWT/VLAIO-funding on the one hand and the total budget of IWT and the science and innovation resources within VLAIO on the other hand.

32% of the marine IWT- and VLAIO-funding was allocated to projects related to blue energy (offshore wind, wave energy, offshore energy storage, etc.) (period: 2008-2017) (figure 30). In addition, there are various Blue Economy-themes that represent between 5% and 10% of the marine IWT- and VLAIO-budget (2008-2017): seabed mining (11%), offshore materials (8%), hydraulic engineering (8%), marine biotechnology (8%), aquaculture (6%), etc.

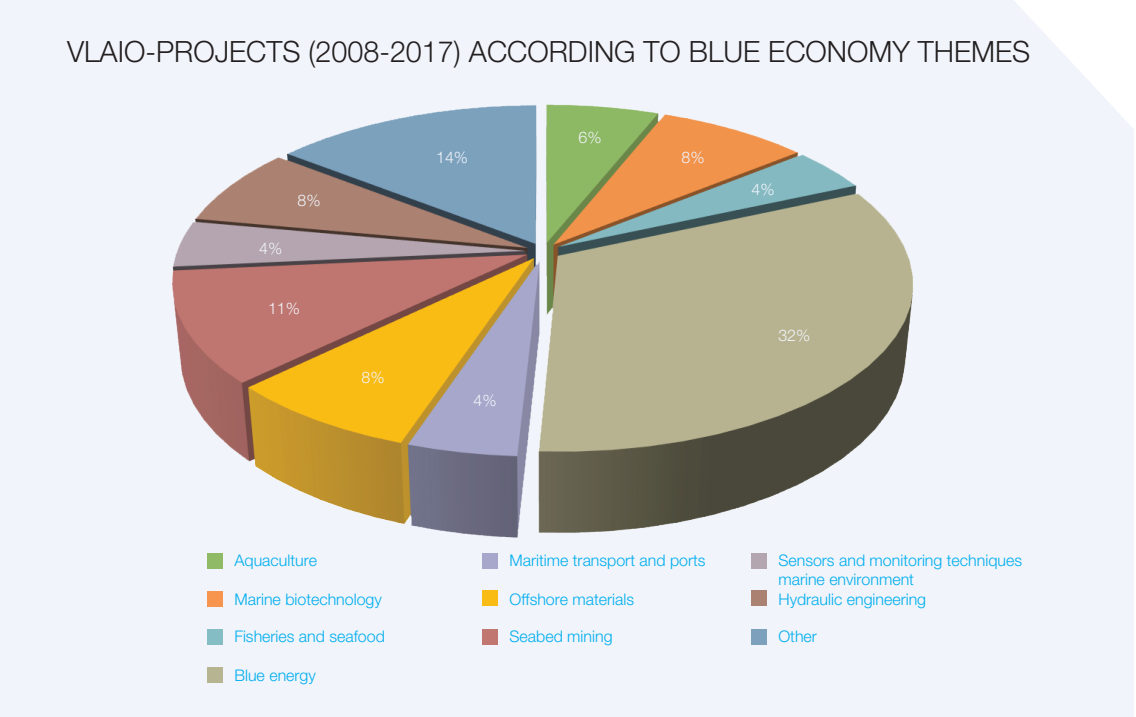

Figure 30. Distribution of IWT/VLAIO-funding in the period 2008-2017 according to the various Blue Economy-themes. Note: A project can be allocated to more than one theme.

VLIR-UOS

The selection of VLIR-UOS-projects, -programmes and -mandates with a possible marine theme was made by VLIR-UOS, based on the (potential) project promoters affiliated with a marine research group (MRG, 2008-2017) (provided by VLIZ in the spring of 2018). This broad list was then carefully screened by VLIZ for initiatives with a marine topic.

In total, 68 marine VLIR-UOS-projects, -mandates or -programmes were identified between 2008 and 2017 (with a promoter affiliated with an MRG), representing a total budget of 11.0 million euro (1.1 million euro/year on average)[18]. No clear trend can be observed in the marine VLIR-UOS-funding, although a decline can be observed in the number of initiatives in recent years (but not necessarily in the budget) (figure 31).

More than half of the total VLIR-UOS-budget for marine projects, mandates or programmes (with a promoter affiliated with an MRG) was allocated to the so-called International Course Programme (ICP) to support capacity building activities within the marine training programmes in Flanders (see **3.5 Marine and maritime education and training programmes**) (figure 32).

[18] For comparison: in 2016, the total budget of VLIR-UOS amounted to approximately 35 million euro (*VLIR-UOS Annual Report 2016*).

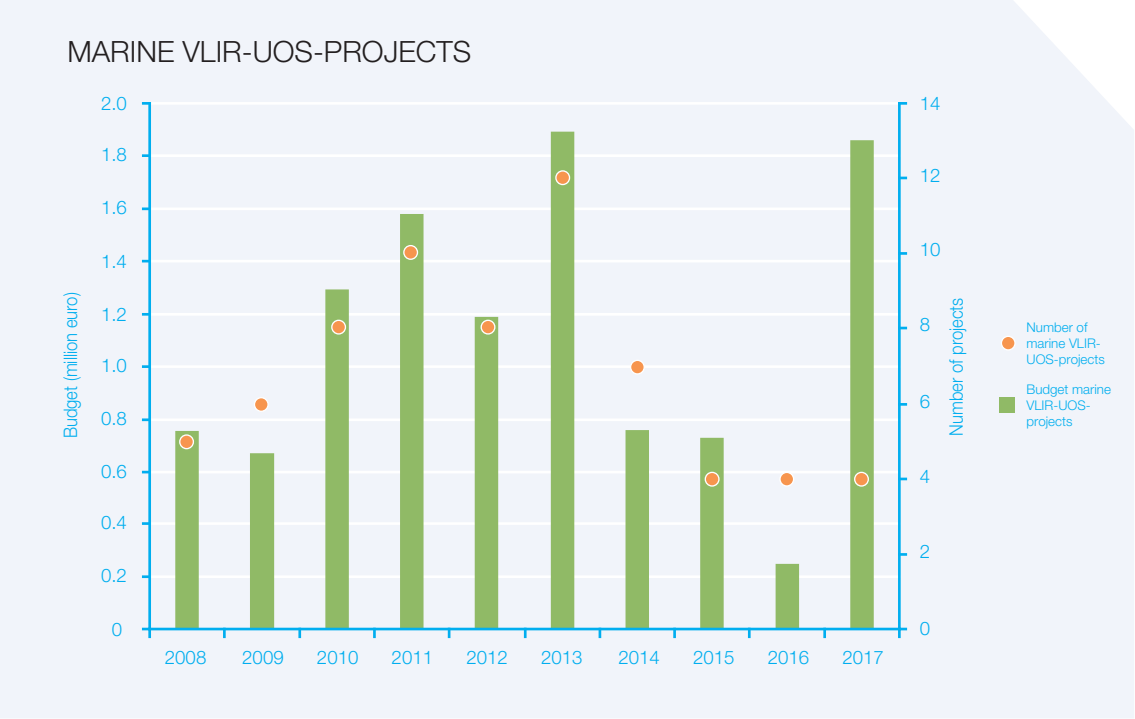

Figure 31. Evolution of the annual VLIR-UOS-budget (in million euro) for marine projects, mandates and programmes (with a promoter affiliated with an MRG) (budgets are allocated to the starting year). The figure also shows the number of marine VLIR-UOS-projects, -mandates and -programmes funded per year.

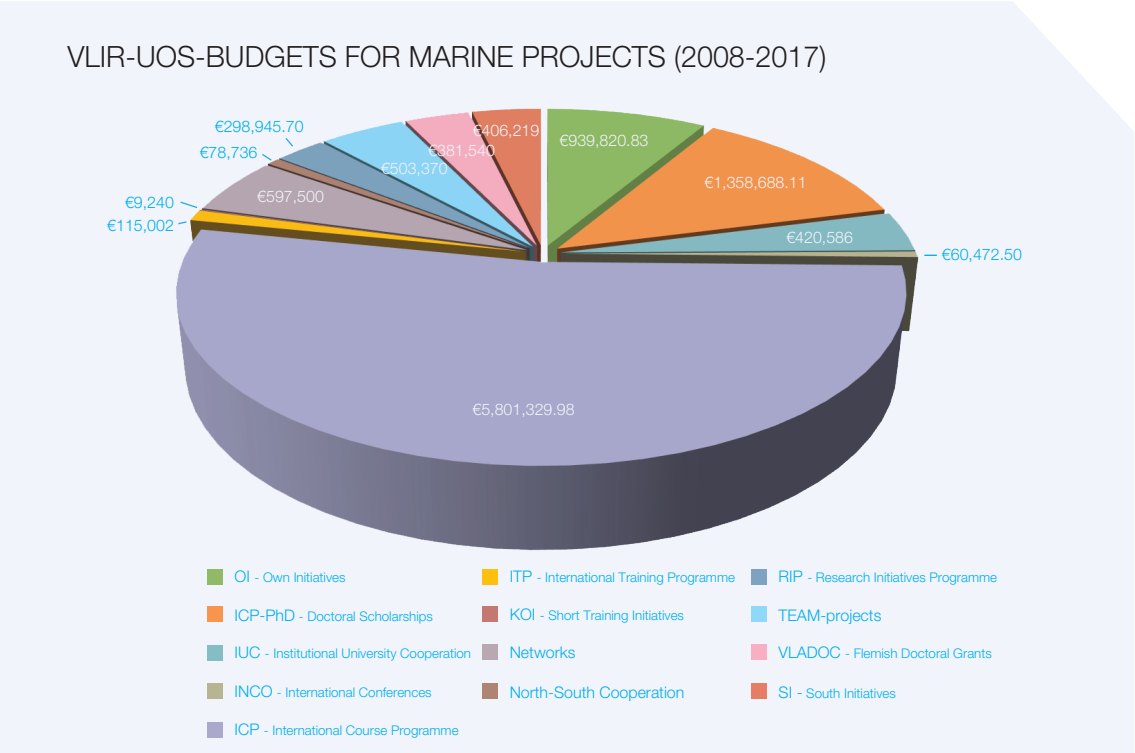

Figure 32. Distribution of the VLIR-UOS-budget (euro) for marine projects, mandates and programmes (with a promotor affiliated with an MRG) according to the programme (period 2008-2017).

OVERVIEW OF 10 YEARS FUNDING OF MARINE RESEARCH AND INNOVATION (2008-2017)

The current Indicator Report lists the budget streams for marine research and innovation in Flanders/Belgium (knowledge institutes and companies) in the most evident competitive funding channels. Hence, it is worthwhile to integrate the reported figures over the past 10 years in order to detect trends in the funding of the marine research and innovation landscape. However, there are a number of important restrictions and remarks that have to be taken into account:

- The reported figures do not present an exhaustive overview of the funding of the marine research and innovation landscape. A number of important funding streams are not included in the report: e.g. direct public funding of universities and scientific institutes, investments in research infrastructure, additional funding channels such as CIP, COSME, COST, FIVA, etc.;
- The reported figures are not always coherent over the entire period 2008-2017:
  - Horizon 2020 is not an exact copy of FP7 as other channels such as the Competitiveness and Innovation Framework Programme (CIP) and the European Institute of Innovation and Technology (EIT) have also been integrated;
  - VLAIO was established in 2016 from the merger of IWT and Enterprise Flanders (AO). Certain funding programmes of IWT were transferred to FWO. It should be noted that in the current report only the projects and mandates of IWT are included in the period before 2016;
  - The figures of the EFF are the only ones reported according to the year of disbursement (and not according to the starting year of the project), which causes a (very) slight distortion of the trend;
  - The budget of the Interreg programme was not included in this overview, as the different degree of completeness between Interreg IV and V may cause a distorted trend;
- VLIR-UOS is distributed on a Flemish level but the underlying funding is linked to a federal budget line. Hence, the VLIR-UOS budget was included in the federal funding in figure 33.

Taking into account the aforementioned limitations and remarks, the following findings with regard to the funding of marine research and innovation can be noted (figures 33 and 34):

- No clear trend (neither increasing nor decreasing) can be observed in the total sum of reported funding for marine research and innovation projects (2008-2017);
- In the period 2008-2017, there were a number of short-term decreases in marine research and innovation budgets that can be related to major changes in research funding institutes. A striking example is the transition from FP7 to H2020 (2014), but also the switch from IWT (and Enterprise Flanders) to VLAIO (2016) (and the transfer of certain IWT-programmes to FWO) and the federal start-up of the BRAIN-be-programme (2011) can be classified under this category. It should be noted that these short-term decreases are accentuated by the way in which the funding is presented (with the exception of EFF, the budget of a project is fully allocated to the starting year);
- Over the past 10 years, the funding for marine/maritime companies has gradually increased in the reported channels. This increase is mainly observed in the Flemish and European funding and can be partly linked to the aforementioned limitations of the reported figures that occur during the transition from FP7 to Horizon 2020 and IWT to VLAIO. For some of the precursors of Horizon 2020 (CIP, EIT, etc.) and VLAIO (Enterprise Agency) we do not dispose of figures on the budget. Furthermore, the observed increase in funding for marine/maritime companies can be attributed to policy decisions at the European and Flemish level to explicitly focus on so-called Blue Growth sectors (see e.g. COM (2012) 494 and COM (2014) 254. It is to be expected that this increase will continue with the establishment of the *Blue Cluster*, the Flemish spearhead cluster that specifically focuses on blue innovation;
- Linked to the point above, it can be observed that the importance of European funding for the Flemish/Belgian marine research and innovation landscape is gradually increasing. As mentioned earlier, it should be underlined that Horizon 2020 is not an exact copy of FP7. The figures also show that the increase in budget for marine European projects with a Flemish/Belgian partner is not linked to an increase in the number of projects (evolution towards fewer projects with a higher partner budget);
- The funding of marine research at university associations reveals a rather decreasing trend. This decrease is mainly observed in the channels for fundamental research such as FWO and BELSPO. As far as the federal research programme is concerned, this trend may probably be attributed to the policy decision to reduce the programmatic funding that is relevant for marine research. At present, the underlying causes for the decrease in FWO-funding for marine research are not entirely clear. Certainly for the research projects, the decrease in the overall success rate seems to play a role. However, it is unclear to what extent other factors (excellence, policy decisions of universities, an evolution towards more applied research, etc.) exert an influence as well.

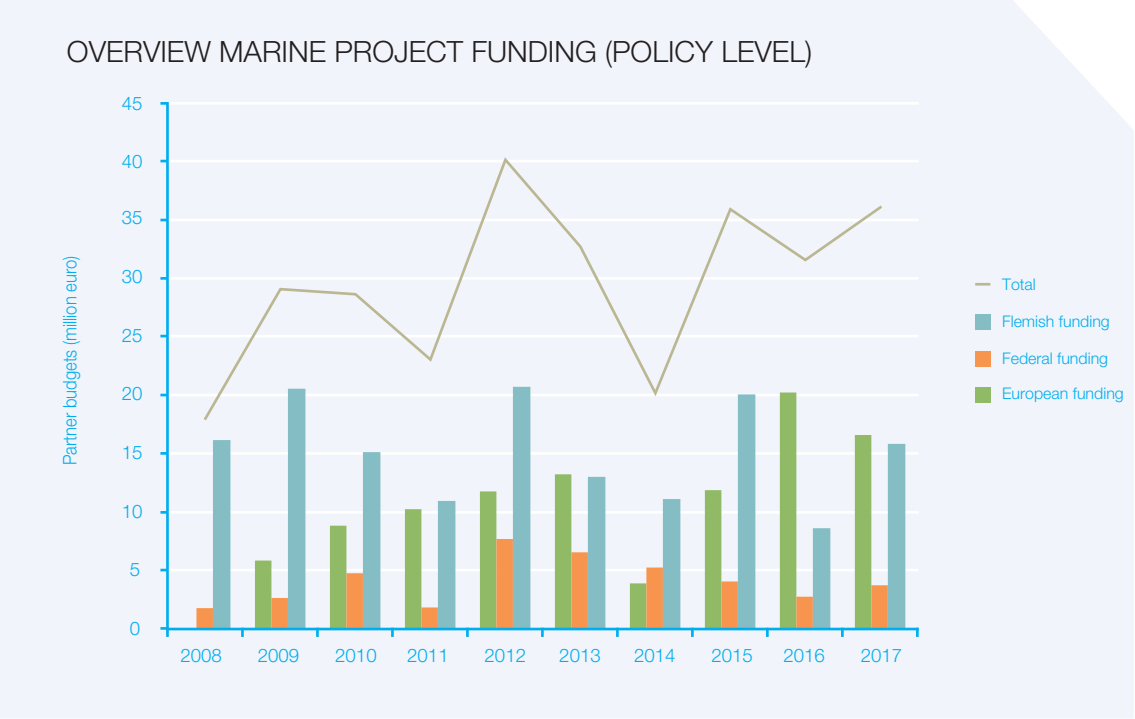

Figure 33. Evolution of the sum of the reported funding channels for marine research and innovation at European (FP7, H2020, EMFF- and EFF-cofunding), federal (BELSPO and VLIR-UOS) and Flemish level (FWO, BOF, IWT and VLAIO) in the period 2008-2017. (With the exception of EFF, project budgets are allocated to the starting year of the project).

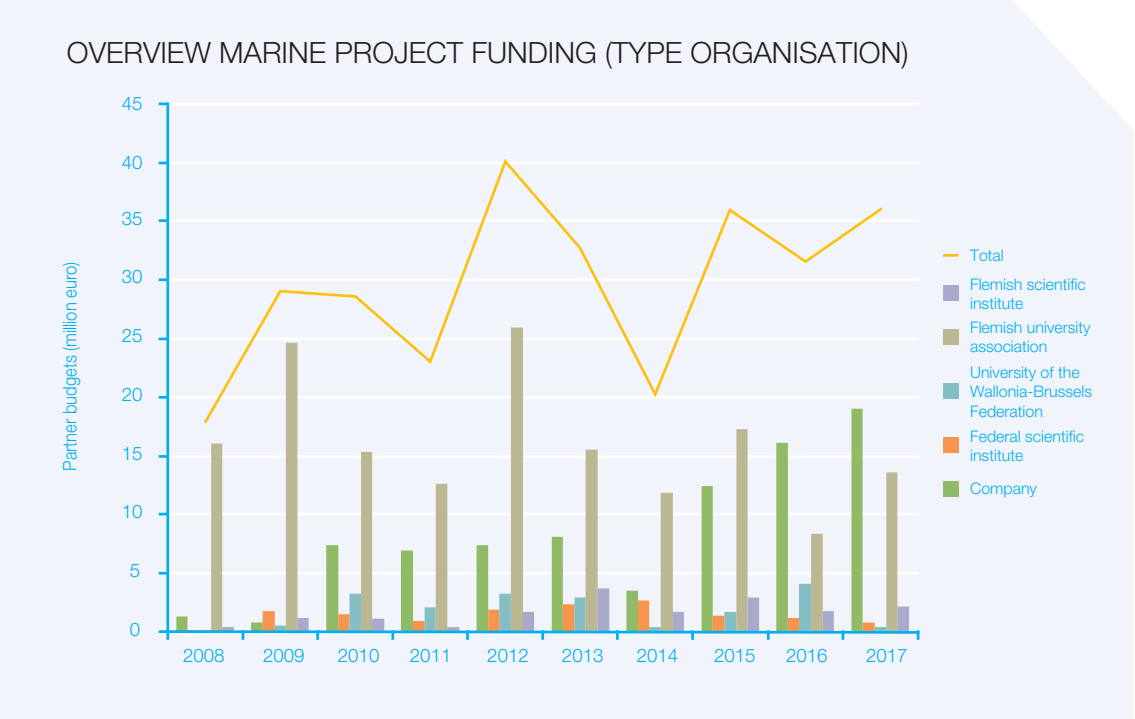

Figure 34. Evolution of the sum of the reported funding channels for marine research and innovation according to the type of organisation in the period 2008-2017. In this overview figure, channels at European (FP7, H2020, EMFF- and EFF-cofunding), federal (BELSPO and VLIR-UOS) and Flemish level (FWO, BOF, IWT and VLAIO) were included. (With the exception of EFF, project budgets are allocated to the starting year of the project).