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Machine Technology Center Turku Ltd

Overview of maritime industries, related higher education and industrial-academic cooperation in Northern Germany

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Contents

1 Summary

The present report provides an overview of maritime technology-related industries and education in Northern Germany with the aim to enable the identification of common German–Finnish interests in education and industrial development. These similarities may be a base for future bilateral cooperation in education to develop and sustain a globally competitive and leading role in the maritime sector.

Within this report the term maritime refers to technologies, industries, research and education related to aquatic environments. That is, shipbuilding, offshore construction and energy technologies as core maritime technologies but also subsea technologies or aquaculture which are often referred to as marine technologies or industries. Also, sectors such as maritime and port logistics, ship operation and management or coastal tourism are included in the survey on existing education programs and industries in Northern Germany.

By summarizing the main activities and key technologies in maritime industries and research in Northern Germany, the report aims to assess the importance of collaboration between companies and universities and research institutes for the creation of a prospering and globally leading maritime sector. An overview of funding tools for joint research and development (R&D) projects is given. The dependency of the well-developed maritime education and the strong research environment is assessed. Special emphasis is given to the joint education programs and initiatives between universities, universities of applied sciences, vocational schools and companies.

Shipbuilding, subsea technologies and globally competitive research in these sectors play a historically important role in Northern Germany and have been built over decades. Especially for marine (subsea) research, some of the world's leading research institutes and cluster of national research institutes (e.g. the MARUM or the German Marine Research Consortium) are located in Northern Germany and well-established collaborations between public research and specialized companies, mostly SMEs, exist. The education at universities and universities of applied sciences benefits significantly from the availability of state-of-the-art research infrastructure and qualified staff. Close cooperation between companies and research institutes and universities allows for mutually beneficial developments in research and technologies.

An overview is given on the current situation of the maritime industries and related education and training possibilities, and the projected future needs and demands of the sector. Public and private initiatives that aim to sustain a future-proof education and industry are summarized. Based on current and future needs, potential collaboration opportunities for German and Finnish universities are indicated.

To identify cooperation opportunities, a number of interviews with relevant stakeholders from universities and companies have been conducted. Relevant actors have been interviewed about their experience with joint R&D and education, and their view on future developments. Special attention has been given to questions regarding future expertise and know-how need. Possible needs for internationalization of the maritime sector in general, and relevant education programs in particular, have been discussed. All interviews have been qualitative interviews. Most interview partners emphasized that they present their personal experience and subjective assessment of the current and future situation. Therefore, the report presents a differentiated overview of all relevant topics but does not reproduce personal statements of individuals.

2 Information and data collection

To compile a general overview of maritime industries in Northern Germany and the related higher education opportunities and needs, a variety of tools was employed. General information was retrieved from online and print resources provided by Federal Ministries and other governmental institutions, universities, inter-trade organizations, research associations and networks, funding organizations and other relevant private institutions. The literature research was complemented by data base and other online resource searches.

For the main chapters on maritime education, university–industry cooperation, and current and future need for qualified engineers and skilled workers, a series of interviews with representatives of universities and companies has been conducted. The information gained through these interviews has been combined to provide a comprehensive overview of opinions and assessments of the current and future situation of maritime education and industries in Germany.

The information provided by the interviewed experts has been complemented by personal experience and knowledge on maritime research, education and academic-industrial education. The report intents to provide an objective, neutral overview. Yet, due to the nature of information inquiry through interviews and consultation of interest groups, biases through subjective assessments cannot be excluded.

3 Maritime industries in Northern Germany

Within the framework of this report a survey on maritime industries in Northern Germany has been conducted to provide an overview of relevant technologies. The overview is general and meant to indicate the relation between public R&D activities and education in the maritime sector which will be summarized in the following chapter. The term "maritime industries" comprises all technologies related to the aquatic environment. That means shipbuilding as well as environmental monitoring technology, offshore energy and subsea exploration technologies. The region of Northern Germany hosts small and medium-sized companies (SMEs) in nearly all maritime technology sectors. Existing inter-trade organizations, e.g. the Maritime Cluster Northern Germany[1] or the Association of German Ship Building and Marine Technologies[2], provide a comprehensive pool of information about the multitude of companies. Despite the variety of companies, a few major technology areas dominate the maritime industries: shipbuilding and related businesses and marine measurement and monitoring technologies. These are followed by maritime logistics and offshore wind energy[3].

3.1 Strengths of maritime industries

Ship design and construction has a long history in Norther Germany and despite several crises during the past decades, around 130 shipyards exist in Germany[4,5]. The governmental decision for the "Energiewende"[6], the shift from nuclear and fossil energy to renewable energy, fostered good progress in the offshore energy industries[7]. A third pillar of maritime industries is marine measurement and monitoring technologies which find application not only in coastal and offshore areas but also in inland waters. A strength of the German maritime industries are strong inter-trade organizations that develop and advocate the interests of the entire community and stay in close dialog with the politics, public research and education organizations[2].

3.1.1 Shipbuilding

Still during the 2010s, design and construction of cargo vessels was the most important business for most of the larger yards in Norther Germany[8]. These vessels required less advanced technologies, R&D work and engineering expertise compared to special vessel types or mega yachts. With the breakdown of the Western European container and tanker vessel market since 2010, this vessel type has become insignificant with respect to orders, and it is virtually not built anymore in Western Europe[5,8]. Due to existing overcapacities, declining charter rates and price competition through Asian yards, it is not expected that building of container vessels will gain importance in Germany again. As a consequence of these developments, many yards in Northern Germany became insolvent which made skilled workers and engineers available to the labor market and decreased the attractiveness of the shipbuilding industries for young professionals. This is especially true for the more rural areas in the Federal State of Mecklenburg-Vorpommern but also Schleswig-Holstein.

Yards that predominantly built cruise vessels, yachts or navy vessels or that managed to shift their activities to these sectors, went through the crises and manage to maintain a globally competitive position[5,8]. At least for the larger German yards as Meyer, Lürssen including Blohm + Voss, Abeking and Rasmussen and the MV Werften group, the order situation at the end of 2016 allows for some optimism until early 2020s (J. Polzer, Maritime Business Seminar Helsinki, 24/11/2016; 5; personal communications).

Special vessels and platforms for offshore wind energy installations are another emerging market that provides chances for many of the smaller German yards. As for cruise vessels or yachts, these new offshore technologies are still engineering intensive and the costs for construction and material are not the dominant factors, yet. This gives German and other Western European yards an advantage over Asian competitors. This effect is supported by the fact the main market for renewable offshore energy is within the European seas. The increasing importance of special vessels and platforms also creates a demand for more engineers and skilled workers[5,9].

3.1.2 Offshore technologies

Offshore technologies in the context of this report refer to platforms and constructions for hydrocarbon and renewable energy production, subsea surveillance, monitoring and maintenance technologies, telecommunication, and all related technologies.

Among the offshore technologies, especially offshore wind energy is important in current R&D and business activities and is detailed in the following section. Marine monitoring and surveillance technologies such as sensors and sampling instrumentation, autonomous vehicles, geophysical instrumentation and other subsea technologies are an important sector in Northern Germany. Characteristic for these offshore technologies are the enormous number of research institutions (<200 3,5) and SMEs which often work in close cooperation in the development and testing of new technologies. German research institutes and companies are globally competitive in innovative and specialized offshore technologies such as autonomous subsea exploration (hydrocarbon extraction and mining) and monitoring. Around 500 companies involved in this sector generate a turnover of around 11 billion euros per year.

3.1.3 Offshore energy

Offshore energy production comprises the traditional hydrocarbon industry, i.e. oil and gas exploitation, and renewable energy exploitation as wind energy, wave or tidal power plants.

Despite the dramatic decline of oil and gas prices in recent years, significant investments in research and development for offshore fossil fuel exploitation are made10. In the focus of developments are technologies for safer, cost-effective exploitation of deep sea resources. While terrestrial and near-shore reserves and resources are on the decline, constantly significant new discoveries are made in deep waters. Deep water oil and gas recovery demands sophisticated technologies that minimize the technical and environmental risks related to exploitation in harsh environments. The technology trend is towards fully automated exploitation and transport systems on the seafloor which make surface platforms obsolete. While Norway is the leading nation for subsea E&P technology, German companies and research institutes have significant know-how in and potential for development of system components and system integration3,10 (and personal communications).

Climate change, declining fossil fuel resources and risks of nuclear power generation boost R&D and industrial activities in exploration of renewable energy. Currently, the most promising alternative offshore energy sources are wind and wave or tidal power. In 2010, the German government adopted the "Energiewende", a transition to a society based on renewable energy. The main goals are to abandon nuclear energy production by 2022 and to reduce CO2 emission by 95% (compared to 1990) until 20506. In the course of the Energiewende, offshore wind energy R&D and related industries received a boost. Technology developments include new turbines, energy storage, transport and management systems, foundation and anchoring structures, new materials and surface treatments resistant to wind and water forces, and biofouling, monitoring and maintenance systems and new vessel types for transport, deployment and maintenance work8-12.

3.1.4 Next generation maritime technologies

The German government identified the maritime economies as a major factor of Germany's global competitiveness in research, industrial production, technology and logistics and launched a multi-year research, development and innovation program (RDI) "Next generation maritime technologies" (Maritime Technologien der nächsten Generation)[13]. The program aims to strengthen Germany's expertise and leadership in all sectors of maritime business and research. The core instrument of the program are joint R&D projects between public research institutes and companies through which new technologies are developed. Projects may involve only two partners, however in most cases many industry and research partners are involved. Thus cross-innovation and business-business cooperation is fostered.

Technology & market challenges controlling future R&D & business activities[13]:
Increasing environmental and climate protection requirements
Increasing energy demand and costs
Ensuring raw material resources
Increasing offshore and inland water transport cargo volumes
Improvement of maritime safety and security
Increase of productivity and cost effectiveness
Development of offshore wind energy capacities
Increase of offshore and deep water oil and gas exploitation

The program addresses several short- and intermediate-term goals as well as long-term goals that set the development and business targets on a decadal time scale[13]. R&D activities on next generation maritime industries will influence the German maritime industries and induce a shift from the dominant traditional shipbuilding to flexible, scalable offshore structures, autonomous transport, survey and maintenance systems, renewable energy harvesting, carbon sequestration and fully digitalized design processes. That is, Germany's maritime industries will further diversity14. This has, and will have, a significant influence on the maritime education and training programs. Joint R&D programs ensure that industrial and public RDI activities are evolving hand-in-hand. As university-based education and training in Germany is greatly dependent on, and benefits from, research expertise, it is expected that the education in maritime topics will meet the markets' demands also in future.

Maritime long-term goals of the national development program[13]:
Zero emission vessels
Full simulation capabilities of design and production processes
Significant increase of productivity and cost reduction
Intelligent and autonomous systems for deep-sea installation, maintenance and removal operations
Improved safety and efficiency in shipping
Research along the entire value chain with networking of all stakeholders
Active environmental and climate technologies
Improved exploitation and capitalization of inland water transportation potentials
System solutions for marine energy and raw material exploitation

3.1.5 Inter-trade organizations

The diverse maritime industries and businesses are organized in a number of national inter-trade organizations which represent the industries' interests, foster collaboration between companies, research institutes and politics. Many of these organizations also address questions regarding vocational and university-based education. The largest and most relevant inter-trade organization are listed in Table 1. While some of these organizations represent all companies that are active in certain areas, e.g. mechanical engineering, most of them are dedicated to maritime industries.

Table 1: List of relevant inter-trade organizations that represent the interest of the maritime industries in Germany.

Organization	**Link**
Center of Maritime Technologies e.V.	http://www.cmt-net.org/
Foundation Offshore Wind Energy	http://www.offshore-stiftung.de/
German Association for Marine Technology e.V.	http://www.maritime-technik.de/
German Ship Owners' Association	http://www.reederverband.de/en.html
German Wind Energy Association	https://www.wind-energie.de/en
Maritime Cluster Northern Germany	http://www.maritimes-cluster.de/
Verband Deutschen Maschinen- und Anlagenbau e.V.	http://www.vdma.org
Verband für Schiffbau und Meerestechnik e.V.	http://www.vsm.de/
Zentralverband der Deutschen Seehafenbetriebe e.V.	http://www.zds-seehaefen.de/

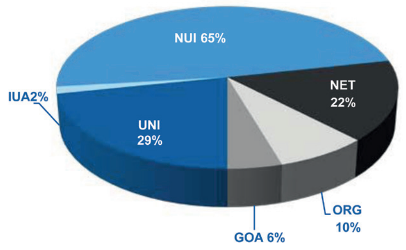
For instance, the "Maritime Cluster Northern Germany" brings together companies from all maritime sectors since 2011. While at first mostly stakeholders from the Federal States of Hamburg, Lower Saxony and Schleswig-Holstein joint the cluster, to date also companies from Bremen and Mecklenburg-Vorpommern are active in the cluster. The Maritime Cluster Northern Germany is the interface between stakeholders from industry, academia and politics. It establishes platforms for dialogue, promotes contacts to other relevant industries and networks, and supports its members in their efforts to develop ideas, services and products and to establish them in the market[1].

4 Maritime research in Northern Germany

Maritime research activities are concentrated in Northern Germany, mostly in the Federal States of Hamburg, Lower-Saxony and Mecklenburg-Vorpommern. Public research is carried out at universities and a number of research institutes under the umbrella of large foundations and associations such as the Helmholtz15 and Leibniz16 Associations, Max Planck17 and Fraunhofer18 Gesellschaften. Additionally, some research centers which are associated with a university are funded through the German Research Foundation (DFG).

In a recent study by the Projektträger Jülich (PTJ), a comprehensive overview is given on German research institutes and organization that are active in the field of maritime technologies3. 777 maritime research groups exist in Germany, including individual institutes of certain research organizations such as the Helmholtz or Leibniz Associations and individual departments or chairs at universities. If universities are counted only as entire units, still 285 institutions exist that carry out maritime research3. These institutions may be divided into non-university institutions (NUI), universities (UNI), networks (NET), organizations (ORG), government agencies (GOA) and research institutes that are associated with a university (IUA). When considering individual departments and chairs at universities, 63% of all maritime research institutions are located at universities, 23% at non-university institutions, 6% in networks and 3% in governmental agencies and organizations, and 2% are institutes associated with a university (IUA). When considering only universities as single entities, 29% of all maritime research institutions are universities, 65% are non-university institutions, 22% belong to networks, 10% to organizations and 6% to governmental agencies (Figure 1; 3).

Figure 1: Maritime research by institutions and organizations in [%]. NUI = non-university institutions, UNI = universities, NET = networks, ORG = organizations, GOA = government agencies IAU = research institute associated with a university. From 3, modified.



The maritime research infrastructure assessment by the PTJ comprised the entire Germany, however a graph of research units per federal state illustrates that most maritime research institutes are located in the Federal States of Northern Germany (Figure 2; 3). The only non-coastal state in the top six maritime research states is North-Rhine Westphalia which is the state with the largest population and a strong inland water transport sector3.

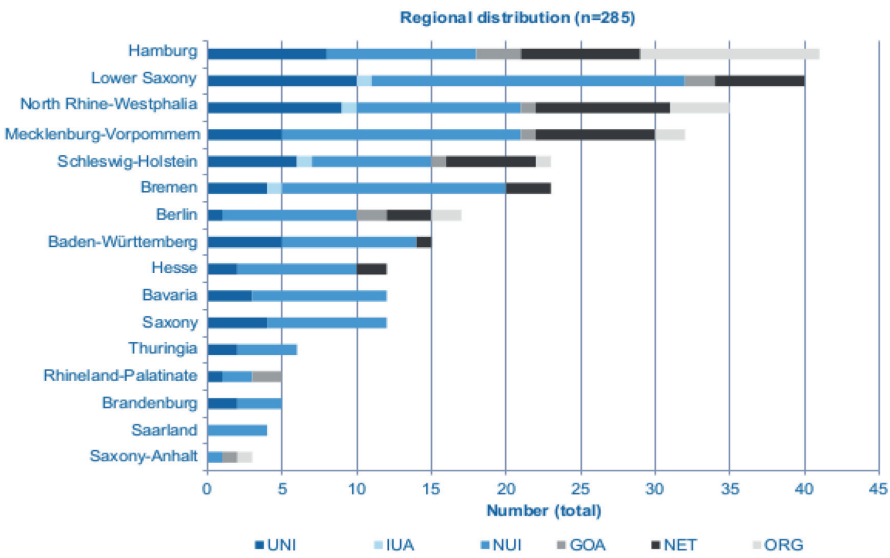


Figure 2: Total number of maritime research institutions per Federal State. The five Northern German Federal States are among the top six Federal State with respect to maritime research infrastructure. NUI = non-university institutions, UNI = universities, NET = networks, ORG = organizations, GOA = government agencies IUA = research institute associated with a university. From 3, modified.

4.1 Strengths of maritime research

Figure 3 illustrates that most research activities in public institutions focus on subsea technologies and monitoring, surveillance and environmental engineering, while most research institutions operate under the topics of shipbuilding and marine research and conservation (Figure 4). The putative mismatch between the dominance of subsea, monitoring, surveillance technologies and environmental engineering related research, and the large number of shipbuilding and marine research and conservation institutions may be explained by the fact that some of Europe's the largest marine research institutes such as the Helmholtz Centers GEOMAR Center for Ocean Research, Alfred-Wegener Institute for Polar and Marine Research, the MARUM Center for Marine Environmental Sciences or the Max-Planck Institute for Marine Microbiology develop and utilize a large array of subsea and marine technology. Further, all these institutes collaborate closely with university research groups that are active in the same field of marine environmental research and technology development. Thus a group that is active in marine microbiology or geology research might at the same time develop new autonomous survey and sampling systems and sensors.

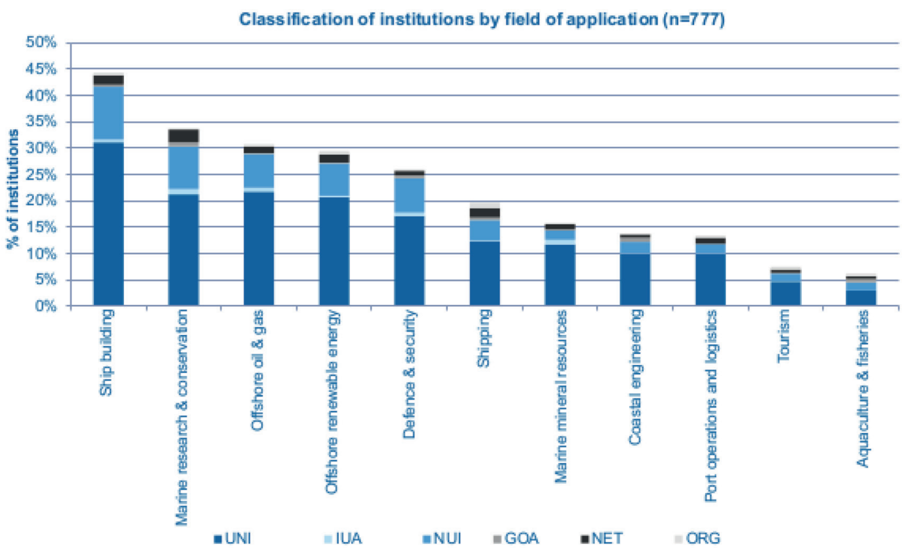


Figure 3: Focus areas of maritime research. The number of institutions doing research on certain topics maritime technologies is given in [%]. NUI = non-university institutions, UNI = universities, GOA = government agencies, IUA = research institute associated with a university. From 3, modified.

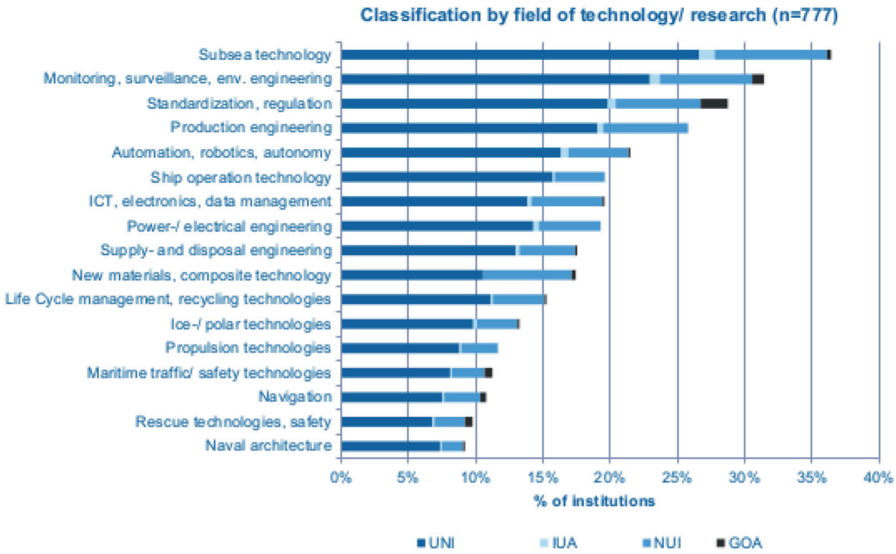


Figure 4: Research institutions by field of application. The number of institutions that assign themselves to a certain field of application is given in [%]. NUI = non-university institutions, UNI = universities, NET = networks, ORG = organizations, GOA = government agencies IUA = research institute associated with a university. From 3, modified.

In general, the German maritime research benefits from close cooperation between universities, research institutes, governmental agencies and relevant companies. In the field of marine, subsea and offshore technology, research institutes and university develop and test new technologies often in collaboration with SMEs. Of special importance in this context is sea-going research which is facilitated by Germany's large fleet of medium and large-sized research vessels which operate around the year in all oceans. Further, much of the larger tools such as vessels, AUVs, ROVs, drill rigs etc. is pooled in a European program through which other European research institutes can utilize these technologies19,20. In turn, much experience from field applications is gained from the European partners that have significant expertise in marine and maritime technologies. The testing and development of technologies during expeditions at sea provide insights and experiences that SMEs would not be able to gain.

The collaboration between public research institutes and companies is fostered through national programs as detailed in section 7.

Maritime research in Germany is carried out in a variety of different institutions. An overview of different organization types is given below, however due to the vast number and diversity of institutes the overview may be incomplete. A comprehensive database of research institutes is provided through the "Research Map" by the German Rectors' Conference21. Generally, these institutions are well inter-linked and carry out much of their R&D work together. The competences in maritime R&D also affect the education in relevant sectors as many researchers also teach at universities. Further, students often have the opportunity to gain hands-on experience with the latest technologies through field work or student assistant jobs.

4.1.1 Maritime research at universities

Research might be carried out in a variety of different maritime sectors at the same university. This explains the large number of research groups (777) identified in a recent study by the PTJ3. While most of the universities' research groups are active in applications related to shipbuilding (Figure 4; 3), naval architecture is only done by approx. 7% (Figure 3; 3), while subsea technologies are research topics for 26% of all research groups, followed by monitoring, surveillance and environmental engineering with 23% (Figure 3; 3).

To enable innovative, competitive research and education at universities a variety of special funding opportunities exists in Germany. For the most advanced research groups/universities, funding is provided through the "Excellence Initiative". The excellence initiative was initiated by the Federal Ministry of Education and Research to foster cutting-edge research at German universities and research institutions, improve inter-disciplinary research and improve scientific education. To date the excellence initiative is run by the DFG and the German Science Council. Currently, the third line of funding provides support for 43 centers of excellence and 45 graduate schools.

The Excellence Initiative is complemented by the establishment of a number of "Excellence Cluster" which may go beyond university level by joining research expertise from several institutes to a strategic network. Excellence cluster might be complemented by graduate schools, thus ensuring excellent education of young research professionals22. Relevant maritime Cluster of Excellence are the "Future Ocean" cluster in Kiel23 and the "The Ocean in the Earth System – MARUM – Center for marine Environmental Sciences" cluster in Bremen24.

Research centers funded through the German Research Foundations are associated with universities and are funded through thematic calls. Only centers which perform internationally competitive, interdisciplinary research will be funded through this funding initiative 25. Currently, the MARUM24 is the only maritime DFG Research Center.

So called "Collaborative Research Centers" are university-based multi-disciplinary research programs which are funded for up to 12 years 26. These research initiatives are an efficient tool to develop leading research excellence. Such initiatives also have a positive effect on the education as they attract excellent international researchers and have access to state-of-the-art infrastructure which are made available to teaching as well.

4.1.2 Maritime research institutes

Besides the university-based research, significant R&D and scientific expertise is concentrated in the maritime research institutes. Research institutes may be associated with universities or are "stand alone" institutions that receive funding from associations, foundations or the government. Usually, these funding associations support a variety of different research disciplines, not only related to the maritime sector. Also, several maritime research institutes might be organized under the same association, for example the GEOMAR Ocean Research center and the Alfred-Wegener Institute for Polar and Marine Research which are both under the Helmholtz Association. Further, maritime research is carried out at institutes with mainly non-maritime research, such as the German Aerospace Center (DLR). The DLR recently received governmental funding to establish a new center for maritime safety in the Federal State of Bremen which will complement the activities of their maritime safety research group 27. A list of relevant maritime research centers, or centers that perform maritime research among other topics, which receive funding from a non-governmental organization is given in Table 2.

Table 2: List of relevant maritime research centers in Germany

Organization and center	Link
Helmholtz Association	
German Aerospace Center (DLR)	http://www.dlr.de/en/
Forschungszentrum Jülich	http://www.fz-juelich.de/portal/home
GEOMAR Helmholtz Centre for Ocean Research Kiel	http://www.geomar.de
Helmholtz Centre for Environmental Research	http://www.ufz.de
Helmholtz-Zentrum Geesthacht Centre for Materials and Coastal Research	http://www.hzg.de/index.html.en
Helmholtz Centre Potsdam – GFZ German Research Centre for Geosciences	http://www.gfz-potsdam.de/portal/-
Karlsruhe Institute of Technology (KIT)	http://www.kit.edu/english
Leibniz Association	
Deutsches Schiffahrtsmuseum – National Maritime Museum (DSM)	http://www.dsm.museum/
FIZ Karlsruhe – Leibniz Institute for Information Infrastructure (FIZ KA)	https://www.fiz-karlsruhe.de/
Leibniz Institute for Applied Geophysics (LIAG), Hannover	https://www.liag-hannover.de/
Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Berlin	http://www.igb-berlin.de/
Leibniz Institute for Baltic Sea Research Warnemünde (IOW)	http://www.io-warnemuende.de/en_index.html
Leibniz Center for Tropical Marine Ecology (ZMT), Bremen	http://www.zmt-bremen.de/
Max-Planck Gesellschaft	
Max Planck Institute for Marine Microbiology	https://www.mpg.de/154811/marine_mikrobiologie?section=all

Fraunhofer Gesellschaft	
Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute	https://www.hhi.fraunhofer.de
Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS	https://www.iais.fraunhofer.de/
Fraunhofer Institute for Material Flow and Logistics	http://www.iml.fraunhofer.de/en.html
Fraunhofer-Einrichtung für Marine Biotechnologie	http://www.emb.fraunhofer.de/
Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM	http://www.ifam.fraunhofer.de/en.html
Fraunhofer Institute for Wind Energy and Energy System Technology	http://www.iwes.fraunhofer.de/en.html
Fraunhofer Center for Maritime Logistics and Services	http://www.cml.fraunhofer.de/en.html

5 Maritime education in Northern Germany

Education in professions with relevance for maritime industries is versatile in Germany. Generally, education possibilities may be separated into vocational training and studies. Studies can be further divided into studies at universities and universities of applied sciences. The courses in the studies are usually offered as traditional programs leading to a B.Sc. or M.Sc. degree (or similar). However, for a number of courses of study also “dual study programs” exist. These cover similar content as the traditional courses but students have longer internships or practical trainings in companies to gain work experience. Dual study courses are offered by universities and universities of applied sciences in cooperation with companies.

5.1 Vocational training in maritime jobs

Currently 312 recognized occupations requiring formal training exist in Germany 28. Seven of these job profiles are distinct maritime occupations (Schifffahrtskaufmann, Hafenschiffer, Fachkraft für Hafenlogistik, Schiffsmechaniker, Schiffszimmerer, Bootsbauer, Segelmacher; 28). However, many of the other occupations find application in the maritime industries. The content of the formal occupation training is regulated, in most cases, by the Federal Ministry for Economic Affairs and Energy, in coordination with gilds and industry associations 28,29 and is intentionally kept as general as possible to enable the skilled workers to work in many different industries 29. For instance, a construction mechanic may work in the shipbuilding, car or construction industry.

5.1.1 Content and course of vocational training programs

All recognized occupations requiring formal training are implemented as dual education programs. In the dual education system, approximately one third of the education period (2–3.5 years, depending on the job profile) is spend in vocational schools, the rest in companies. A common training curriculum includes 1–2 days theoretical education per week and 3–4 days practical work29.

The content of the education program is standardized which ensures that each trainee acquires the same skills and has similar qualifications after accomplishment of the education program. For trainees that are educated in companies that are too specialized to offer all required practical trainings, a possibility exists to complement their training in a second company. The costs that arise to the secondary company are largely covered by the Federal Ministry of Economic Affairs and Energy.

The content of the theoretical and practical curriculum is coordinated by the vocational schools and the companies and monitored through the Federal Ministry of Economic Affairs and Energy29.

To ensure the sustainability of occupations and formal training, technical and societal changes and developments are monitored by all stakeholders (companies, gilds, industry organizations and the federal state). If changes to the training curriculum are need as a response to changing requirements, these are coordinated with the relevant industries and governmental organizations and implemented on a national level through the Federal Ministry of Economic Affairs and Energy 29.

5.2 Courses of studies at universities

In contrast to a recognized occupation requiring formal training, the courses of the studies leading to a university degree are planned and implemented more flexibly and may vary significantly in content and degree of specialization between different universities. The curricula are largely defined by the responsible faculties. In this context, the importance of the research focus and expertise of a faculty is obvious: as much of the teaching at universities is done by the research staff, the curricula will reflect the main areas for research, at least in advanced bachelor or master degree studies. As an example, the Faculty of Geosciences at the University of Bremen has a strong research focus on marine geosciences, including relevant subsea technologies. It offers a master program in marine geosciences and provides students at an early stage with practical contact to marine technologies and research.

As a consequence of the decentralized planning and implementation of courses of study, more opportunities exist to acquire knowledge and competences which are specific to certain fields of maritime technologies and industries. Examples of specialized courses of study include naval architecture, maritime transport, navigation and logistics, or ship's electrical engineering. However, most maritime-specific courses of study are offered by universities of applied sciences. Courses of maritime studies offered at Northern German universities are listed in Table 3.

The flexibility in study curricula and possibilities for specialization during advanced studies enables students in more general courses of study, e.g. electrical engineering or transport and logistics, to orientate themselves towards the maritime industries. Common options for such specialization are internships or thesis works. The advantages and disadvantages of specialized and general courses of study are discussed in section 6 “Current and future needs in industry and education”.

Table 3: Maritime courses of study at universities in Northern Germany.

University	Course of study	Link
Jacobs University Bremen	International Logistics Management and Engineering B.Sc	http://www.jacobs-university.de/il-program
Jacobs University Bremen	International Logistics Management and Engineering M.Sc.	http://www.jacobs-university.de/ilme
Hamburg University of Technology	Naval Architecture (B.Sc.)	https://www.tuhh.de/tuhh/studium/studienangebot/bachelor/schiffbau.html
Hamburg University of Technology	Naval Architecture and Ocean Engineering M.Sc.	http://www.tuhh.de/alt/tuhh/education/degree-courses/masters-programs/schiffbau-und-meerestechnik.html
Hamburg University of Technology	Ship and Offshore Technology (M.Sc. Joint Masters Strahlsund & Hamburg)	http://www.strath.ac.uk/naome/studyhere/postgraduatestudies/shipoffshoretechnology/
University of Rostock	Bachelor Programme: Mechanical Engineering -> Specialization in Ship and Offshore Engineering	http://www.lsb.uni-rostock.de/en/study-programmes/
University of Rostock	Master Programme: Ship and Offshore Engineering	http://www.lsb.uni-rostock.de/en/study-programmes/

University of Rostock	International Master: Advanced Design of Ship and Offshore Structures – EMship	http://www.lsb.uni-rostock.de/en/study-programmes/
Carl von Ossietzky Universität Oldenburg	B.Sc./ M.Sc. Physics and B.Sc./ M.Sc. Engineering Physics with specialization in offshore wind energy technologies	https://www.uni-oldenburg.de/en/physics/
Carl von Ossietzky Universität Oldenburg	Marine Sensors (M.Sc.)	http://www.uni-oldenburg.de/nc/en/students/course-of-study/?tab=application&id_studg=559

5.3 Courses of studies at universities of applied sciences

The majority of courses of study with a maritime specialization are offered by universities of applied sciences. Table 4 provides an overview of these study programs (as of 2016).

Universities of applied sciences usually require a larger portion of practical work than traditional universities. Therefore, students gain more hands-on work experience already during the bachelor studies. Work experience might be acquired through internships, project or thesis work or a combination of these. The overall duration of internships ranges from several weeks to one year, depending on the subject and university of applied sciences. While students acquire more applied knowledge through this study design, trade-offs are made in the theory and scientific research. The students are self-responsible to establish contacts for internships or thesis work but may benefit from established long-term cooperation between universities and relevant local companies.

Table 4: Maritime courses of study at universities of applied sciences.

University	Course of study	Link
City University of Applied Sciences Bremen	Shipping & Chartering B.A.	http://www.hs-bremen.de/internet/en/studium/stg/issc/
City University of Applied Sciences Bremen	Ship Management (B.Sc.)	http://www.hs-bremen.de/internet/en/studium/stg/nautik/
City University of Applied Sciences Bremen	Naval Architecture and Ocean Engineering B.Eng.	http://www.hs-bremen.de/internet/de/studium/stg/sm/index.html
City University of Applied Sciences Bremen	Int. Degree Course Naval Architecture and Ocean Engineering B.Eng.	http://www.hs-bremen.de/internet/de/studium/stg/idino/
City University of Applied Sciences Bremen	Integrated Degree Course Naval Architecture and Ocean Engineering B.Eng.	http://www.hs-bremen.de/internet/de/studium/stg/smp/index.html
City University of Applied Sciences Bremen	Naval Architecture and Ocean Engineering M.Eng.	http://www.hs-bremen.de/internet/de/studium/stg/smm/
University of Applied Sciences Bremerhaven	Cruise Tourism Management B.A.	http://www.hs-bremerhaven.de/en/study-courses/bachelor/cruise-tourism-management/
University of Applied Sciences Bremerhaven	Maritime Technologies B.Sc.	http://www.hs-bremerhaven.de/en/study-courses/maritime-technologies/
University of Applied Sciences Bremerhaven	Ship Operation Engineering B.Sc.	http://www.hs-bremerhaven.de/en/study-courses/ship-operation-engineering/

Jade Hochschule	Maritime Economics and Port Management B.Sc.	http://www.jade-hs.de/en/departments/maritime-studies/prospective-students/courses-of-study/maritime-economics-and-port-management/
Jade Hochschule	International Transport Management B.Sc.	http://www.jade-hs.de/en/departments/maritime-studies/prospective-students/courses-of-study/international-transport-management/
Jade Hochschule	Nautical Sciences B.Sc.	http://www.jade-hs.de/en/departments/maritime-studies/prospective-students/courses-of-study/nautical-science/
Jade Hochschule	Maritime Management M.Sc.	http://www.jade-hs.de/en/departments/maritime-studies/prospective-students/courses-of-study/international-maritime-managementmsc-distance-study
Jade Hochschule	Meerestechik (B.Sc.)	http://www.jade-hs.de/apps/studiengang/index.php?id=14&einzel=1
University of Applied Sciences Flensburg	Schiffstechnik – Schiffsmaschinenbau B.Sc.	http://www.fh-flensburg.de/fhfl/schiffstechnik0.html
University of Applied Sciences Flensburg	Schiffstechnik – Schiffsbetriebstechnik B.Sc.	http://www.fh-flensburg.de/fhfl/schiffstechnik0.html
University of Applied Sciences Flensburg	Maritime Transport, Navigation and Logistics B.Sc.	http://www.fh-flensburg.de/fhfl/seeverkehr_nautik_logistik.html
Hamburg School of Business Administration	Maritime Management (Dual – B.Sc.)	http://www.hsba.de/en/study/bachelor/maritimemanagement/

Hamburg School of Business Administration	Shipping (MBA)	http://www.hsba.de/en/study/master/mba-shipping/overview/
University of Applied Sciences Kiel	Schiffbau und Maritime Technik (B.Sc.)	https://www.fh-kiel.de/index.php?id=s
University of Applied Sciences Kiel	Schiffbau und Maritime Technik (M.Eng.)	https://www.fh-kiel.de/index.php?id=s
University of Applied Sciences Kiel	Offshore – Anlagentechnik (B.Sc.)	https://www.fh-kiel.de/index.php?id=oat
University of Applied Sciences Emden/Leer	Schiffs- und Reedereimanagement (B.Sc.)	http://www.hs-emden-leer.de/studium/studiengaenge/schiffs-und-reedereimanagement.html
University of Applied Sciences Emden/Leer	Nautik (B.Sc.)	http://www.hs-emden-leer.de/studium/studiengaenge/nautik.html
University of Applied Sciences Stralsund	Maschinenbau – Ausrichtung Schiffbautechnik	http://www.fh-stralsund.de/lehrangebot/lehrebaum/powerslave,id,938,nodeid,.html
University of Applied Sciences, Technology, Business and Design Wismar/Warnemünde	Ship's Electrical Engineering (B.Sc.)	http://www.hs-wismar.de/was/studium/fakultaet-fuer-ingenieurwissenschaften/bereich-seefahrt/studiengangsinformationen/schiffselektrotechnik-bachelor/
University of Applied Sciences, Technology, Business and Design Wismar/Warnemünde	Nautical Science/Maritime Transport (B.Sc.)	http://www.hs-wismar.de/was/studium/fakultaet-fuer-ingenieurwissenschaften/bereich-seefahrt/studiengangsinformationen/nautikverkehrsbetrieb-bachelor/

University of Applied Sciences, Technology, Business and Design Wismar/ Warnemünde	Ship Operation/ Plant and Supply Technology (B.Sc.)	http://www.hs-wismar.de/was/studium/fakultaet-fuer-ingenieurwissenschaften/bereich-seefahrt/studiengangsinformationen/schiffsbetriebs-anlagen-und-versorgungstechnik-bachelor/
University of Applied Sciences, Technology, Business and Design Wismar/ Warnemünde	Operation and Management of Maritime Systems (M.Sc.)	http://www.hs-wismar.de/was/studium/fakultaet-fuer-ingenieurwissenschaften/bereich-seefahrt/studiengangsinformationen/operation-and-management-of-maritime-systems-master/
University of Applied Sciences, Technology, Business and Design Wismar/ Warnemünde	Schiffsbetriebstechnik (Dual)	http://www.hs-wismar.de/was/studium/fakultaet-fuer-ingenieurwissenschaften/bereich-seefahrt/studiengangsinformationen/schiffsbetriebs-anlagen-und-versorgungstechnik-bachelor/studienrichtung-schiffsbetriebstechnik/

5.4 Dual course of study

Dual or joint courses of study are special arrangements of full-time studies and practical trainings which are offered by several universities of applied sciences in cooperation with companies. Different arrangements of dual courses of study exist. While some are full-time studies with complementary vocational training during the lecture-free periods, others are a combination of shorter study and training periods.

Some dual courses of study provide the successful graduates with both, a job qualifying university degree and a recognized vocational education as a skilled worker (“Vocational Training Integrated Learning Programs”). Prerequisites for such dual courses of studies are a higher education entrance qualification and a signed indenture with a relevant company30.

So called "Job Integrated Learning Programs" are tailored for skilled workers who have accomplished a vocational training program and wish to extend their professional skills though additional academic studies. For the period of their studies, the students and their employer formally agree on an exemption. These dual courses of study usually do not require a higher education entrance qualification and are excellent means for professionals without a high school degree to obtain an academic education30.

The most common dual course of study is the "Work Integrated Learning Program" which combines regular university studies with longer internships (several weeks up to one year). During these study courses, students obtain a university degree but no degree in a recognized occupation requiring formal training30.

Common for all dual course of study arrangements is the need for a coordinated education and training curriculum between the universities and companies, which goes much beyond arrangements for internships or practical trainings. Also, in many cases the students receive a regular apprentice salary from the companies.

5.5 Established education and training cooperation between companies and universities

Different kinds of education and training collaborations exist between Northern German universities or universities of applied sciences and companies. Cooperation programs range from companies' commitments to take interns or provide topics and support for thesis work to joint coordination of study and vocational training curriculum content and activities.

A survey and comprehensive listing of all established cooperation is beyond the scope of this report, given the number of approx. 2,800 SMEs and large companies that are relevant to maritime education31. Table 5 provides an overview of universities that offer dual courses of study in collaboration with major maritime companies. Table 6 indicates which major companies offer internships and thesis works on a regular basis. Most companies that do not have formally established education and training cooperation with universities still offer thesis work or internships based on students' and/or universities' initiatives. Though such activities are a major cost factor, especially for smaller businesses, most companies see this as an investment in the future. In many cases, interns and thesis workers can also provide valuable support to daily activities or even R&D tasks.

Table 5: List of major maritime companies that collaborate with universities through dual courses of study (after [2]).

Partner company	Partner universities
Abeking & Rasmussen, Lemwerder	University of Applied Sciences Bremen, University of Applied Sciences Flensburg
Blohm & Voss, Hamburg	Technical University of Hamburg. University of Applied Sciences Hamburg University of Applied Sciences Bremen Nordakademie Elmshorn
Flensburger Schiffbau-Gesellschaft mbH & Co. Kg	University of Applied Sciences Bremen
Fr. Fassmer GmbH & Co. Kg, Berne	University of Applied Sciences Bremen
German Dry Docks GmbH & Co. Kg, Bremerhaven	University of Applied Sciences Bremen
Lloyd Werft Bremerhaven AG	University of Applied Sciences Bremen
Fr. Lürssen Werf, Bremen, Rendsburg, Peene Werft GmbH & Co. Kg Wolgast	University of Applied Sciences Bremen, Jade University of Applied Sciences Wilhelmshaven, Oldenburg, Elsfleth
MV-Werften Wismar, Warnemünde, Strahlsund, Meyer Werft, Papenburg	University of Applied Sciences Bremen, University of Applied Sciences Emden, University of Applied Sciences Osnabrück Jade University of Applied Sciences, BA Emsland, BA Ost-Friesland
MV Werften Wismar, Warnemünde, Strahlsund	University of Applied Sciences Wismar
Siemens, Region Hanse	University of Applied Sciences Hamburg FHW Berlin

ThyssenKrupp Marine Systems GmbH Kiel, Emden, Hamburg	University of Applied Sciences Kiel, Nordakademie Elmshorn Technical University of Hamburg, University of applied Sciences Hamburg, University of Bremen, University of Applied Sciences Emden/ Leer
Wärtsilä SAM Electronics, Hamburg	University of Applied Sciences Hamburg, Nordakademie Elmshorn
Zeppelin Power Systems GmbH & Co. Kg	University of Applied Sciences Hamburg/ FOM Essen Dual University of Applied Sciences Baden-Würtemberg

Table 6: List of major Northern German shipyards and maritime companies that offer internships for pupils and students (entrance and advanced internships) and thesis works.

Company	**Location**	**Link**
Abeking & Rasmussen Schiffs- und Yachtwerft SE	Lemwerden	www.abeking.com
Blohm & Voss GmbH	Hamburg	www.bohmvoss.com
Flensburger Schiffbau Gesellschaft mbH & Co. Kg	Flensburg	www.fsg-ship.de
Fr. Fassmer GmbH Co. Kg	Berne, Motzen	www.fasmer.de
Fr. Lürssen Werft GmbH Co. Kg	Bremen, Schacht-Audorf, Wolgast, Wilhelshaven, Rendburg	www.luerssen.de
German Dry Docks GmbH & Co. Kg	Bremerhaven	www.germandrydocks.com
German Naval Yards Kiel GmbH	Kiel	www.germannaval.com
Lloyd Wert Bremerhaven AG	Bremerhaven	www.lloydwerft.com

Lux-Werft und Schiffahrt GmbH	Niederkassel-Mondorf	www.lux-werft.de
Meyer Werft GmbH	Papenburg	www.meyerwerft.de
Neptun Werft GmbH	Rostock	www.neptunwerft.de
Nobiskrug GmbH	Rendsburg	www.nobiskrug.com
MV-Werften	Wismar, Warnemünde, Strahlsund	www.mv-werften.com
Peters Werft GmbH	Wewelsfleth	www.peters-schiffbau.de
Tamsen Maritim GmbH	Rostock	www.tamsen-maritim.de
ThyssenKrupp Marine Systems GmbH	Kiel, Hamburg, Emde	www.thyssenkrupp.de
Wärtsilä SAM Electronics GmbH	Hamburg	www.sam-electronics.de

5.6 Other joint activities

Besides education and training related activities, universities and companies in Germany offer a variety of educational activities and programs to engage with young professionals or scholars that just start their higher education or vocational education. Such activities might be job fairs, open days, demo days, lecture series by professionals or exhibitions that present science and technologies to the public. A successful non-industrial example is the MARUM "MeerErleben" exhibition which is touring through large shopping centers and museums presenting marine research and relevant technologies to interested citizens of all age groups. Another public activity by the same institute is the "SchoolLab" where young scholars learn about ocean sciences and become curious researcher and experts of tomorrow[24].

Through events like job fairs[32,33] and industry information events at universities[34], companies get in touch with students and young professionals. Such events are not only good platforms to promote a certain industry or company, they are also an easy and informal way for students to make first contacts for internships, thesis work or later job applications. SMEs as well as large companies confirm that such events are mutually beneficial and provide a good opportunity for the industry to recruit entrants.

6 Current and future needs in industry, research and education

For planning of strategic education partnerships between German and Finnish universities, it is crucial to identify the short- and long-term needs of the industry and research institutions. The latter is of great importance as much of the teaching and education expertise in Germany originates from the R&D activities. The collaborations between universities and other research institutions and small to large companies is based on the research know-how of the institutions and the need of the companies. A comprehensive assessment of the R&D targets of both, research institutions and companies by the PTJ [3], showed that the future needs and R&D targets are evaluated slightly differently by research institutions and by companies. However, the major topics are similar. As the R&D activities at universities have a large impact on the teaching of future professionals and the cooperation with companies, the teaching objectives cannot be analyzed isolated from research objectives.

Obviously, certain fundamental elements of teaching curricula are not affected by the research activities of a university and will not change much over time, e.g. fundamentals of engineering mechanics in a degree program on mechanical engineering. Yet, practical examples and application cases given in introduction lectures might already reflect the R&D expertise of the university. The overall design and implementation of a degree program, e.g. whether courses specific to shipbuilding, wind energy or car design are offered in a mechanical engineering or automation program, are finally determined by the research expertise of an university grown over time.

Further, a significant amount of third party funding for universities and research institutions may stem from national joint research projects with companies. These projects are major tools for university-company cooperation. Joint R&D cooperation is enabled through similar objectives of public research institutions and companies. However, the long-term research objectives are also influenced by the RDI strategy of regional and long-term industrial project partners. The teaching and education of future professionals is thus also affected by the RDI objectives of relevant industries. To establish education partnerships between Germany and Finland, it is therefore of great importance to first identify matching research interests and expertise of potential German and Finnish Universities and then overlapping RDI interests of regional industries. As a consequence, the two intersections will define the current and future needs for joint professional education and training.

In the following paragraphs a summary of identified research and innovation needs from the perspective of German universities and companies is given. The statistics are from a comprehensive study by the PTJ [3] and complemented by the results of qualitative interviews with experts from German universities, companies and consultancies and major inter-trade unions. Results and evaluations from literature are referenced accordingly, information acquired within the surveys for this report are presented in report style without reference to a specific company or person. The views of individual stakeholders and groups are complemented by brief descriptions of governmental initiatives and programs that aim to strengthen key technologies and build sustainable, competitive industries.

Education programs and strategies are seldom the main target of such programs but in most cases part of them. Adjustments in study curricula and education targets are not made instantly but are rather a permanently ongoing transformation process. A current need of skilled workers and young professionals with an academic education cannot be served "on short notice" but it requires years to train people with the required skills. Therefore, it is of utmost importance that R&D objectives and business goals are planned and communicated between universities, industries and other relevant stakeholders on decadal timescales.

6.1 Industrial R&D needs and importance of technologies

A comprehensive survey by the PTJ [3] identified the most relevant maritime technology fields and R&D objectives from an industrial stakeholder perspective and compared this to the universities' and research institutions' point of view. These findings are summarized below and complemented with information retrieved through surveys made within this report.

The comparison of the identified R&D needs (Figure 5) and the most relevant technologies (Figure 6) shows that there is a good match between these parameters. That is, for technologies that companies consider as most relevant, companies also have the largest R&D demand or need[3]. More than 25% of all interviewed companies have a need for further academic, industrial or joint R&D activities in propulsion technologies, monitoring, surveillance and environmental engineering, ICT, electronics and data management and power engineering. These topics are followed by research on new materials, ship operation technology, subsea technologies and automation, autonomy and robotics, for which 20% of the companies require increased R&D action [3].

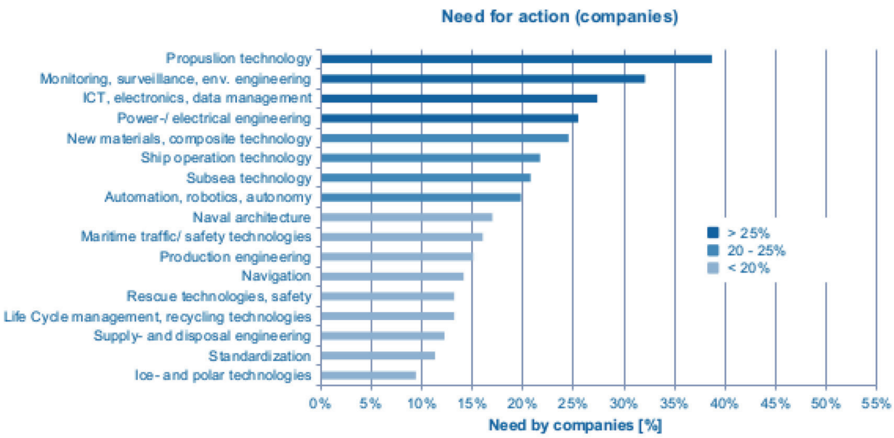


Figure 5: Need for R&D action in specific fields of maritime technologies as indicated by companies in [%]. From 3, modified.

Figure 6 illustrates the technology relevance along with the need for R&D actions. Monitoring, surveillance and environmental engineering is an important technology for almost 55% of all interviewed companies, followed by propulsion technologies (51% of companies). The largest need for action was identified for innovation in propulsion technologies (approx. 40% of relevant companies. The third most relevant technology identified in the survey by the PTJ is ICT, electronics and data management (approx. 45% of all companies)[3].

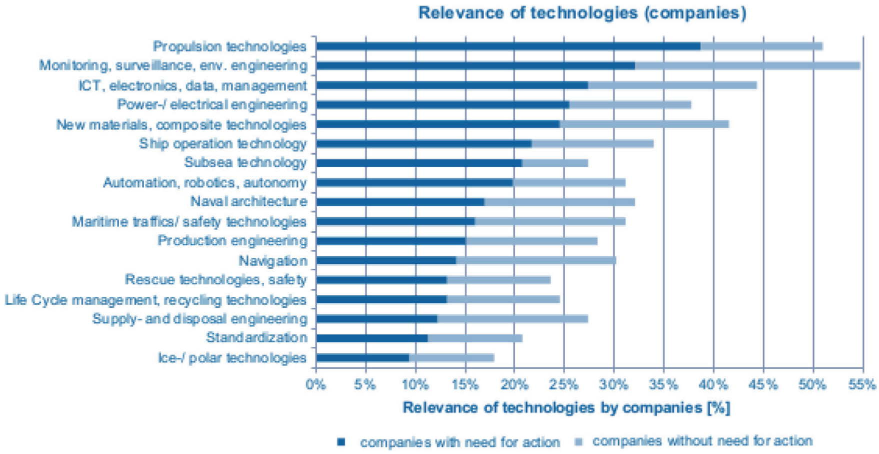


Figure 6: Relevance of certain fields of maritime technologies for companies and need for R&D action in [%] of surveyed companies. From 3, modified.

A similar assessment of the importance of technology was made by industry stakeholders interviewed for the present report. Most companies (SMEs and large companies) identified topics related to "Industry 4.0" as the most relevant R&D target. The ICT and Big Data management and utilization ranked ahead of low-consumption and emission-free propulsion technologies and offshore (including subsea) autonomy. ICT, electronics and data management are relevant for almost all maritime industries ranging from shipbuilding and operation, to offshore energy, logistics and aquaculture. Besides the actual need for improved global satellite communication and data transfer, data management and security, a number of surveyed SMEs also identified "political strategies" as a technology driver for digitalization and Industry 4.0 initiatives following the directive "research need is where funding is available". Yet, most companies follow global market developments carefully and aim for long-term planning of their business strategy, including R&D and education cooperation with public bodies. Table 7 indicates contemporary and projected technology focus areas (after [3]; complemented).

Table 7: Technology R&D topics with current and future relevance (after [3]; complemented).

Currently relevant technology R&D topics	Relevant future technology R&D topics
Alternative propulsion systems, efficiency, emissions	**Alternative propulsion systems, emissions**
Alternative propulsion and fuel	Hybrid and electrical drives
Battery technology for maritime and offshore applications	Utilization of solar and wind energy
Energy saving	Intelligent propulsion systems
Performance monitoring	CO_2-neutral ship operation
Emission regulations and directives for reduction of sulfur and exhaust gas emissions	Methanol
LNG technologies and storage	
Crew qualification for LNG bunkering	
Digitalization and data security	**Digitalization and data security**
Big data, machine learning, data mining	Digitalization of ship operation
Networks	Autonomous vessels
VSAT internet connection for vessels	Data exchange and data services
AIS, GNSS, Radar technology	Interlinked communication , safety, performance and logistic chains
Data security	Integration of AIS, GNSS, Radar
	Data security
	Acoustic and optical subsea communication with satellite links

Subsea technology and inspection ROV/AUV, new sensors Deep sea applications Electrohydraulic propulsion Optimization of data transfer and energy supply Automation of offshore drilling Subsea welding seem control and repair	**Subsea technology, inspection, maintenance** Deep sea missions Automated ROV/AUV-based inspection, maintenance, repair Autarkic, autonomous systems Autonomous exploration systems
Production Industrial 3D printing Process simulation for one of production Improved engineering time	**Production** Industry 4.0 New materials New production processes including additive manufacturing
Aquaculture Implementation of aquacultures RAS	**Aquaculture** Digitalization RAS for shrimps and low-price fish Trophic maritime aquaculture Mobile multi-purpose platforms

Logistics	Energy generation, distribution, storage
Simulation of ferry and RoRo terminals	Energy to gas conversion
Intermodal transport	Wave energy
Offshore logistics center	Alternative energy generation, distribution and storage
	Gas hydrate exploitation
	Carbon sequestration
	Biofuels from marine resources
Offshore wind energy	
Energy generation, distribution, storage	
Positioning and approach of wind farms	

Despite long-term strategies and planning, recent turbulences in global shipbuilding industries illustrate that global markets are sensitive and might require much flexibility from industrial and public stakeholders. The dramatic order decrease for offshore, cargo and tanker vessels in Europe and the relative importance gain of the cruise vessels business, especially in Germany and Finland, may be an example of such development. The shift towards cruise vessels based industries includes a changed demand for skilled workers and professionals with an academic education which might be difficult to meet on-time.

The following paragraphs list some of the currently most relevant industrial and public R&D areas in Germany. These influence the education and training objectives for the coming years as detailed above.

6.2 Focus areas of industrial and public research

Research and development is carried out in public institutions and companies alike and in many instances through joint activities. Figure 7 illustrates the R&D needs as indicated by companies and research institutions, Figure 8 illustrates the match of public research and need by companies. For most technology fields the public and private objectives match rather well, though the subsea technologies and surveillance and monitoring are prioritized stronger by research institutions[3].

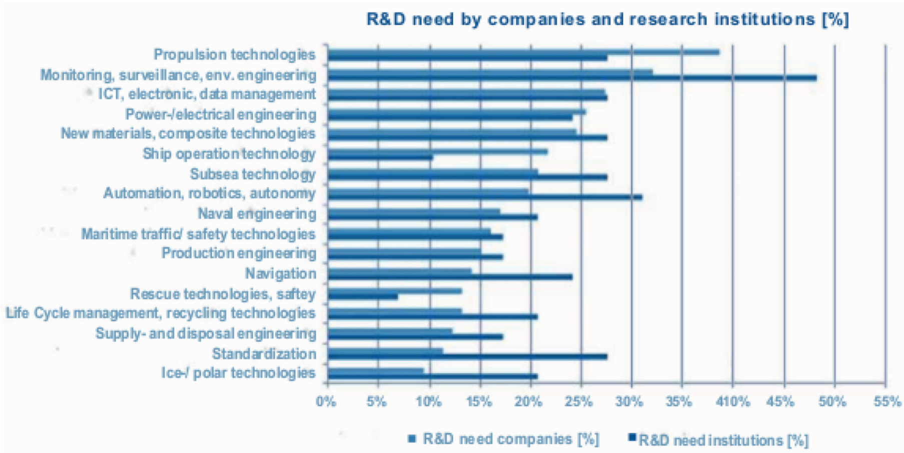


Figure 7: R&D needs as indicated by institutions and companies. From [3], modified.

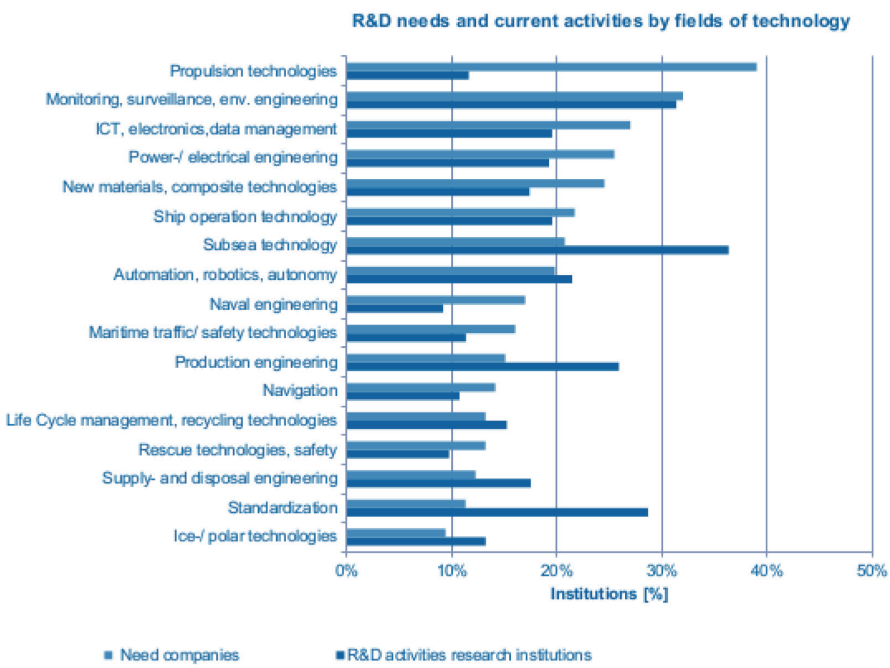


Figure 8: R&D activities of research institutions and need indicated by companies. From [3], modified.

6.2.1 Major public research objectives/ focus areas

Public research is carried out in universities and research centers that associate with a university or belong to a research association such as Helmholtz, Leibniz or Max Planck. Research objectives are historically grown and shifts of research focuses are incremental, following a long-term strategy. However, also new institutes are founded if a demand for technology of fundamental research exists in a certain field. Examples related to maritime research include the opening of the “German Center for Artificial Intelligence – Robotics Innovation Center” unit in Bremen with a department for underwater robotics in 200935 or the recently announced buildup of a center for maritime safety in the Federal State of Bremen under the German Aeronautics Center27. Also, beyond institute level, research associations seek to boost technology competences, e.g. by bringing together globally competitive research in space and deep sea sciences as through the Helmholtz Association initiative “Robotic Exploration of Extreme Environments” (ROBEX)[36].

Already in 2003, the “ForWind” joint research center for wind energy research was founded by the Universities of Oldenburg and Hannover and Bremen (since 2009)[37]. These new research centers concentrate on urgent, novel R&D needs, however they utilize expertise and research competences that are available from research groups within the main organization and local partner institutes such as universities and established research institutions [27,35].

The “German Marine Research Consortium” (KDM) was established a year later with the aim to advance science and research in marine sciences, foster the collaboration between member institutions and with German, European and international marine research partners, including the joint use of infrastructure and large equipment and to lobby for the interests of German marine research[19].

Such initiatives largely depend on available know-how, availability of scientific experts and public funding. The ability to respond to an increasing demand for R&D, and therewith also education, capacities with the creation of dedicated, strategically important research units, stems from long-term strategies build together by public actors and industries[38].

6.2.2 Major industrial research objectives

Shipbuilding (cruise ships, yachts, navy vessels, other):

With 130 yards and around 80,000 associated working places, ship design and construction is still a major German industry [2,4]. However, with the decline of cargo and tanker vessel and the increase in cruise-, special operation vessels or mega yacht orders other technical expertise is needed. This is reflected also in a demand for skilled workers, engineers and other professionals with an academic education [9,39,40]. The German shipbuilding industry is globally competitive in the supply of special vessels (civil and naval vessels), cruise vessels and mega yachts mainly due to its innovation and engineering expertise. To sustain this competitiveness it is crucial to maintain a cutting-edge research and technology leadership as vessels or vessel types are not in serial production any longer [4,9,41].

To date, enough skilled worker and engineers are available for German shipbuilding industries, however some yards and suppliers indicate that especially electrical engineers and ICT and data management experts become more difficult to recruit. Near and long-term R&D and education activities are needed with respect to energy generation and management systems, data and communication systems and recycling systems for large cruise vessels. Alternative, low-energy, low-emission and low-noise propulsion systems are crucial R&D topics and professional education objectives. The increasing ice-free periods in the arctic regions along with predicted increases of arctic offshore hydrocarbon exploration generate a need for new arctic and ice technologies enabling cost-efficient and safe vessel operations.

Offshore technologies and energy:

Offshore technologies and energy covers all technologies related to offshore hydrocarbon exploitation and renewable energy harvesting. The “Energiewende” initiated by the German government fosters both, R&D activities and industrial production of technologies related to offshore wind energy harvesting, storage and transport. Yet, the conventional energy sources, oil and gas, will remain important. With the decrease of terrestrial and continental shelf reserves and resources, deep-sea exploration and production (E&P) activities become increasingly important and provide a market for special technologies [42].

With respect to fossil fuel exploitation there is, and will be, a demand for advanced E&P technologies including fully autonomous seafloor-based extraction, preprocessing and transport technologies using underwater robotics and drilling technologies, novel technologies for cost-efficient exploitation of gas hydrates and CO_2 sequestration[10,13,42]. Though economically not relevant, yet, exploration and exploitation of marine mineral resources ("deep sea mining") might become a relevant industry in future to serve the global demand for raw materials. Germany follows a long-term strategy concerning deep-sea mining and research is being carried out by leading marine research institutions. Technology suppliers and yards need to develop their capacities to respond to a potential demand of specialized technologies.

Offshore wind energy production has seen a boom in recent years, despite challenges in deployment of platforms and power grids that allow to transport, distribute and manage the energy. Despite a reduction in governmental subsidies for wind and other renewable energies in future, it is foreseeable that offshore wind energy is a growing global market that bears a large potential for German industries and labor market [8,43]. Technology R&D and training of qualified professionals is especially required for the design and construction of larger, more efficient wind turbines, foundations for deep(er) water deployment of turbines and peripheral infrastructure, and special vessels for deployment and maintenance. These technology fields include new materials, grid design and management, and sensor- and maintenance technology.

Marine surveillance and maintenance technologies:

Marine surveillance and maintenance technologies are well represented by Northern German SMEs and research institutions. This application field covers hydrographic and geophysical exploration technologies and low to high frequency hydroacoustics, underwater robotics for exploration and maintenance, and surface and subsea environmental monitoring technologies. Relevant technologies are developed for civil and military operations.

While the national and global market for these technologies generates lower turnovers than, e.g. shipbuilding, it is an important economic factor with more than 80 companies and a steadily growing German global market share44. As marine surveillance, monitoring and maintenance technologies have significant synergies with the entire offshore technology market, it is expected that its importance will increase in future. To date Germany has significant know-how and academic research expertise but no global leadership in relevant fields of technology. Therefore, strengthening research, industries and education is desired and required [13,44].

6.3 Current and future demand for qualified personnel by the industry

Concrete statistics on the development of employment rates in maritime industries are available only for the shipbuilding industries. The maritime industries-related research and education are so diverse that a comprehensive employment and labor market assessment would be beyond the scope of this report. Below the current figures for the German shipbuilding industries are given, complemented by a qualitative assessment of current and future needs of the industry and available figures for other maritime industries.

The peak employment rate in the German shipbuilding industries during the last decade was reached in 2008 with approx. 23,600 yard employees. Following the global shipbuilding crises, the number of German yard workers declined to 16,700 in 2013. Since then, the number of employees increased gradually to >18,000 in 2015[5,9,31]. Due to the shift towards design and construction of technically demanding vessels, such as mega yachts, cruise vessels, navy vessels and specialized vessel types, the portion of engineers and other specialists with an academic education is steadily increasing. By 2015, more than 20% of all yard employees held an engineering (or similar) degree [9,31,38]. Only in R&D and technical services more people with engineering and other academic degrees are employed in Germany9. With the predicted increasing demand for engineers due to age fluctuations and expected growth of the shipbuilding market, a shortage of qualified engineers might be seen in coming years. However, an increase of engineer education might be possible only to a very limited extent, due to the existing education capacities and attractiveness of the industry. Lower attractiveness of the shipbuilding industries, e.g. compared to aeronautics or car industry, is partly due to the high number of temporary workers which shipyards employ to respond to changing market situations. Temporary work contracts are significantly more common in the German shipbuilding industry than in other technology-intensive industries, with rates exceeding 40% in some companies (2013; 9).

Offshore wind energy-related industries are the next most significant business with a share of approx. 37% of all maritime industries and more than 24,000 employees (2016; [45]). Germany is well represented in the offshore wind energy market with more than 25% of global market leaders and a predicted significant increase in global market share, turnover and a national employment growth by 1/3 until 2021 (compared to 2016)[7,43].

The third most important maritime industry sector is the offshore oil and gas market, despite the fact that Germany does not have any offshore resources. Offshore oil and gas industries represent approx. 17% of all maritime industries, with a turnover-share of more than 60% [42]. Though German companies are not among global market leaders they have significant know-how with global relevance in selected technologies and a slow but steady growth is foreseen 42.

Industries such as maritime environmental engineering, subsea sea technologies, maritime safety/ security and coastal engineering each represent some 6% of all maritime industries in Germany. For all of these industries, significant growth is predicted for the next years including an increasing impact on the global market [40,44,46].

Maritime technologies as aquaculture, deep sea mining and ice and polar technologies have no significant share of German maritime industries, however for all of these industries a significant growth is predicted[46], which is also reflected by the assessment of the importance of these technologies by companies[3].

All the above mentioned maritime technologies have a high demand for engineers and skilled workers. For all sub-disciplines more than 50% of all employees hold, and are expected to hold an academic degree[46]. In 2016, no significant lack of experts existed in the German maritime industries, however all stakeholders foresee a shortage of engineers and natural scientist with relevant expertise and training in the near future. Interviews with representatives of yards and the shipbuilding supplier industries indicate that especially electrical engineers, ICT and network engineers and experts on system integration are increasingly difficult to recruit. Further, the shipyards have an existing demand for skilled welders. Due to increasing importance of near-shore and offshore energy generation, a need for civil engineers with background in marine construction is expected. Yet, beside the above mentioned exception, no lack of qualified professionals exists.

To attenuate the expected shortage of academics and skilled workers, actions have to be taken to increase the attractiveness of the maritime industries, e.g. compared to aeronautics, to recruit more high school graduates to the relevant courses of study. At the same time, the capacities of the universities and universities of applied sciences need to grow to educate a larger number of young professional.

Certain occupations and courses of study have seen an increasing specialization in recent years. Examples include new B.Sc. degrees in maritime logistics and trade or offshore wind engineering. While a few interviewed industry and academic representatives generally appreciated such developments, the large majority favors education programs through which graduates obtain more traditional engineering degrees. In most cases young professional will have a “training-on-the-job” period during the early stages of their career, irrespectively of the degree of specialization of their studies. Having more a general education, they may be employed more flexibly within a company.

Despite the reluctance of companies and universities towards increasing specialization of education, most appreciate a specialization of individual students through the choice of traineeships and thesis works.

6.4 Needs in education: the universities point of view

Almost all representatives of universities identified the low attractiveness of maritime industries, especially related to shipbuilding, as a major problem. Due to several crises in the shipbuilding industry and the “often negative media coverage” in Germany, shipbuilding industries would not be well recognized by young people that are on the search for an attractive, interesting course of study. Many universities and research groups wish for image campaigns that promote the importance and future potential of the industrial sector.

The coordination of industrial needs, academic R&D interests and academic education is considered as excellent by the vast majority of the interviewed stakeholders. Especially joint research projects, dual courses of studies, thesis work and internships offered by companies are perceived as efficient and informal means to coordinate common interests.

“Top-down” recommendations or decisions regarding new or modified study curricula and education foci are generally not considered as efficient and effective means to respond to the changing demands for experts with an academic education. Rather, improved funding for joint projects and intensified university–industry cooperation is suggested to meet future demands of both, professional education and R&D.

With respect to increased internationalization of academic education, no conclusive statement can be made. Generally, neither universities nor relevant companies see an immediate need for internationalization. It is regarded as an option to improve teaching and research if international partner universities have R&D competences which do not exist in Germany and German universities are able to offer complementary competences to the international partner. In other words, in some cases international cooperation might be mutually beneficial and desirable. Yet, improved intercultural competences, language skills etc. are not considered as a major requirement by German industries. This assessment was supported by a number of industry representatives.

A number of university representatives were concerned about the education in natural sciences pupils receive in primary and secondary schools in Germany. From their point of view, pupils are not sufficiently educated in natural sciences, especially mathematics and physics, which results in low interest and capabilities in these disciplines. To compensate this putative lack of education, intervention on the political level is suggested as well as support for university initiatives such as school labs and summer schools that spark pupils' interest for the natural and engineering sciences.

7 Tools for national and international university–industry cooperation

Interfaces of public research and education and industrial RDI activities are predominantly realized through joint research projects, formal cooperation in education through dual courses of study, and more informal cooperation in education through thesis work and internships.

7.1 Project-based cooperation

As detailed above joint research, development and innovation projects between German universities and companies are an efficient tool for turning fundamental research results and expertise into industrial innovations and products. At the same time, joint research projects help to align public research objectives with industrial R&D needs in Germany. Academic education at German universities is strongly influenced by the research objectives, expertise and history of the relevant faculties and therefore the joint research and long-term collaboration between universities and regional maritime industries also affect the education and training of young professionals.

A dedicated funding program targeting the development of "Next Generation Maritime Technologies" by the Federal Ministry for Economic Affairs and Energy (2011–2017) is a very effective tool for joint RDI projects in Germany[13]. The program is open for any joint proposal (at least one company and university) that aims to develop new technologies or take existing technologies to marketability. Examples of research targets include novel ship propulsion systems, intelligent subsea robotics, sustainable waste water treatment on cruise vessels or improved ship operation in heavy seas. An overview of funded projects and project partners can be found in the "Förderkatalog" of the German government[47]. Through the program, universities and public research institutes may obtain 100% funding for their research and development activities including costs for materials, staff and testing, while companies still receive 50% funding for their R&D costs.

This and similar programs have been well received by industrial and public actors and Germany and are the preferred tools for cooperation, especially in R&D intensive industries3. Especially, in the field of underwater robotics and automation and marine surveillance, monitoring and environmental engineering, companies may benefit from universities' and research institutes' experience that stems from field deployments and research expeditions. Through joint projects, companies have the opportunity to test common developments during scientific research expeditions. Often such extensive testing would not be affordable for companies.

To date such funding programs are open to German partners only. However, to foster German–Finnish cooperation in R&D and related education, it is desirable to establish similar opportunities for international joint cooperation.

7.2 Education based cooperation

The lowest level of education-based cooperation between universities and companies are student internships. Many courses of study at universities and universities of applied sciences require that students gain some working life experience in a company. This is achieved through internships usually lasting for a period of a few weeks to months. In most cases, students seek a suitable internship placement themselves, yet long-term cooperation between universities and companies usually facilitate the students' search. Especially in engineering sciences, students often write their thesis on a project that they carry out in a company. During their thesis project they work on a technical problem given by the company. Such arrangement is mutually beneficial to the students (universities) and companies. The students get insights into the company's R&D processes and a glimpse of real working life, while the thesis results are often valuable information for the companies. Yet, the supervision of temporary interns and thesis workers does not require no long-term commitment from a company.

More formal education cooperation is established through dual courses of study where students acquire a practical training on a profession related to their academic studies. In a dual course of study arrangement, universities and companies have to align their teaching/ training schedules, the curricula and companies have to commit themselves to provide sufficient resources for the vocational training. In some instances companies pay a regular salary to the students. Though many dual courses of study with a maritime background exist in Germany, they are almost exclusively national arrangements. That is in most cases no agreements exist with international companies and/or universities. One of the exceptions is, e.g. Cruise Tourism Management at the University of Applied Sciences Bremerhaven which includes a one-year internship abroad.

Interviews with German companies indicate that in most industries there is no actual need for internationalization, nevertheless many companies would generally be open for international cooperation in education, e.g. by taking international trainees or even through the establishment of international dual course of study programs. It should be mentioned that all interviewed industry representatives mentioned that a basic command of German language would be an advantage as German is still the "working language" in most engineering departments.

8 Tools and opportunities for German–Finnish university cooperation

As detailed above, the hurdles for cooperation between German and Finnish universities are relatively low in case mutually beneficial research expertise exists. Several potential tools for cooperation exist.

8.1 Cooperation through joint education

Possible technologies that have been identified as potential area for cooperation between German and Finnish universities are ice and polar technologies, maritime ICT applications and alternative, novel propulsion technologies. These are technologies where representatives of German maritime study programs see a development need in Germany.

Opportunities for cooperation that were mentioned by university representatives, range from joint lecture series and summer schools to international degree programs that follow the model of "EMSHIP"[48]. Possible financial support for such student and/or teacher exchange might come from established programs, such as ERASMUS, ERASMUS+, ERASMUS-MUNDUS or industrial scholarships.

Further, the German Research Foundation (DFG) has established agreements with the Academy of Finland through which researcher exchange might be enabled. Support for the establishment of international cooperation in vocational training might be provided by the "Nationale Agentur beim Bundesinstitut für Berufsbildung"[49] or by the "¨Federal Institute for Vocational Education and Training"[50] which aim at an internationalization of vocational training and education.

8.2 Cooperation through joint research

Beside joint education initiatives, also increased R&D activities between German and Finnish universities should be considered as a mean for improved cooperation. However, funding programs exclusively targeting bilateral cooperation are scarce. Occasionally, the German Federal Ministry for Economic Affairs and Energy and the Finnish Funding Agency for Innovation TEKES open calls for bilateral cooperation. The most recent call for joint German–Finnish industry projects that targets joint product or service development at a market entry level also enables university or research institution cooperation through subcontracting[51]. From the point of view of many German university representatives, such projects would be the most efficient tool for the establishment of bilateral R&D and education cooperation.

Research projects might also be facilitated through established agreements between the German Research Foundation and the Academy of Finland. Additionally, EU-wide funding opportunities exists, e.g. the European Social Fund (ESF), which might be applicable for bilateral projects. An excellent program selection tool for German university-based research is provided by the German Federal Ministry for Economic Affairs and Energy[52].

9 Recommendations and outlook for future bilateral education activities

Surveys and interviews carried out for the present report indicate that most universities and companies do not have an immediate demand for further internationalization of young professionals and students. The technology intensive maritime industries recruit their professionals mostly in Germany and most of the R&D as well as manufacturing work is done in Germany. However, know-how exchange would be a strong driver for bilateral education initiatives. At most German universities, the education foci are strongly affected by the research expertise. That this, the research activities somewhat control the teaching. Especially, in technology intensive research, universities' research objectives are often interlinked with the interests of regional industries through joint research projects. In order to establish mutually beneficial education cooperation it might be most effective to:

1) Assess the R&D and education needs of German industries,

2) Identify the research development needs of the universities,

3) Identify what research and technology know-how Finnish universities can offer,

4) Identify what know-how import would benefit Finnish universities and companies.

Interviews at German universities, research centers and SMEs indicate that especially Finnish know-how in ice technology, innovative propulsion systems and ICT might be of great interest for German universities and companies. Also Finnish expertise in ship design is highly valued, however concerns were expressed about "the strong orientation of Finnish stakeholders towards the Asian market" which might result in significant know-how export. Some stakeholders suggested that special care should be taken that Finnish–German technology and engineering advantages are secured.

Once matching research and education interest have been identified, most German universities would be open for a variety of academic cooperation, ranging from joint lecture series to joint degree programs. Some representatives of medium-sized companies indicated a general interest to participate in international dual course of study programs.

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