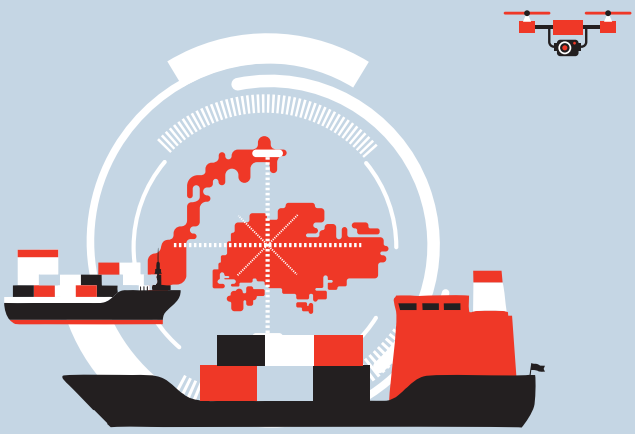
Innovation Norway

Market Report

Maritime Technologies in Singapore

The Maritime Industry Transformation in Singapore

- opportunities for Norwegian technology companies



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Forewords

Tormod Cappelen Endresen

Ambassador of Norway to Singapore 2012-2017

Norway and Singapore have two of the world's most comprehensive maritime clusters. Thankfully, we understood a long time ago that we are stronger together - our maritime cooperation dates back almost 200 years. Today, a complete cluster of Norwegian controlled companies forms part of Singapore's vibrant maritime community.

We are both advanced nations that competes not on price, but on quality, technology and innovation. In the face of challenging markets and increased competition, it is my firm conviction that we stand to gain from an even closer co-operation. In some market segments and capacities, we are friendly competitors. That does not preclude that we team up in the many areas where we have complementary strengths. I thank the authors of this report for their attempt to map and analyse these areas.

There is a lot to build on. Commercially, our maritime communities are fully integrated. In maritime policy and vision for the future, our countries are fully aligned. In research and development, our collaboration is marked by trust and longstanding personal and institutional ties.

The ocean space holds great opportunities for countries that excel in the new and existing ocean industries. Few countries are better placed to pursue these opportunities than the ocean partners Norway and Singapore.

Throughout history, oceans and seas have been vital conduits for trade and transportation. Around 70% of the global surface is covered by water. There is a great focus on the necessity of exploring, exploiting and utilizing a larger share of the Earth's marine resources in a future perspective. We are talking about sustainability in marine transportation, fish and food production, energy generation and mineral extraction. In the context of ocean health, the need for sustainable ocean development has never been stronger.

Norway's living standard and prosperity development has at a large extend been based on our rich natural resources and through utilization and development of our industries in shipping, oil and gas and aquaculture. In parallel, knowledge, experience and new technologies have developed in line with the needs; radical and incremental innovations and transformation of expertise from one sector to another.

More than ever, Norway and Norway's business community relies on building on these advantages in order to maintain a leading position and to ensure an international and global competitive edge. A relevant knowledge base is crucial for making the right choices and strategies for developing solutions to meet future customer needs.

An important part of Innovation Norway's role is to uncover market opportunities and facilitate market access for Norwegian industries through our international presence and cooperation. Bilateral cooperation in the fields of science and technology, research and education, industry and government are an integral part of our work. The report "Maritime Technologies in Singapore" is carried out in accordance with this.

Norway and Singapore enjoy a long-time maritime collaboration that has strengthened both countries' maritime technology and competence clusters. On this basis, we look forward to stay as a partner with Singapore to continue our efforts to deliver the most innovative and high-tech solutions that benefit the maritime industry. The good relationship and trust between our two nations benefit both parties and will serve a strong basis for a long lasting bilateral collaboration.

Torunn Aass Taralrud

Director
Innovation Norway
Singapore

Executive Summary

The Norwegian think-tank Menon Economics ranked this year Singapore as The Leading Maritime Capital in the world for the 3rd consecutive year. Singapore has the world's second largest container port and the busiest transhipment hub with 130,000 vessels entering its ports annually, connecting Singapore to more than 600 other ports in 123 countries. At any time, there are more than 1,000 vessels in its port and harbour. Singapore continues to be the world's top bunkering port and is recently building up capacity to be one of the leading LNG bunkering ports in Asia. The maritime and port industries provide more than 170,000 jobs and contributes to 7% of the Gross Domestic Product. The maritime industry cluster includes international conglomerates like Keppel Corporation and Sembcorp, international port operator PSA Corp and more than 3,500 maritime companies covering the entire value chain.

Singapore's maritime industry has been severely hit by the latest year's downturn in global shipping and offshore sectors driven by low oil prices and sluggish investments in the oil and gas sector. The offshore and maritime industry suffered a decline of 15% from 2015 to 2016, and another 11% decline last year. The industries lost 9,900 jobs from 95,500 in 2015 to 85,600 at the end of last year. However, The Singapore government is taking a proactive role to support and revitalize the struggling maritime industry. The Maritime and Port Authority (MPA) is developing an Industrial Transformation Map covering innovation, productivity skills and internationalisation for the maritime sector as part of the governments S$4.5 billion Industry Transformation Programme. The aim is to transform Singapore's maritime industry from transhipment and manufacturing-centred to more service, value-adding and knowledge-driven industries. This must be done by neutering talent, innovation and entrepreneurship; inventing and embracing new technologies and not at least connecting industry, research institutions, universities and government in a positive "knowledge spiral".

The relationship between Norway and Singapore is often mentioned as "an ocean partnership". Singapore has been the preferred location for Norwegian shipping and ship services companies for well over a century, and Norway has used Singapore yards for their oil rigs and specialty vessels for the offshore oil & gas industry for decades. Today there are around 200 Norwegian companies in Singapore within shipping, financial services and ship building/maritime equipment. The substantial Norwegian engineering and equipment company cluster has a strong standing with the yards in Singapore, engaging especially in speciality vessels and rigs for Norwegian owners and for arctic and North Sea conditions. Furthermore, Singapore and Norway is benefiting from maritime research and technology development cooperation over the last 20 years.

The recent Industry Transformation push from government and industry opens for new and enhanced opportunities for Norwegian companies that can offer competitive solutions to meet the new problem statements in the industry.

The objective of this report is to identify the trends and strategies for the development and transformation of the Singapore maritime and O&M (offshore and marine) industry, and connect these trends to opportunities of engagmeent for Norwegian technology and services companies. The report and analysis is based largely on the specific road maps and strategies from the various relevant governmental agencies, company reports, media coverage and on interviews with key stakeholders in the Singaporean and Norwegian maritime eco-systems.

The report is structured into five main themes: Smart Shipping – covering digitalization and computerized technologies; Green Shipping – technologies related to energy efficiency and emission reduction; Port Technologies and Ocean Technologies with a special discussion on aquaculture technology, and finally a discussion on research collaboration. For each theme, we aim to connect the specific problem statements and market needs in Singapore to Norwegian expertise and solution offerings , for example within autonomous vessels, electrification of maritime transport and aquaculture technologies.

Chapter 3 Smart Shipping

The new wave of technology in the ship operations industry is very similar to Industry 4.0. We call this Shipping 4.0. The new digitalization age will revolutionize and transform the way the shipping industry operate, the way we do business and the way in meeting customer needs as they consistently require sustainable transport.

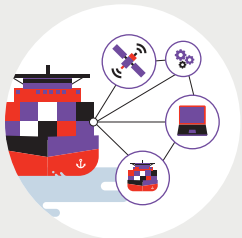
Singapore aims to be a key player in the global digital economy and opens up new opportunities in this new digital age. The shipping industry is constantly looking for cost-effective technology and business solutions to improve its competitiveness.

Singapore's port and maritime industries are gearing up to deal with digitalisation and disruption of global transport supply chains. As a mega port operator, Singapore aspires to embrace adoption of latest digital technologies to operate its next generation port for ships coming in full operation by the year 2030.

This chapter gives an overview of the emerging technological trends within Smart Shipping that are higher up the priorities in Singapore within the technologies in maritime digitalization, autonomous systems, automation & robotics, big data analytics, e-navigation, and maritime cyber security. The transformational impact on digitalization and how this is linked to growth potential in the use of sensors, collection of data, real time monitoring and analysis.

We also highlighted the various initiatives that Singapore has collaborate with industry partners across the maritime value chain for maritime technology innovation like the establishment of MPA Living Lab, Research collaboration between Norway and Singapore as well as relevant funding opportunities by Singapore government agencies.

Norway has been world leading in developing technologies for improving the overall efficiency of the maritime industry. Having developed maritime clusters, structures for innovation and a good climate exists between cooperation with Singapore, industry and academia, this opens up many good opportunities for Norwegian companies with the right technology and specialization to offer innovation solutions in the world's leading maritime nation.



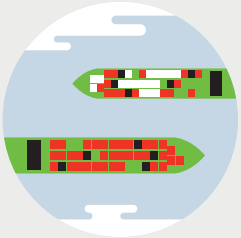
Chapter 4 Green Shipping

Green Shipping is about reducing emission from the shipping, harbour and port activities in Singapore. Although emissions from international vessel traffic is included in Singapore's national GHG (Green House Gases) emission budget, Singapore has ambitious pledges for reducing its carbon footprint. The MPA has introduced a 5-year, S$100 million Maritime Singapore Green Initiative (MSGI) which includes schemes to enhance the energy efficiency and reduce CO2 and SOx emission for its domestic fleet. The MSGI furthermore has funding schemes for free technology development and deployment, having led to more than 20 projects including 60 vessels since the launch in 2011. The Green Energy Program and LNG Bunkering Pilot Programme were added in 2016 for promoting adoption of alternative maritime fuel sources such as batteries and Liquefied Natural Gas (LNG). Two LNG-fuelled harbour crafts are currently being built by Keppel and financially supported by the MPA green shipping funds.

LNG is specifically discussed in this report, as Singapore's interest goes beyond LNG as a cleaner maritime fuel for its domestic waters. In addition to being a major LNG consumer, Singapore have ambitions of both becoming one of the main LNG trading hubs in the world, and a major LNG bunkering harbour.

Norway's decade long leading position within the maritime LNG value chain is well recognised among the Singaporean stakeholder such as the MPA, the yards, shipping companies and R&D community. The more relevant problem statements and technology needs are currently probably around LNG bunkering and associated safety issues and around small-scale distribution. As the demand for more LNG fuelled vessels increase, Norwegian technology for ship and engine technology will become more attractive. Another upcoming business opportunity area is on large-scale LNG-fuelled floating power generators, either barge-type (Gravifloat for example) or FSRU (Floating Storage and Regasification Unites) concepts for application in power-hungry countries in this region.

Innovation Norway in Singapore is actively promoting Norwegian LNG competency and technology in Singapore and Southeast Asia through networks, meeting arenas and business development support.



Chapter 5 Port Technologies

The foundation of Singapore was the establishment of its port by Sir Stamford Raffles in 1819. Today Singapore second largest container and busiest transhipment port in the world, in addition to offering port services for bulk, ro-ro, car and coaster carriers. The master plan is to move the current 6 port terminals to the new mega-port of Tuas over the next 30 years. This new port – "the port of the future" – will feature new digital solutions to become among the most efficient, safest and most environmentally sustainable ports in the world.

The port operator PSA Corp. has launched an incubator and technology promotion concept called PSA unboxed which also lists a rather detailed "menu" of specific problem statements and technology needs related to the current and future port development. These technology needs are categorized in areas such as Safety and Security; Automation, autonomy and robotics; Smart machines, cranes and systems; Digitalization and data management; Energy and environmental sustainability. Chapter 7 offers details on the specific technology needs within these categories that PSA and other port stakeholders will need to develop or acquire from national and foreign technology and solution providers.

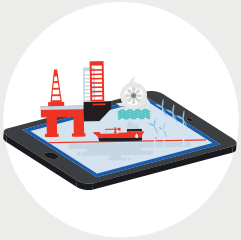
Although the Norwegian ports are minuscule compared to Singapore, much of the problem statements and technology needs are rather generic in nature. Technologies such as the Next-generation Vessel Traffic Management System (VTMS) developed by Kongsberg Norcontrol in cooperation with MPA is a good example where Norwegian excellence in maritime IT is of high demand. An interesting entry for Norwegian high-tech start-ups with relevant technology into the port opportunity space is though the PSA unboxed incubator and technology development schemes. However, local presence, local partnerships and plug-in to local network are essential requirements for success in the vibrant port technology market in Singapore.

Chapter 6 Ocean Technologies

As mentioned, the government and industry is working hard to evolve its manufacturing industry, including yard and offshore engineering, from manufacturing-centred to knowledge based and innovation-driven. An essential part of this transformation is establishment of world-class marine and offshore research facilities. The Technology Centre for Offshore and Marine, Singapore (TCOMS) locate at National University of Singapore is intended to be the national integrator for R&D between institutions like A*STAR, the universities and industry. A core facility is the S$100 million ocean basin with its 50 meter pit for deep ocean technology modelling and studies. The TCOMS will focus on advanced and innovative shipbuilding technologies; ocean energy; aquaculture and large-scale floating structures.

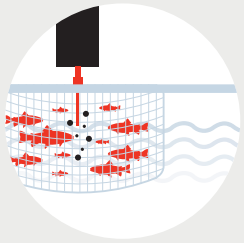
From a Norwegian point of view, TCOMS and the Ocean Basin may represent both a competitor to marine research centres like Sintef Ocean/Marintek, as much as an unique opportunity for research and technology development/testing cooperation with a facility conveniently located in Asia.

Still under contraction, TCOMS is entering MoUs with several technology and class companies such as DNV GL, Lloyds Register, Rolls-Royce Marine for cooperation within design, "smart technologies", robotics and autonomous vessels. These are all key areas of expertise for the Norwegian maritime clusters, and Singapore is actively inviting cooperation with Norwegian and other centres of maritime excellence. The established R&D cooperation channels between Singapore and Norway discussed in chapter 8 can offer gateways into the Singapore M&O research community.



Chapter 7 Aquaculture Technologies

Aquaculture technologies is granted special attention in this report, since Singapore currently is looking to substantially increasing its domestic seafood production through land-based and oceanic aquaculture. Despite the obvious differences in farmed species, production volumes, climate and land availability, the Norwegian aquaculture and associated supply chain can offer relevant solutions to Singapore. Furthermore, alliances with Singaporean marine technology companies can open opportunities to supply aquaculture solutions to the rapidly expanding seafood producing neighbouring countries such as Vietnam, Indonesia and Myanmar.



Chapter 8 Research and Development cooperation

According to Singapore's Research, Innovation and Enterprise plan (RIE2020), the four key pillars of Singapore's future knowledge-driven economy are Health & Biomedical Sciences; Urban Solutions & Sustainability; Services and Digital Industry, and in this context most relevant: Advanced Manufacturing and Engineering, where yard/shipbuilding, marine and offshore (M&O) industries are key contributors. Supported by the SG19 billion RIE2020 funds, comprehensive R&D across the maritime and M&O sectors is performed at the Maritime Institutes at each of the leading universities and under MPA, in addition to a number of joint corporate laboratories. Singapore Maritime Institute (SMI) was established by the National Research Foundation, the leading research institute A*STAR and MPA to develop the strategies and programmes to enable the transformation of Singapore into a global maritime knowledge hub. SMI's road map to reach this target is presented in chapter 8.

Recognising the long commercial relationship and joint benefits of R&D cooperation between the "ocean partners", the MPA and the Research Council of Norway entered a formal research cooperation MoU in 2000. Based on good outcome in terms of 25 R&D programs, education and training initiatives, this agreement is now in its 6th 3-year duration. Notable projects include the SESAME Straits program for traffic management in Malacca straits where 6 Norwegian companies and universities joined forces with MPA, the Norwegian coastal administration and Singapore companies, and also three ongoing projects energy efficiency under the joint funding scheme by MPA and Research Council of Norway.

The potential for enhancing the R&D cooperation between Singapore and Norway is substantial within all the technology areas discussed in this report. In fact, considering the strong push from the Singapore government to transform the industry, R&D relations may offer most effective entries for Norwegian technology companies into the Singaporean and Southeast Asian maritime, marine and offshore markets. The Research Council of Norway is recognising Singapore as an interesting global partner and have a representative (the author of this report) at the Norwegian embassy in Singapore.

Acknowledgements.

As mentioned, this report is built on a combination of research of the generous volumes of publicly available websites, report and whitepapers and interviews and discussions with experts of the Singaporean maritime eco-system. Singapore has an impressively transparent and effective communication with respect to governmental strategies, plans, programmes and funding schemes. The business newspapers and periodicals offers excellent reports and analysis of financial trends, and the leaders of key institutions are outspoken. Our interviews and in-depth discussions with experts and leaders of institutions and industry has for the author been both very educational and enjoyable.

The authors would especially thank Dr. Jasmine Siu Lee Lam, Associate Professor and Director of the MSc Maritime Studies programme and Cluster Director (Maritime clean energy research) in Energy Research Institute at Nanyang Technological University (NTU). Jasmine was the author and mentor on the chapter on Smart Shipping. We would furthermore like to thank her colleague Eng Kiong Koh, Programme Director for Maritime Clean Energy at the Energy Research Institute of NTU for his great contribution and insights on the topics of Green Shipping and Ocean energy.

We would like to thank professors Chan Eng Soon and Yean Khow Chow of National University of Singapore for their explanations on the importance of the new maritime research facility TCOMS and the ocean basin. A special thanks to the members of the Maritime and Port Authority and the Singapore Maritime Institute, including Wai Wah Tham, Ah Cheong Toh, Kwong Heng Goh, Keng Nee Chan, Thomas Ting, Liang Keon Yow and many others for their support and knowledge sharing on the entire span of maritime industries and research in Singapore. We would also like to thank Elton Fong and his team at PSA Unboxed; Kong Whee Tan, Jonathan Yap, Chin Hua Lee of the Economic Development Board; Ørnulf Jan Rødseth, Senior Scientist, SINTEF Ocean; Jennifer LEE, Regional Manager, NAVTOR Singapore; Claire Cheong of IE Singapore; Huan Sein Lim and Joo Yong Wee from the Agri-Food and Veterinary Authority of Singapore and Korshed Alam for excellent discussions and information sharing.

Finally I would like to thank Lasse Karlsen of the Norwegian maritime authority and Kjell Røang of the Research Council of Norway for their guidance and contributions to this report.

Innovation Norway Singapore,
August 2017.

Dr. Per Christer Lund *(author)*

Jeffrey Lai *(co-author)*

2.0

The Leading Maritime Capital Of The World

MARITIME SINGAPORE

Ever since Sir Stamford Raffles excited a deep port at Keppel Harbour in 1819, Singapore has been one of the leading trading hubs in Asia. Today, Singapore is the second largest container port in the world with more than 30 million TEU[2.1], second largest port in terms of cargo tonnage and the world's busiest transhipment hub. 130,000 vessels are entering its ports annually, connecting Singapore to more than 600 other ports in 123 countries. At any time, there are more than 1,000 vessels in its port and harbour[2.2]. Singapore continues to be the world's top bunkering port with 48.6 mton bunker sales, and is recently building up capacity to be one of the leading LNG bunkering ports in Asia.

The Norwegian think-tank Menon Economics is ranking Singapore as the leading maritime capital in the world for the 3rd consecutive time. In their 2017 report «Leading Maritime Capitals of the World"[2.3], Menon points out that Singapore's strength lies in its geographic location with proximity to important markets combined with its position as the key marketplace for shipping with an important centre for commercial management.

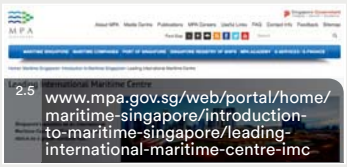
Singapore is frequently ranked as one of the world's leading international Maritime Centres (MC)[2.4] with more than 140 international shipping groups as well as leading players in ship management, finance, brokering, insurance, law and class. The local business spending from this sector was SG$3.5 billion (NOK21billion) in 2016. Singapore hosts headquarters and representative offices of international maritime organisations such as the Baltic Exchange, Asian Ship-owners Forum, International Bunker Industry Association, International Association of Independent Tanker Owners and Baltic and the International Maritime Council[2.5].

2.1 Twenty-foot Equivalent Unit – measure for capacity of container ships.

2.2 Sources: IMO, World Shipping Council, PSA

2.3 www.menon.no/wp-content/uploads/2017-28-LMC-report.pdf

2.4 Xinhua-Baltic Exchange Shipping Centre Development Index published in 2016; Menon Economics report on top maritime centres, last issue 2017.

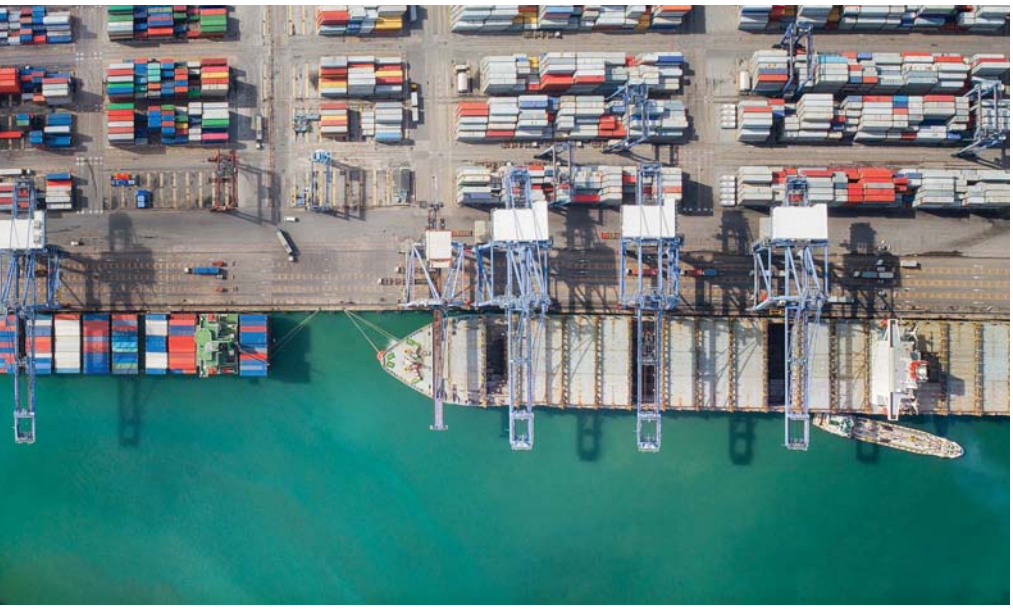


2.5 www.mpa.gov.sg/web/portal/home/maritime-singapore/introduction-to-maritime-singapore/leading-international-maritime-centre-imc

Maritime and port industries are important segments in Singapore, contributing to 7% of the Gross Domestic Product and providing more than 170,000 jobs. Singapore is home to the fourth largest fleet in the world – 88 million gross tonnes, and manages the world's second largest fleet. The pro-business government is financially and politically defending Singapore as a global strategic centre for maritime business and a leading international maritime centre.

The central pillars in the Singaporean maritime and port eco-system are the Maritime and Port Authority (MPA) and the port operator PSA Corporation. Up until just before Singapore's independence in 1965, all maritime activities were controlled by the Singapore Harbour Board. In 1964, the Port of Singapore Authority (PSA) was formed to handle assets, functions and regulation of the port. In line with the global trends in the late 1990s on privatization, corporatization and financial streamlining of public institutions, the Port of Singapore Authority was corporatized to PSA Corporation Ltd in 1997, and the regulatory functions transferred to the Maritime and Port Authority, established the year before.

Today, the holding company PSA International is fully owned by the Singapore state through its "national wealth fund" Temasek Holdings.



PSA and port technologies will be revisited in Chapter 7. MPA, on the other hand, took the triple function of being the port and harbour authority and regulator; the government's main promoter and developer of the maritime industry in Singapore; and Singapore's representative in international forum. We will revert to MPAs roles many places in this report.

The Singaporean maritime industry cluster includes international conglomerates like Keppel Corporation and Sembcorp, international port operator PSA and a diverse selection of more than 3,500 maritime companies.

Singapore yards has specialized in and holds more than 70% of the world market in jack-up rigs and conversion of FPSO (Floating Production, Storage and Offloading units) and FLNG/FSRU (LNG production, storage, regassification) units. As of 2016, there were a total of 87 shipyards in Singapore, of which 8 yards are engaged in Advanced Offshore Vessels and Rigs. Singapore yards have - like Norwegian yards - their key competitive advantage is its high skilled labour force. Hence, Singapore has a strong position in upgrading and life extension work, in particular in niche segments of offshore vessels and rigs. The major shipyards like Keppel have their own design and work extensively with design created by their own department, KOMtech.

The yards at Keppel and Sembcorp Marine has over the last decade delivered advanced vessels and rigs specialised for tough conditions and the arctic. The Singaporean yard industry is moving up the value chain for innovative solutions in addition to continuous research projects with close cooperation with leading scientists and professors. The opening of the largest integrated yard in Singapore, Tuas, which is set out to be one of the world's most efficient and environmental friendly yards is a strong indicator that the Singaporean yards are willing to invest and enhance productivity and efficiency.

Keppel Corporation, with a market value of SG$ 12 billion, is one of Singapore's largest conglomerates spanning offshore & marine, property, infrastructure and asset management businesses. Subsidiary Keppel Offshore & Marine is world's largest oil rig builder and leading on Floating Production Storage and Offloading (FPSU) and Floating Storage and Offloading (FSO) conversions.

Being exposed to downturn in the global oil & gas markets Keppel O&M is adapting high technology solutions and diversifying business to innovative solutions for oil and gas exploration, production in ultra-deep water and Arctic environments. In partnership with government, academia and the maritime industry, Keppel is an important locomotive for development and deployment of innovative business solutions for Singapore to explore and exploit mineral resources in oceans. The Keppel-NUS Laboratory is an example of this co-development.

Sembcorp Marine is a SG$ 3.5 billion shipbuilding group with a strong global position in ship repair, ship conversion, rig building and offshore construction. The operation in Singapore consists of six yards, with Jurong and Sembawang as the major wholly owned subsidiaries, and a global network of strategic locations in Singapore, India, Indonesia, the United Kingdom and Brazil.

2.1

Outlook For Singapore's Maritime Industry

"2016 was an eventful year for the shipping industry with further changes in the mega-alliances, new mergers and acquisitions, continued excess capacity and depressed rates amidst slower global growth. Despite these challenges, Maritime Singapore sustained its position. 2017 will be another pivotal year. The maritime industry will not only have to navigate through new geopolitical uncertainties and changes in alliance structures, but also new international regulations that will come into effect this year."

Mr Andrew Tan
Chief Executive of MPA
MPA Annual Report for 2016

Singapore's maritime industry has been severely hit by the latest year's downturn in global shipping and offshore sectors driven by low oil prices and sluggish investments in the oil and gas sector.

The last two and half years has been painful especially for the yards and their supply chains operating in the rig and conversion business. Keppel Offshore & Marine has seen its profit fall by over 90% since 2015, and Sembcorp Marine recently reported a 52% profit fall for Q2 2017, mainly due to a sluggish rig and FPSO market.

Overall, the offshore and maritime industry (O&M) in Singapore saw a decline of 15% from 2015 to 2016, and another 11% decline last year. The O&M industries lost 9,900 jobs from 95,500 in 2015 to 85,600 at the end of last year[2.6].

The Singapore government is taking a proactive role to support and revitalize the struggling maritime industry. In addition to direct financial support schemes, such as re-introduction of bridging loans (BL), enhancement of IE Singapore's Internationalisation Finance Scheme (IFS)[2.7], and revision of the Maritime Cluster Funds by MPA, the government established last October the "2030 Maritime Advisory Committee"[2.8] to chart future directions of Singapore's International Maritime Centre (IMC 2030). The committee will review Singapore's current maritime and port development strategy and identify new growth areas to maintain and enhance Singapore's international competitiveness as a leading international maritime centre. The fact that the Norwegian Prof. Torger Reve of BI Norwegian School of Management, CEO Remi Eriksen of DNV GL and Geir Sjurseth of DVB Bank are members of the committee suggests the recognition of Norway as an important "ocean partner" to Singapore.

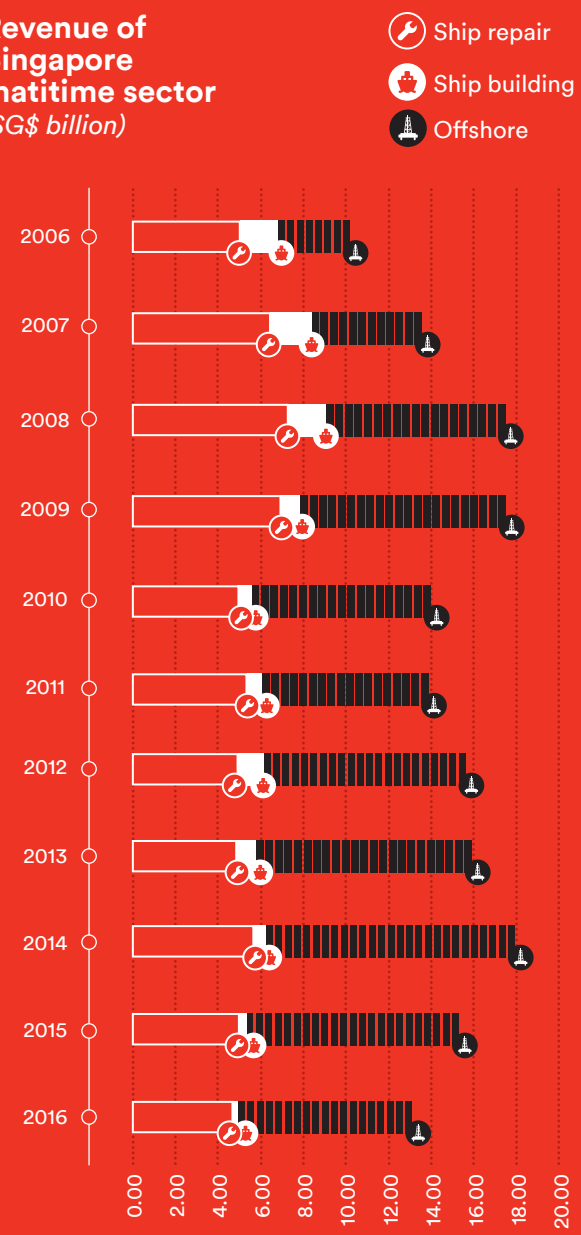
In line with the recommendations from this IMC 2030 committee and the more general Committee of the Future Economy, the MPA will develop an Industrial Transformation Map (ITM) covering innovation, productivity skills and internationalisation for the maritime sector. This is part of the governments S$4.5 billion Industry Transformation Programme[2.9]. To quote Andrew Tan, CEO of MPA, from MPA's 2016 Sustainability Report[2.10]: "MPA will develop an industry transformation map covering innovation, productivity, skills and internationalisation for the maritime sector. This will pave the way for the maritime sector in Singapore to embrace many of the new developments that are impacting industries worldwide as they adapt to industry 4.0, with growing use of digitalisation, data analytics and deployment of intelligent and automated systems to enhance competitiveness and productivity."

The Menon report mentioned earlier confirms the view that for Singapore to be able to maintain and strengthen its position in the maritime world, it need to combine its value as a diverse and vibrant cluster of maritime stakeholders with a strong dedication to develop and deploy new technologies across the entire value chain.

International relations and cooperation is essential for the Industry Transformation. Singapore being the size it is, the government and industry realizes that to be able to attract foreign companies, foreign technologies and not at least foreign talent they have to adapt an open and proactive policy towards international technology development, investment and reserach cooperation.

The objective of this report is a response to the "open invitation" to Norwegian and other countries' technology milieus' to take part in the transformation of the Singaporean maritime and port industries. Given Norway's excellence and global leadership in several of the technology areas prioritized by the Singapore authorities, and Norway's strong standing as "ocean partner", we believe the opportunities for commercial joint business development and academic collaboration between Norway and Singapore will be substantially growing.

Revenue of Singapore matitime sector
(SG$ billion)

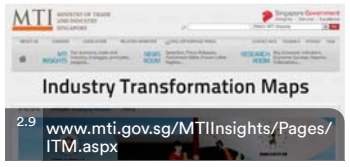


Source: Association of Singapore Marine Industries, Business Times.

2.6 http://www.businesstimes.com.sg/companies-markets/om-sectors-turnover-down-113-last-year

2.7 www.osjonline.com/news/view,singapore-provides-financial-support-for-troubled-offshore-industry_47762.htm

2.8 www.mpa.gov.sg/web/portal/home/media-centre/news-releases/detail/ab6fd580-e101-4f7d-977d-2d129cd73b5a



2.9 www.mti.gov.sg/MTIInsights/Pages/ITM.aspx

2.10 MPA Sustainability/Integrated Report for 2016: http://www.mpa.gov.sg/web/portal/home/about-mpa/annual-report

2.2

Norway and Singapore – Ocean Partners

One year after independence in 1905, Norway set up its consulate in Singapore - a sign of Singapore's importance as a harbour for Norwegian vessels. Over the "hundred over" years since, Norwegian shipping companies, ship service and maritime financial services institutions, and later oil and gas companies chose Singapore as their preferred hub for Asian establishment.

Today about 250[2.11] Norwegian and Norway-related companies are registered in Singapore, the largest Norwegian business community in Asia. Of these, more than 80% are within the maritime and oil & gas industries, covering the value chain from finance, insurance, brokerage, trading and expedition, ship owners, services and consulting, class, engineering and equipment providers.

The bilateral trade between Norway and Singapore decreased 25% between 2014 and 2016, mainly attributed to the downturn in the maritime and offshore industries. Consequently, Norwegian companies are getting more cost conscious, calling home ex-pats and reducing local staff. The embassy and seaman church has observed a 20% reduction of the Norwegian community over the last couple of years.

[2.11] 400 listed companies, but this includes individuals, sales offices, agents and firms without company registration in Norway. The Norwegian embassy in Singapore and the Norway Business Association in Singapore (NBAS) operates with a number of about 250 active companies.

> *"Norway and Singapore enjoy a long-time maritime collaboration that has strengthened both countries' maritime technology and competence clusters. Through a strong focus on sustainability, our cooperation aims to prepare the industry to meet future challenges and environmental demands for shipping. For Norway, innovation and green technology is always high on our agenda. On this basis, we look forward to partner with Singapore to continue our efforts to deliver the most innovative and high tech solutions that benefits the maritime industry"*
>
> Director Torunn Taralrud
> Innovation Norway Singapore

Norwegian engineering companies and equipment suppliers represents a solid industry cluster in Singapore of more than 40 companies. Singaporean yards are well acquainted with Norwegian maritime equipment and are fully aware of its strong position within the offshore and deep ocean equipment. The position of Norwegian ship equipment within the offshore segment is very strong in Singapore, especially where the vessel build or conversion project is ordered by a Norwegian owner, by Norwegian design and/or is built for use in the North Sea. The reason is that few Singaporean suppliers can fulfil the standards and expectations of the Norwegian owners. However, where the vessel is not an advanced vessel to be used in the North Sea, non-Norwegian design is usually preferred, and the position of Norwegian companies appears to be weaker.

In general, Norwegian equipment and expertise is perceived as quite unique, strong and state-of-the art. Norwegian equipment appears to be more likely to be chosen if the vessel has to comply with NORSOK standards.

Examples of larger deliveries from Singapore shipyards to Norwegian owners over the last one year include Sembcorp Marine delivery of the topside of DNO's (Det Norske Oljeselskap – now Aker BP) Ivar Aasen platform in June 2016. The SG$900 million (NOK 5.4 billion) took 40 moths and 14 million man-hours to complete. Most of the major equipment packages were procured from Norwegian vendors.

Keppel Offshore & Marine is completing the installation and integration of topside modules to the BW Offshore's new FPSO vessel BW Catcher. This is the 12th FPSO project between BW and Keppel O&M. Keppel is also upgrading work to the pipelay vessel, Castorone, for Saipem Offshore Norway.

Singaporean direct engagement in Norwegian companies and investment in Norway is much more moderate. Keppel O&M had an office in Stavanger, Norway until it was sold to the engineering company OneCo in 2012.

However, as Singaporean shipyards are expanding and diversifying their business into new segments, we see an increasing interest in advanced Norwegian maritime technology companies. Last year (2016) both Keppel and Sembcorp made strategic investments in Norwegian technologies.

Keppel acquired Norwegian offshore wind foundation company Owec Tower, indicating its interest in ocean renewable energy, and Sembcorp Marine acquired the Norwegian naval architecture and design company LMG Marine AS for SG$20 million (NOK120 million) and a majority stake in the Norwegian technology company Gravifloat for SG$38 million (NOK228million). Sembcorp and French energy company Engie has agreed to deploy the Gravifloat floating platform technology for LNG-to-Power nearshore terminals, focusing on small LNG power businesses with 10 MW to 300 MW capacities.

As mentioned before, the Menon report ranks Singapore as number one leading maritime capital of the world. The nation ranks number one in Shipping; Ports and Logistics; and Attractiveness and Competitiveness and number four on Finance & Law. However, Oslo outranks Singapore as number one and two with regards to Maritime Technologies. This should be taken as motivation for Singapore and Norway to collaborate in developing and commercializing technologies across the maritime industries; especially within shipping and ocean technologies and to some extent port technologies.

As further discussed in chapter 7, Norway and Singapore has an extensive research collaboration within the maritime and O&G sectors. The Research Council of Norway (RCN) and MPA signed an agreement in 2000 on collaboration in research in maritime environment, sustainable energy technology, offshore and marine engineering, and maritime operations and info-communications technology. The research and technology development resulting from this agreement is characterized by substantial company participation from both sides, including DNV GL, Kongsberg Norcontrol IT, Rolls-Royce Maritime, Odfjell Group, BW, IM Skaugen, Høegh and Navtor.

Governmental relations

The Norwegian Maritime Authority (NMA - "Sjødirektoratet") and the Norwegian Coastal Administration (NCA - "Kystverket") have a long history of bilateral and multilateral cooperation with Singapore witnin areas such as navigation and communication; port/ searoute surveillance; e-certificates, piracy prevention; safety and environmental and pollution regulations.

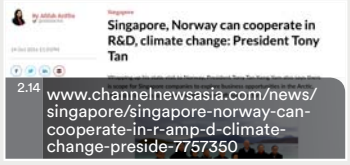
The SESAME Straits project (Secure, Efficient, and Safe maritime traffic Management in the Straits of Malacca and Singapore) completed May this year, is an example of successful projects where Norwegian and Singaporean authorities (MPA and NCA) and companies are developing, testing and demonstrating technologies and solutions of mutual national interest. This project is discussed further in the "Smart Shipping" chapter.

Sharing an increasing interest in developing infrastructure around LNG as a cleaner maritime fuel, MPA and the Norwegian Maritime Authority signed an MoU in Singapore last year together with the Ports of Antwerp, Rotterdam, Zeebrugge, Jacksonville, Ulsan and Japanese ministry MLIT to develop a network of LNG bunker-ready ports across the major global sea-routes[2.12] .

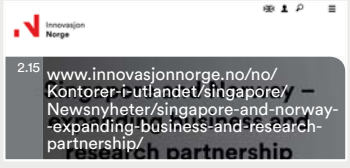
The long lasting and strong official relations between Singapore and Norway was confirmed through the official visit of Norwegian Prime Minister Solberg to Singapore in April 2016[2.13] and the State Visit of Singapore's President Tan to Norway in October 2016[2.14]. In addition to exploring and strengthening R&D collaboration within energy and arctic research, a joint statement on maritime cooperation between Singapore Business Federation, Innovation Norway and the newly established Norway-Singapore Chamber of Commerce was signed. The statement reconfirms the ambition of a comprehensive "ocean partnership" between the two countries[2.15].

2.12 https://www.sjofartsdir.no/en/news/news-from-the-nma/agreement-on-harmonised-lng-bunkering-standards/

2.13 www.straitstimes.com/singapore/singapore-and-norway-reaffirm-close-and-growing-ties



2.14 www.channelnewsasia.com/news/singapore/singapore-norway-can-cooperate-in-r-amp-d-climate-change-preside-7757350



2.15 www.innovasjonnorge.no/no/Kontorer-i-utlandet/singapore/Newsnyheter/singapore-and-norway-expanding-business-and-research-partnership/

Innovation Norway Singapore

Innovation Norway is the Norwegian Government's most important instrument for innovation and development of Norwegian enterprises and industry, and the Norwegian government's official trade representative abroad. Innovation Singapore is equipped with 5 persons including two senior advisors with maritime, offshore and energy competence.

www.innovationnorway.no

Team Norway – the Norwegian Embassy and Norwegian Business Association Singapore

The Royal Norwegian Embassy promotes Norwegian economic, political and other interests in Singapore and facilitate contact between the two governments.
The following organisations are collocated with the Embassy: Innovation Norway; the Norwegian Business Association Singapore (NBAS) and the Norwegian Seafood Council. Together, they make up the Team Norway – an informal grouping of organisations all involved in the furthering of Norwegian interests.

www.norway.no/en/singapore

www.nbas.org.sg

Norwegian Energy Partners (NORWEP)

NORWEP is an outcome of a recent merger between INTPOW and INTSOK in 2017. Norwegian Energy Partners is a network-based organisation, facilitating dialogue between energy companies, technology suppliers, service companies and the government. NORWEP has an energy advisor in Singapore which can support business development of NORWEP members in Singapore[1] .
The main objective is to promote Norwegian energy industry in overseas markets and provide market information as well as assist partners with relevant entry strategies to international markets.

www.norwep.com

Export Credit Norway and GIEK

Export Credit Norway and the Norwegian Guarantee Institute for Export Credit offers financial services to Norwegian enterprises with ambitions to export technologies abroad. They offer competitive financing to buyers of Norwegian capital goods and services worldwide, including ships and subsea technology, solar parks, hydropower turbines and design services. Export Credit deal with the entire loan application process, including commitment, disbursement and monitoring of loans. Export Credit Norway has appointed Jeffrey Lai, from Innovation Norway as the local representative in Singapore.

Foreign buyers of Norwegian products and services are also eligible to assess Norway's government backed export financing system. Interested buyers from either large or small enterprises are welcome to contact the local representative to discuss on how Export Credit Norway can support you with attractive financial options.

www.eksportkreditt.no

www.giek.no

IE Singapore and Innovation Norway cooperation

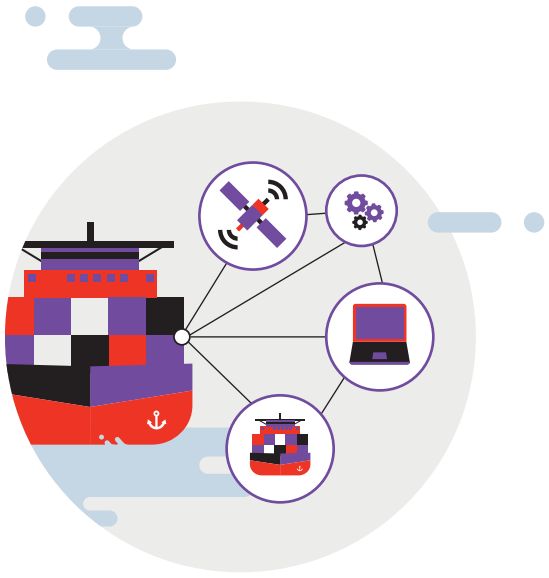
International Enterprise (IE) Singapore is the government agency driving Singapore's external economy and spearheads the overseas growth of Singapore-based companies and promote international trade.
IE Singapore and Innovation Norway Singapore are actively cooperating to identify and facilitate business opportunities and connect Singaporean and Norwegian maritime and offshore companies.

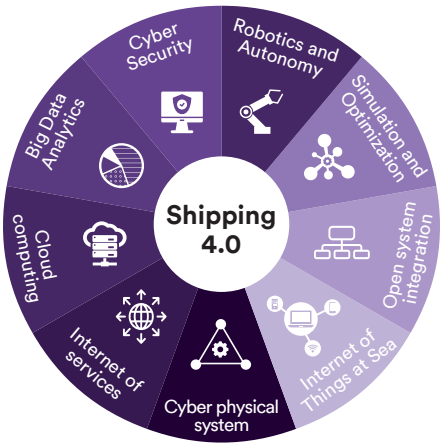
A week-long study tour to Norway in March 2017 connected 13 participants from Singapore to industry clusters, agencies and individual companies in 5 offshore and maritime centres in Norway (Arendal, Kongsberg, Oslo, Bergen and Trondheim). The networking and information exchange with more than 40 Norwegian companies is giving results in new agreements and leads. The tour was supported by Norwegian Energy Partners, the global centres for excellence GCE Node and GCE Subsea, Norwegian centre of excellence Maritime Cleantech and Norwegian Maritime Exporters.

www.iesingapore.gov.sg

3.0

Smart Shipping





Source: Shipping 4.0-MARINTEK

The evolution of "Smart Shipping" starts in parallel with land industry, where shipping has experienced three technical revolutions: steam engines (~1810), diesel engines (~1910) and digital control systems (~1970). Still in parallel with industry, it is facing its fourth revolution based on the so-called "Industry 4.0" revolution, integrating Internet of Things, Cyber Physical Systems, Big Data and other technologies. As with previous revolutions, we expect that "Shipping 4.0" will have a profound effect on shipping operations and on how the business will be put together. The society's focus on energy efficiency and reduced emissions is expected to amplify the uptake of the new technology.

Shipping 4.0 is mainly characterized by a huge increase in available digital information, but also by new service and operation concepts made available with better connectivity between ship and shore. Examples are already emerging in e-navigation, third party analytics and administrative shore services. Supporting evidence is, e.g. in the amendment to the IMO FAL convention which will require electronic port clearance of ships from 2019 and the strong interest in cyber security in IMO and elsewhere. The interest in, and eventual deployment of autonomous ships, can be seen as the culmination of Shipping 4.0.

There are immense opportunities from digital technology and automation that shipping hasn't embraced. The ships might have more efficient engines and operate with larger ships. Yet, the way that we manage, operate and maintain ships hasn't been revolutionized to reap the full benefits of these technologies.

Industry definition of what is a 'Smart Ship'

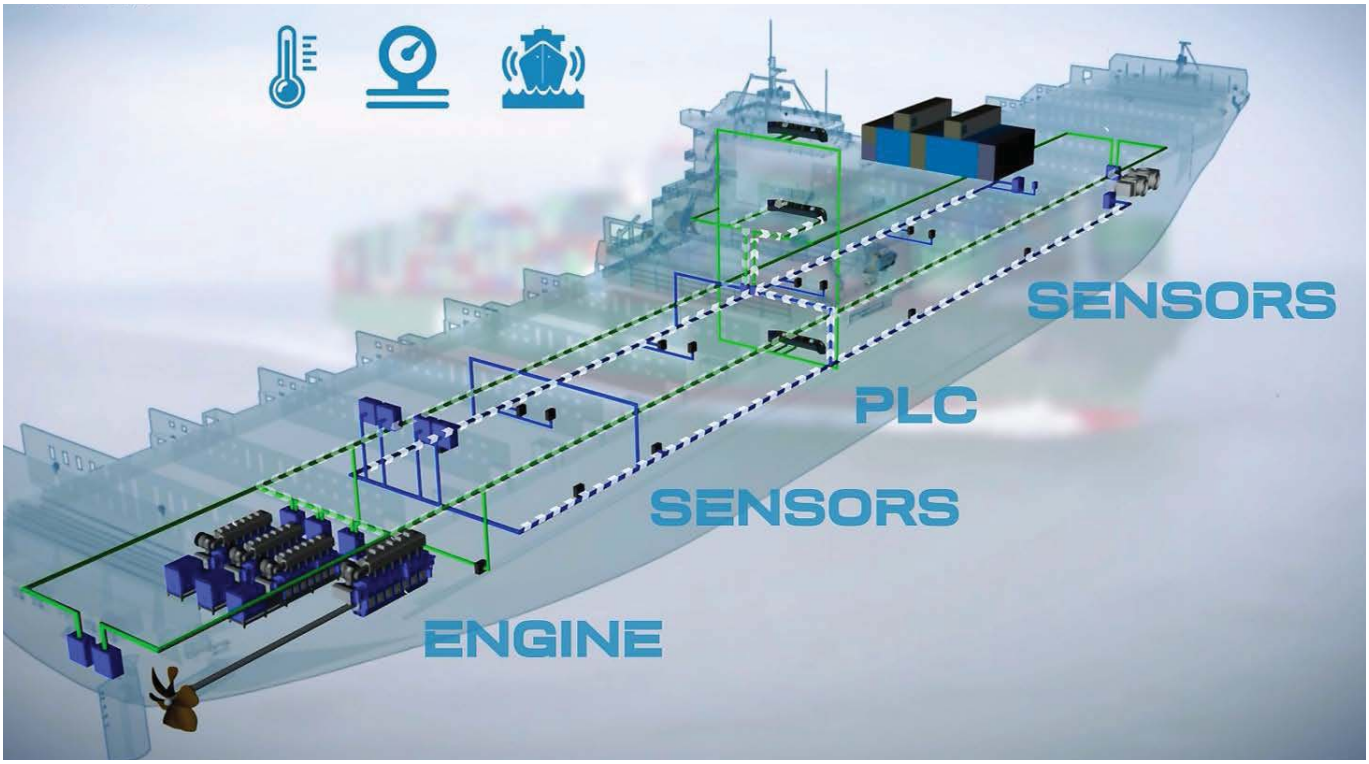
Smart ships are intelligent ships. They operate with every detail of their environment, their parameters, purpose, needs, components and machinery in mind, in order to make decisions that will enhance safer, faster, more efficient operations.

Where is Singapore heading?

As discussed in the previous chapter, Singapore's maritime industry has been and will continue to face hard times due to downturn in the offshore oil and gas sector. To counter these trends, the industry is preparing to transform itself embrace the opportunities within Shipping 4.0.

According to the executive director of Singapore Maritime Institute, Heng Chiang Gnee[3.1], the industry "are now looking at smart ship technologies and smart ports using sensors ... and the skill set of workers could clearly see a shift. For example, a chief engineer who has had a lot of hands-on experience on the ship could potentially, going forward, just sit in a remote place and let all the data of the ship be fed to him". Addressing such a topic as 3D printing, Mr. Heng points out that advances in 3D printing could also disrupt the entire ship repair industry altogether. Soon the technology would be advanced enough to print larger items, such as spare parts for ships that can be as long as a few hundred meters.

Singapore aims to be a key player in the global digital economy and is in a good position to tap on this growth. Among Singapore's key advantages are its high security standards and strong reputation as a "trusted partner".



Source: DNV-GL

[3.1] Interview with the magazine Today, November 2016.

3.1

Digitalization

As the world is being digitalized, the seamless flow of information and communication technology and the increasing big amounts of data will continue to drive changes impacting shipping.

Norway is investing heavily in the digital transformation to build economic growth with a new position paper set to revel government backing for a digital maritime future[3.2].

Norway's leading classification company – DNV-GL believe that the main drivers of change will vastly improve maritime connectivity, lead the advance of cyber-physical systems and 'digital' twins will dominate the digital side of shipping in the coming decade, as vessels increasingly resemble floating computers.

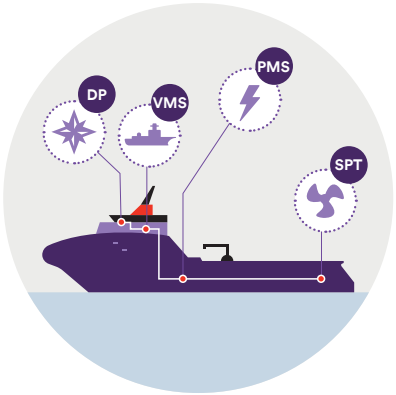
Digital copies of real vessels – dubbed 'digital twins' – will start to be used in earnest by the industry to explore and enhance layouts, design specifications, simulation models, data analytics, and so on. A digital twin of a ship has many potential applications throughout its lifecycle.

Two new digital platforms are being developed to help Singapore's maritime industry adapt to a future where digitalization is disrupting and transforming global transportation and supply chains.

Firstly, the development of the next-generation National Trade Platform connecting shippers, shipping lines, the port, government agencies and logistics players. The project was led by Singapore Customs and the Government Technology Agency, and will replace the existing TradeNet and TradeXchange systems, and aims to support companies in the trade and logistics industry and adjacent sectors such as trade finance. It will be progressively rolled out from end-2017. The project won a price in the e-business category of the World Summit on Information Society (WSIS) Prizes in July 2017[3.3].

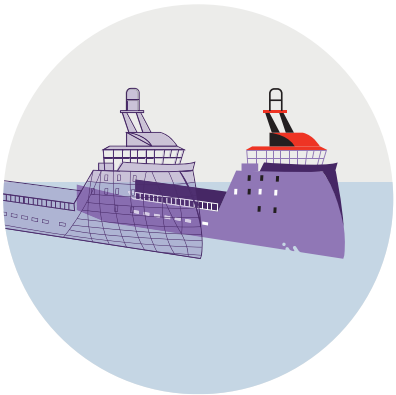
Secondly, the MPA is developing the Maritime Single Window, which will provide a single portal access for submitting documents for port clearance and act as a one-stop integrated, digital platform to connect shippers, shipping lines, the port, government agencies and logistics players.

cyber-physical systems



DP Dynamic Positioning
VMS Vessel Management System
PMS Propulsion Management System
SPT Speed Power Train

'digital' twins



3.2 http://www.fathom-news.com/norway-puts-digital-development-high-agenda/

3.3 http://www.channelnewsasia.com/news/singapore/singapore-s-national-trade-platform-wins-international-award-8944362

Technology Needs And Problem Statements

Digitalization in shipping opens up new opportunity than what physical technology can deliver in terms of higher efficiency gains and operational real-time support. Some of the areas highlighted are:

Maritime connectivity[3.4] refers to where VDES (new data service on the VHF band); Wi-Fi in ports, and, most importantly, satellite communications, improving coverage and bandwidth. Likewise, apart from enhancing safety and efficiency, ship connectivity will also answer the need for more transparent operations and help build trust and collaboration between various industry stakeholders based on the collection and analysis of shared information. Ship connectivity will provide a unique opportunity for maritime authorities to monitor compliance with existing regulations to improve safety, achieve environmental targets, and boost competition in the industry.

1. **Marine Cyber-Physical Systems** where marine navigation systems will increasingly rely on advanced software and sensors to alert the navigator to possible hazards ahead, and propose appropriate courses of action to maintain a safe route.

2. **Digital twin.** In the next decade, ship systems and related digital twins will be designed with the support of cloud-based information management and multi-model simulation platforms. These will allow different stakeholders to populate the digital twin of an asset with modules and evaluate in advance how the system will operate as a whole.

On a wider perspective, the technological developments and solutions for future ships requires a network of specialized and agile companies that can offer innovative services not seen before.

3.4 https://to2025.dnvgl.com/shipping/digitalization/

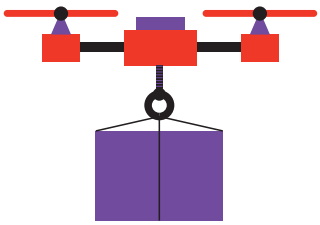
3.5 https://www.nrf.gov.sg/rie2020/growing-a-vibrant-national-innovation-system

Service providers should aspire to focus on the specific technology needs for a digital ship includes:

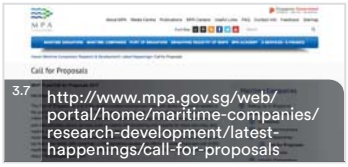
- Condition Monitoring
- Smart Sensors.
- Continuous Emissions Monitoring.
- Automated Ballast Water Treatment Systems.
- Satellite Communications.
- Cybersecurity Management.
- Weather Monitoring.
- Propulsion Monitoring.
- Smart Bridge Technology.
- Nanotechnology and Big Data.

In Singapore, a national initiative by NRF aims to build a strong core of innovation enterprises that drive value creation and economic competitiveness[3.5].

3.2 Automation & Robotics



3.6 http://www.mpa.gov.sg/web/portal/home/media-centre/news-releases/detail/232129a2-ea59-45c8-8bce-afb3ffd3f77f



3.7 http://www.mpa.gov.sg/web/portal/home/maritime-companies/research-development/latest-happenings/call-for-proposals

3.8 http://www.businesstimes.com.sg/transport/maritime-singapore-steps-up-on-digitisation-and-automation

3.9 http://www.mpa.gov.sg/web/portal/home/media-centre/news-releases/detail/b8947c16-bd25-4499-a115-4ca1f8333f82

The shipping industry is often described as lagging other industries when it comes to technology. However, with various challenges on both an individual organization and broader industry level, the shipping industry is increasingly adopting new technologies especially with nowadays rapid development of science and technology.

With maritime heritage since the year of 1819, Singapore is heavily investing itself to be a premier International Maritime Centre (IMC). As a leading maritime capital and to prepare for the transition in the future, Singapore is committed to large-scale research and development (R&D) in automation and robotics for the shipping industry which has been and will continue to be of strategic significance.

The Maritime Innovation & Technology (MINT) Fund[3.6] established by the Maritime and Port Authority of Singapore (MPA) in 2003 has supported more than 290 R&D projects since its inception. Focus areas include environment & energy, operations & logistics, safety & security, ICT & systems, marine and offshore engineering, which has been further extended to cover data analytics, modelling & simulation, autonomous technologies and sensors in light of the Smart Shipping era[3.7].

MPA has constant collaboration with industry partners across the maritime value chain for maritime technology innovation. Recent signed Memoranda of Understanding (MoU) have particularly focused on the new technologies and R&D programmes for a foreseen digitized and autonomous maritime future[3.8]. Automation and robotics are among the key topics to enhance manpower productivity and safety.

In support, the MPA Living Lab announced in March 2017[3.9] provides a technology partnership platform. It is the first of its kind in the region which allows test-bed of locally developed solutions under actual operating conditions. This also facilitates MPA's increasing emphasis on the translation of the R&D outputs into applicable products and solutions. Robotics, drones, autonomous vessels and other autonomous systems are all under the framework for testing and development.

Automation of operations and implementation of robotics will improve work efficiency, productivity and safety on-board and ashore.

Market potential and applications

Singapore is one of the most highly developed industrial economies in the world and is a major consumer of automation equipment. Singapore has been ranked number seven across the world by the U.S. International Trade Administration in their 2016 Industrial Automation Top Markets Report[3.10]. With the worldwide supply increase of industrial robots, Asia/Australia region has seen even greater growth potential (Figures 1 and 2). Robot supplies to Southeast Asian countries have experienced considerable increase, particularly Singapore which is among the most automated markets[3.11].

Automation technology and robotics systems are especially imperative for the shipping industry in Singapore. There are issues of aging population and manpower shortage. While crewing and manning problems are global issues, the shipping industry in Singapore is even more affected with shortage of seafarers. Compounded by very limited land resources, Singapore has put high productivity among the top priorities.

For operations on-board and ashore, automation and robotics have great potential for application. Navigation systems in particular, have seen increased levels of automation. Smaller crew will be needed on-board with more reliable engines, improved loading/unloading technology, intelligent machines for maintenance and repair. Crew may move ashore and remotely operate several vessels concurrently.

Automation and robotics potentially solve the crewing and manning problems. Automation of processes in port operations will save manpower requirement, improve work efficiency and reduce vessel waiting-times and berth idle times.

Automated technology and robotics systems potentially play essential roles in the shipbuilding and repair sector as well. In Singapore, a global shipyard center for ship repairs and maintenance, where higher level of automation could help shipyards with higher efficiency gains and stay more competitive. Moreover, robotics systems can not only improve efficiency and productivity but also spare working people from monotonous and dangerous tasks.

All these technologies and potential applications are significant for the shipping industry in Singapore to stay competitive and cutting-edge, thus creating opportunities for Norwegian companies and R&D institutions. While these efforts aim to solve the challenges for Singapore shipping industry, capabilities acquired can be exported to the rest of the world.

In chapter 5 on Port Technologies, under section 5.4 on automation and autonomy, there are many applications that Singapore Port operators are looking to embrace automation applications to improvement in port management.

3.10 http://www.trade.gov/topmarkets/pdf/Industrial_Automation_Top_Markets_Report.pdf

3.11 World Robotics Report 2016, International Federation of Robotics.

3.3

Data & Analytics

The future competitiveness of the maritime industry in Singapore will be affected by how rapidly shipping operators take advantage of Big Data, according to Martin Kits van Heyningen, CEO of KVH Industries, Inc., one of the world's leading suppliers of satellite communications to the maritime industry[3.12].

In Singapore, data collection and analytics will provide valuable insights on managing port traffic and congestion in addition these data include both hard data (i.e. structured, quantitative, more objective, usually sensed data) and soft data (i.e. unstructured/semi-structured, more subjective, qualitative data, such as textual reports on vessel sightings or marine incidents) collected in different maritime sectors will be critical information for ship owners and authority.

Singapore, as a premier International Maritime Centre and a leading maritime capital, has made intensive investment to develop the data analytics capability in the maritime domain. Such measures are of great strategic significance and will reinforce Singapore's competitiveness as a hub port, and support an increasing international maritime cluster.

As part of the two-year agreement, IBM will create a unified platform to integrate real time data and provide a consistent view of data points across MPA to empower port operators to make more informed decisions. For example, with vessel positional and weather data, the platform will report on any vessel path inferences to avoid accidents[3.13].

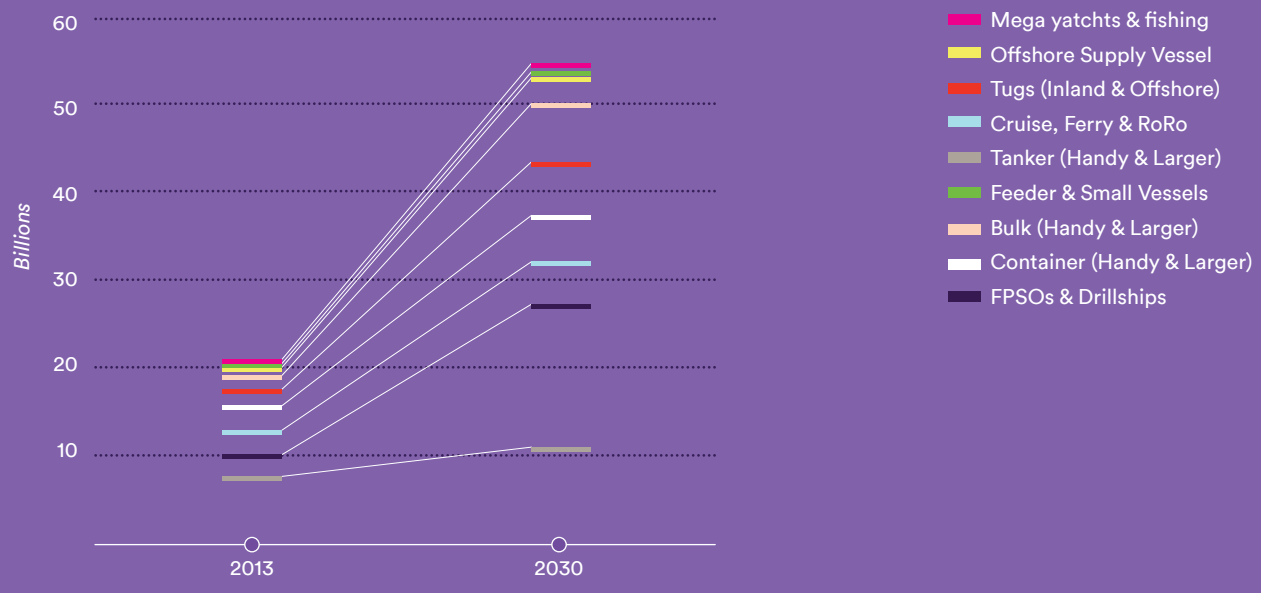
To capture this opportunity, asset owners and operators will need to bring together equipment with sensors, data storage and processing servers, analytics software and the right talent. Singapore government has newly launched the MPA Living Lab, a platform which provides real operating conditions in the port of Singapore and focuses on developing capabilities in data analytics and intelligent systems, autonomous systems and robotics, smart and innovative infrastructure and safety and security. This serves as a good example of the efforts in strengthening the data analytics capability.

3.12 https://www.porttechnology.org/news/big_data_key_to_maritime_industry

3.13 http://www.mpa.gov.sg/web/portal/home/media-centre/news-releases/detail/6a054eff-e932-47bf-8558-ed73bc181ad9

Market potential and applications

In the shipping industry, it has been estimated that the opportunity across the industry from the internet is approximate US$25 billion today and will exceed US$50 billion by 2030 (as shown in Figure 3). Maritime stakeholders will benefit from using the data to reduce fuel consumption, increase equipment reliability, decrease maintenance costs, and ensure environmental compliance. Based on the global fleet as of 2013, the value creation potential is estimated at approximately US$20 billion[3.14].



Estimated growth in value creation for industrial internet application in maritime

Figure 3 Industrial internet value creations in maritime industry

Given the great value creation potential for various maritime sectors, the MPA is looking deeper into big data as a way to improve port operations and activities. The authority foresees the port being able to use data analytics platforms to complement the port management systems in detecting anomalies and supporting both operations and planning processes.

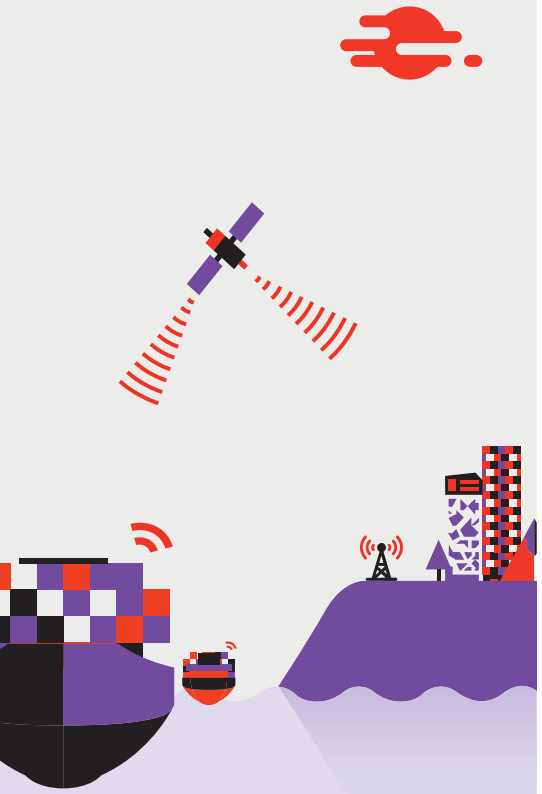
With respect to video analytics, MPA has CCTV coverage across the container terminals and the port waters. The next challenge is to cover the whole port with surveillance sensors.

In addition, the maritime industry and even the public sector are exploring the use of drone technology in areas such as improving service delivery. MPA is looking at drones for a variety of reasons. Currently, to collect data, a boat is needed to navigate around the port. But using a boat may not be the most efficient way to collect data as the boat's speed is limited and there is heavy marine traffic. This serves as an opportunity for players who can provide relevant technology platform and increase MPA's efficiency and safety both in the port waters and in the container terminals.

3.14 ESRG analysis based on multiple data sources, including: Lloyd's Register, IMO

3.4

E-Navigation



The inception of e-Navigation concept took place way back in the year 2006, when the International Maritime Organization (IMO) decided to include a well-defined strategy to integrate new and existing navigational tools for enhancing handling and safety of ships at the sea.

Modern ships use digital equipment such as AIS, ECDIS, Integrated Bridge Systems, Automatic Radar Plotting Aids, Long Range Identification and Tracking, GMDSS and several other sophisticated electronic navigational tools. The main aim of the e-Navigation concept is to develop a system which can properly organize all the ship's data at one place in order to help improving navigational safety of the ships.

E- Navigation is defined by IMO as: "the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and securing sea and protection of the marine environment.

Singapore is an early adopter of implementing e-navigation in South East Asia region. This is to support the presence of large international shipping groups in anticipation of IMO regulations to adopt electronic charts and replacing paper charts in the near future. The three important criteria for e-navigation are: ship systems, shore-based systems and communications system.

Maritime industry powered by developments in E-Navigation

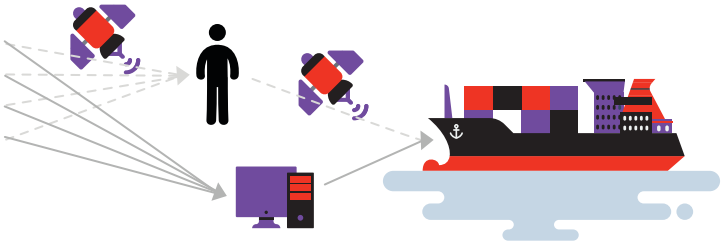
Over the next few years, e-navigation technology will be the central of focus as industry players, global e-navigation leaders and solution providers work on improving solutions that will cater to the needs of the industry.

To build a future ready maritime Singapore, more international collaboration is expected as Singapore takes the lead to embark on a firm plan to develop a comprehensive next-generation traffic management to manage its busy traffic at port and maintain best records for ship incidence as well as with the progressive development of a fully automated port taking shape by 2020.

By end of the year 2017, the Maritime Authority of Singapore (MPA) will shortlist suitable solutions providers with relevant e-navigational domains to participate and explore further progression from concept to test bedding for the next generation vessel traffic management system.

Norwegian solutions providers are welcome to explore development and business opportunities as well as how it can cater to the needs of the industry. This includes relevant solutions within smart shipping, digital platforms of the future, big data, autonomous systems, and cyber security

3.5 Autonomous Vessels



If technology could make it happen, great benefit potentials are expected with autonomous vessels. Shortage of seafarers is a global issue in the shipping industry. With expected growth of maritime trade volumes and more vessels in the future, manning problems may become even more severe. Deployment of autonomous vessels is regarded as the most effective solution. In addition, autonomous vessels are expected to meet competitiveness, safety and sustainability challenges.

The Norwegian Shipping industry is very actively pushing on the development of autonomous vessels. Recently in 2017, the Norwegian Maritime Authority and the Norwegian Coastal Administration agreed to open the world's first autonomous ship testing area. The Norwegian Forum for Autonomous Ships (NFAS) brings together and shares information with organizations interested in autonomous ships. Norway is also taking the lead in building autonomous cargo ships. The vessel "YARA Birkeland" scheduled to start sailing in 2018 will be the world's first fully electric and autonomous container feeder with zero emissions[3.15]. In addition, Norway's Kongsberg Maritime and the UK's Automated Ships Ltd (an M Subs Ltd subsidiary) have signed a Memorandum of Understanding (MoU) to build the world's first unmanned and fully-automated vessel for offshore operations[3.16]. In January 2017, Automated Ships Ltd will contract the 'Hrönn', which will be designed and built in Norway in cooperation with Kongsberg. Sea trials will take place in above-mentioned Norway's newly designated autonomous vessel test bed in the Trondheim fjord and will be conducted under the auspices of DNV GL and the Norwegian Maritime Authority (NMA). The Hrönn will ultimately be classed and flagged, respectively.

Autonomous vessel is also on Singapore's agenda towards the Smart Shipping era. Autonomous technologies and sensors are among the focuses of the Maritime Innovation & Technology (MINT) Fund established by the Maritime and Port Authority of Singapore (MPA)[3.17]. In addition, they are also under the scope of Maritime Cluster Fund introduced MPA, which aims to facilitate the growth of Singapore's maritime cluster by supporting the industry's manpower and business development efforts as well as its drive for productivity improvements[3.18]. The MPA Living Lab provides the platform and allows for the development and testing of autonomous systems including autonomous vessels, drones within its framework conditions[3.19].

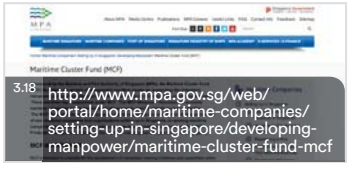
An MoU between MPA and DNV GL for maritime R&D and innovation has been renewed for an expanded scope[3.20]. One key area is intelligent shipping systems such as autonomous vessels for maritime purposes, to enhance safety and sustainability of shipping and port activities. This is aligned with Singapore's efforts to keep pace with developments in smart ships and ports as the industry moves towards adopting smarter shipping systems to achieve higher standards of efficiency, productivity and safety.

In short, autonomous vessels will first operate within State waters and gradually branch out to international waters if they are successfully operated in coastal areas. Extensive testing and continuous R&D is mandatory to reach wider operational areas as well as for larger ships. At the same time, regulatory and legal frameworks need to be developed to facilitate a safe and responsible uptake of new technology and solutions.

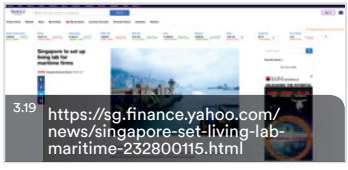
3.15 https://www.wsj.com/articles/norway-takes-lead-in-race-to-build-autonomous-cargo-ships-1500721202

3.16 https://www.km.kongsberg.com/ks/web/nokbg0238.nsf/AllWeb/65865972888D25FAC125805E00281D50?OpenDocument

3.17 http://www.mpa.gov.sg/web/portal/home/media-centre/news-releases/detail/232129a2-ea59-45c8-8bce-afb3ffd3f77f



3.18 http://www.mpa.gov.sg/web/portal/home/maritime-companies/setting-up-in-singapore/developing-manpower/maritime-cluster-fund-mcf



3.19 https://sg.finance.yahoo.com/news/singapore-set-living-lab-maritime-232800115.html

3.20 http://www.mpa.gov.sg/web/portal/home/media-centre/news-releases/detail/6172e16c-583f-4b79-8fa9-d7f3adca81ca

3.6

Maritime Cyber Security

With the move towards “Smart Shipping” and “Big Data”, the shipping industry is increasingly reliant on technology across virtually all fronts, from navigation at sea to shipboard and onshore operations. The advancement in broadband technologies has supported such digital transformation. At the same time, it makes the shipping industry vulnerable to the emerging risks in the cyber domain.

Maritime cyber security is now a major concern with the increasing use of new and sophisticated communication technologies, also due to the growing sophistication of cyber-attacks. It is an area of vital interest to ship-owners, operators, governments, and many other stakeholders. It is imperative for the industry to protect against all forms of cyber-attacks.

Technology needs and Problem Statements

The Internet of Things (IoT) is driving increasing automation with growing numbers of connected devices and the amount of data generated. The increasing trend of the frequency, complexity and severity of cyber-attacks has alerted greater emphasis on cyber security. Maritime cyber security requires comprehensive measures to protect the network and computer assets both on-board and ashore, and all computerized equipment/systems supporting maritime operations.

The Maritime and Port Authority of Singapore (MPA) and the Singapore Shipping Association are working to gather the industry-wide efforts to address maritime cyber security issues, together with Cyber Security Agency of Singapore (CSA). As maritime players are becoming more dependent on IT systems across different technology platforms, it is important that good knowledge, security procedures and processes are in place so that operators know how to identify a potential security threat or have been trained to respond when a cyber-attack is in process. Besides, to prevent technology becoming a crutch for the maritime players, resilience needs to be maintained in the cyber-physical systems.

Market potential and applications

Singapore has put forth a holistic national cyber security strategy as a Smart Nation[3.21]. The four pillars underpinning the plan include: building a resilient infrastructure, creating a safer cyberspace, developing a vibrant cybersecurity ecosystem, and strengthening international partnerships. Therefore, the efforts in maritime cyber security are well in line with Singapore's national cyber security aims.

Singapore was ranked number one in the U.N. International Telecommunication Union (ITU)'s cyber security survey in July 2017[3.22]. The ranking was based on criteria including legal, technical and organizational institutions, educational and research capabilities, cooperation in information-sharing networks, technical and practical implementation. It is the organization-wide and industry-wide awareness, understanding, knowledge and finally capacity to deploy the proper strategies, capabilities and programmes that could lead to maritime cyber security.

Despite Singapore's good reputation in cyber security, it needs continuous efforts in view of the growing variety and sophistication of cyber security threats. The Norton Cybersecurity Insights Report[3.23] - carried out by security firm Norton and released in November last year - showed that victims of cybercrime in Singapore lost an average of $545 each in the past year, higher than the global average of US$358 (S$498). The figures were US$483 for China and US$261 for Australia. In the 2016 Global Economic Crime Survey conducted by PwC, cybercrime was among the top five most pervasive economic crimes in Singapore[3.24]. Singapore is becoming more of a target for cyber criminals with cybercrime incidents rising dramatically from 15% in 2014 to 43% in 2016 (percentage of respondents that suffered an economic crime were hit by a cyber-incident). The figure for Singapore based companies was higher than the global average (Figure 1). The consequential losses are also alarming. The Monetary Authority of Singapore (MAS) estimated the overall financial damage including costs for data loss or unplanned downtime to be almost 2 billion Singapore Dollars in 2014[3.25].

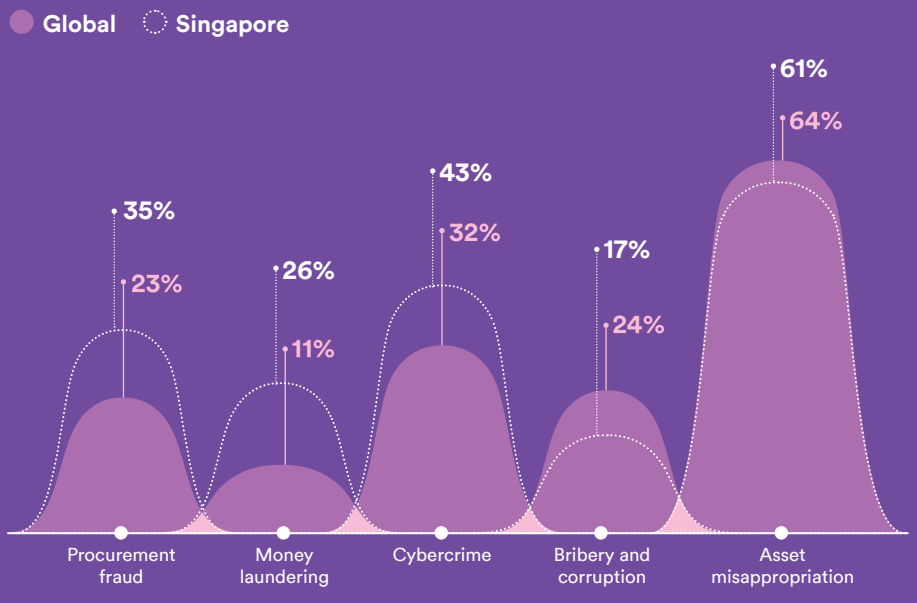


Figure 1. Top 5 Economic Crimes: Singapore vs. Global

3.21 http://www.channelnewsasia.com/news/singapore/national-cybersecurity-strategy-aims-to-make-smart-nation-safe-p-7743784

3.22 http://www.reuters.com/article/us-cyber-un-idUSKBN19Q19L

3.23 http://www.straitstimes.com/singapore/police-data-set-to-show-online-crime-on-the-rise

3.24 https://www.pwc.com/sg/en/consulting/assets/economic-crime-survey/economic_crime_survey_2016_singapore.pdf

3.25 http://www.todayonline.com/singapore/cybercrime-costs-hit-s2b-insurance-take-low

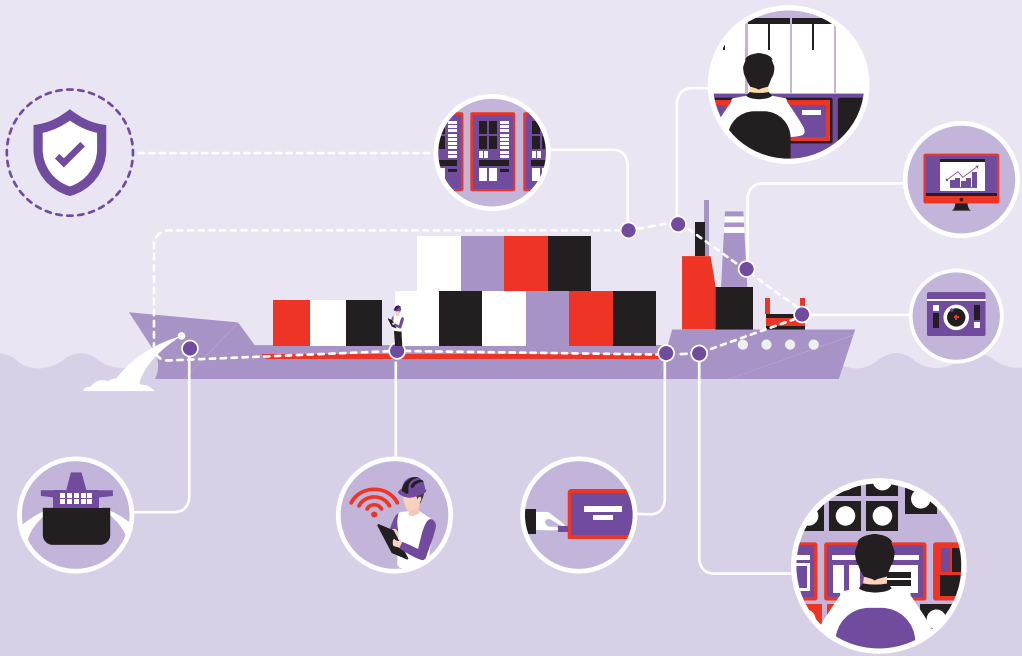
Most organizations in Singapore including those in the shipping industry have increasingly recognized the importance of cyber security. However, not all of them are adequately prepared to deal with cyber-attack incidents or with necessary response plans in place. Increasingly, maritime organizations have been seeking guidance from cyber security experts.

The Guidelines on Cyber Security Onboard Ships was released by BIMCO, together with other joint industry working group members including Cruise Lines International Association (CLIA), International Chamber of Shipping (ICS), International Association of Dry Cargo Shipowners (INTERCARGO), International Association of Independent Tanker Owners (INTERTANKO), International Union of Maritime Insurance (IUMI) and Oil Companies International Marine Forum (OCIMF). These guidelines have been aligned with the recommendations given in the International Maritime Organization's (IMO) Guidelines on cyber risk management which were adopted in June 2017. They provide useful information on how to effectively segregate networks, how to securely manage the ship to shore interface, how to handle cyber security during port calls and when communicating with the shore side.

Market potential is also foreseen as more and more maritime organizations are setting up dedicated IT security budgets and cyber security planning processes. A comprehensive cyber security plan comprises detection systems, robust processes, and equipped individuals. It is critical in enabling the maritime organizations to detect threats early and mitigate their impact.

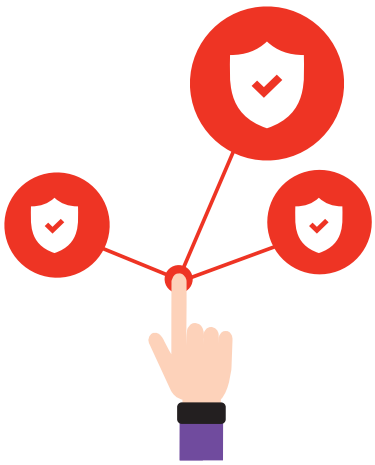
Hardware and software applications for maritime cyber security have very good potential. Security intelligence systems are demanded, for instance, to trigger alerts for any unusual activities. Process plan and management are equally essential. Specially set-up security operations center or dedicated team can help monitor and respond to incidents flagged by systems. Cyber incident response plans need to be built into the cyber security process as well. Moreover, training services for cyber skills, cyber security awareness and capabilities are deemed significant as the shipping industry is going smart at a rapid pace.

Locally, individual awareness and more robust capabilities are built in the maritime industry in Singapore. Industry wide collaboration efforts are also promoted for a better maritime cyber security. Research programmes and development projects are ongoing continuously to address the concerns of cyber incidents. Going international, as under one of the national cyber security pillars, international collaboration is being sought for a next level of maritime cyber security to meet rapidly evolving cyber threats on a global scale.



Relevant Cyber Security organizations based in Singapore

To align with the national cyber security strategy, efforts are undertaken for maritime cyber security in Singapore. Here are the key stakeholders and contacts in Singapore.



Cyber Security Agency of Singapore[3.26]

The Cyber Security Agency of Singapore (CSA) is the national agency overseeing cybersecurity strategy, operation, education, outreach and ecosystem development. The key responsibilities of CSA are in Strategy and Policy Development, Cyber Security Operations, Industry Development, and Outreach. In Strategy and Policy Development, the aim is to strengthen cyber security of Singapore's critical sectors: government, infocomm, energy (power), land transport, maritime, civil aviation, water, security and emergency, banking and finance, and health. In Cyber Security Operations, the main focus is to ensure effective coordinated operations in response for cyber-attacks, and in Industry Development, the goal is to develop a robust ecosystem equipped with proper manpower to respond to and mitigate cyber-attacks. Lastly, in Outreach, CSA aims to foster relationships with local and global industries and thought leaders, through public outreach activities enhancing cyber security awareness.

National Cybersecurity Research & Development Laboratory (NCL)[3.27]

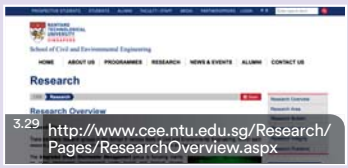
The National Cybersecurity R&D Laboratory (NCL) is a shared national infrastructure that provides computing resources, repeatable and controllable experimentation environments, as well as application services for the cybersecurity R&D community. The infrastructure includes a cluster of 300 nodes that provides a wide range of provisioning mechanisms, security data and security services. NCL aims to provide a platform that fosters and encourages collaboration among researchers in academia, the industry as well as government bodies both locally and internationally through the sharing and validation of research outcomes. The laboratory was established in November 2015 and is funded by the National Research Foundation (NRF).

Relevant organizations based in Singapore for Smart Shipping

NUS-Singtel Cyber Security Research and Development Laboratory[3.28]

The S$42.8 million NUS-Singtel Cyber Security Research and Development Laboratory seeks to create a broad spectrum of research capabilities and novel technologies to address cyber security threats. It has two objectives: first, to develop novel data analytics techniques that allow IT service providers to detect and respond to security attacks as they occur in real time; and second, to come up with new approaches to design and implement IT systems that are "secure by design", and thus able to resist a broad array of attacks.

3.28 http://nus-singtel.nus.edu.sg/



3.29 http://www.cee.ntu.edu.sg/Research/Pages/ResearchOverview.aspx

3.30 http://news.nus.edu.sg/highlights/tcoms-leads-deepwater-research

Nanyang Technological University (NTU), School of Civil and Environmental Engineering, Maritime Studies[3.29]

NTU has contributed significantly to the development of maritime tertiary education and research in Singapore. Research in Maritime Logistics focuses on methodological and application issues relating to the process of planning the efficient, cost effective flow of freight with an emphasis on sea-freight transport. The research addresses the issues related to the role of ocean carriers in the global supply chain as well as the intermodal interactions between sea-freight and other transport modes. On Port Economics and Management, a wide variety of perspectives are drawn from economics, management, technology, strategy and policy. Port studies are closely related to trade, in particular international trade, economic performance and maritime transportation. Hence, the research area is very significant for most countries and regions. Working closely with the MPA, the Singapore Maritime Institute and maritime commercial companies, NTU is actively propelling its maritime R&D and education activities, thus contributes to the overall effort in enhancing Singapore's smart shipping capability.

Technology Centre for Offshore and Marine (TCOMS)[3.30]

The Technology Centre for Offshore and Marine, Singapore (TCOMS) is a joint venture between NUS and Agency for Science, Technology and Research (A*STAR). TCOMS is a national Centre of Excellence which launched on 31 October 2016 and scheduled for completion in 2019. Supported by Singapore Economic Development Board (EDB) and Maritime and Port Authority of Singapore (MPA), TCOMS aims to develop and validate innovative concepts and solutions for marine and offshore engineering (M&OE) operations through strategic global partnerships with industry, research institutions and academia. A MOU has been signed between MPA, Alpha Ori, LR and TCOMS at the Singapore Maritime Technology Conference and the parties aim to jointly establish a Centre of Innovation and conduct joint research in the areas of Data Analytics for Smart Shipping, use of Robotics and Unmanned Systems in port and shipping for operations, maintenance and inspections in hazardous zones, and maritime cybersecurity.

Robotics Research Centre at Nanyang Technological University[3.31]

The Robotics Research Centre (RRC) was established in 1994 at Nanyang Technological University, which is the first interdisciplinary research centre on robotics in Singapore. Major research activities include healthcare and assistive robotics, infrastructure robotics, industrial robots and manufacturing automation, autonomous vehicle, and autonomous systems. R&D projects in RRC have been receiving public and private funding from A*STAR, National Medical Research Council, Ministry of Education, Ministry of Defence, National Research Foundation, Media Development Authority, Infocomm Development Authority, NRF SMART, Singapore Millennium Foundation, Singapore Heart Foundation, Lee Foundation, ST Engineering and various industry players. The Centre has active links with the industry and has provided consultancy services to industry as well as undertaken contract research.

Advanced Robotics Centre at National University of Singapore[3.32]

Another major Singapore-based robotics research facility is the Advanced Robotics Centre (ARC) at National University of Singapore which was established in 2013. The goal of ARC is to lead and support robotics research in Singapore, and over time, gain international recognition as a peak of excellence in robotics research. One core research theme of ARC is human-centered collaborative robotics, with the goal of developing the scientific foundations, technologies, and integrated platforms that enable symbiotic human-robot interaction and collaboration.

Kongsberg Maritime Pte Ltd[3.33]

Kongsberg Maritime is a wholly owned subsidiary of Kongsberg Gruppen (KONGSBERG) which is an international technology corporation that delivers advanced and reliable solutions that improve safety, security and performance in complex operations and during extreme conditions. It provides the shipping industry with various systems for dynamic positioning and navigation, marine automation, safety management, as well as cargo handling, subsea survey and construction, maritime simulation and training, and satellite positioning. With integrated energy, handling and operational solutions, they help enhance efficiency and safety through maritime technology for the shipping industry including the shipbuilding and floating production sectors.

3.31 http://rrc.mae.ntu.edu.sg/Pages/Home.aspx

3.32 http://arc.nus.edu.sg/

3.33 https://www.km.kongsberg.com/

Cyclect Electrical Engineering Pte Ltd[3.34]

Cyclect Electrical Engineering specialises in the marine and offshore sectors, with customers ranging from global shipping companies to shipyards, Floating Production Storage Offloading (FPSOs) and oil rig operators. Their services cover automation and control systems, to design and engineer automation and alarm system. The application areas include engine room, cargo loading, fire alarm, power packs, uninterruptible power supply (UPS), printed circuit board (PCB), power generation systems, control systems and bow thruster systems.

Rolls-Royce Pte Ltd[3.35]

Rolls-Royce is a pre-eminent engineering company focused on world-class power and propulsion systems. Rolls-Royce has been active in Singapore's marine industry for more than 30 years, and in 2009 relocated its global headquarters for the Merchant Marine business to Singapore in recognition of the increasing importance of the Asia Pacific markets, with over 80 per cent of global commercial shipbuilding taking place in Asia. Rolls-Royce has more than 20 years' experience of using equipment health management (EHM) to help customers get the most out of their assets. Rolls-Royce analyses billions of data points every day and have developed a capability to detect, diagnose, and prioritise issues with critical equipment and a deep understanding of the tools, processes and business models needed to do that.

ST Engineering Group[3.36]

ST Engineering is an integrated defence and engineering group specializing in the Aerospace, Electronics, Land Systems and Marine sectors. They leverages on multi-sector capabilities to develop advanced solutions for commercial and defence customers across industries[3.37].

In April 2017, ST Engineering Group's deep experience in robotics and autonomous solutions, ST Engineering launched the Singapore Autonomous Vehicles Consortium to facilitate and strengthen collaboration between industry partners and institutes of higher learning (IHL) to develop AV standards as well as accelerate the application and adoption of AV technologies in Singapore. These efforts will support the development of testing requirements for AVs undertaken by the Centre of Excellence for Testing & Research of AVs – NTU (CETRAN). Led by its land systems arm ST Kinetics, the consortium includes A*STAR's Institute for Infocomm Research (I²R), National University of Singapore's (NUS) Faculty of Engineering, Singapore University of Technology & Design (SUTD), Nanyang Technological University (NTU) through the ST Engineering-NTU Corporate Lab and Singapore Institute of Technology (SIT)[3.38].


3.34 https://www.cyclect.com.sg/cyclect/


3.35 https://www.rolls-royce.com/country-sites/singapore.aspx


3.36 https://www.stengg.com/en/marine/


3.36 https://www.stengg.com/en/marine/


3.38 https://www.stengg.com/en/newsroom/news-releases/st-engineering-drives-development-of-autonomous-vehicles-for-urban-mobility/

Opportunities Space for Smart Shipping

Summary

Market Drivers:

- Singapore's next generation port will require smart technology and advanced data management system to manage increasing complexity in Global hub operations by 2020.
- Singapore is one of the world's busiest port, plans to develop with domain players to build the Next-Generation Traffic management system.
- MPA will focus and lead on building maritime cyber security efforts in line with Singapore's overall Cybersecurity Strategy across the country.
- Communication Technologies will see increasing demand in Singapore towards a fully automated future port.

Problem Statements:

- Lack of quality data integrated platform to connect shippers and shore operators. The realizations of data analytics are constrained by low bandwidth and high implementation costs.
- How to achieve interoperability between e-navigation and existing systems Develop safer navigation and system integrity.
- Increased data networks use by shipping leads to more vulnerability for security threats. Interconnectivity of shipboard systems presents higher risks that needs better protection.
- Increasing complexity and problems in the use of satellite & wireless communications.

Norwegian strengths and opportunities:

- Strong competence in maritime operations and simulation technologies. Eg. ICD software, Kongsberg. Digital shipping: MoU between Singapore, Norway and Denmark.
- Norwegian companies are well known in delivering navigational systems to Singapore. Eg. Kongsberg Norcontrol; Navtor AS.
- The cluster around the Center of Cyber and Informaiton Security (CCIS) at NTNU Gjøvik is world class and highly acclaimed.
- Leverage on the good reputation of Norwegian reliability in communications technologies. Eg. Telenor; Jotron

Relevant domain:

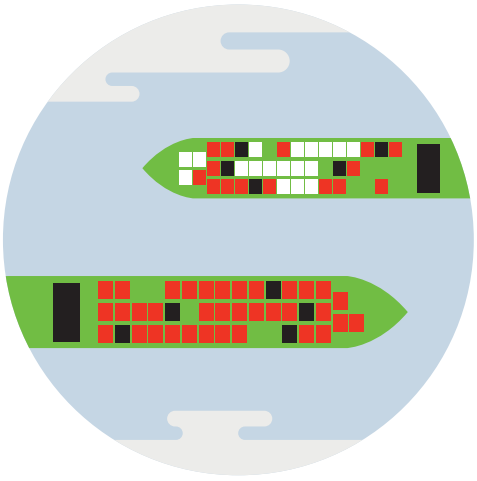
- Digitalization using big data and analytics plus advanced automation technologies.
- Adoption of the latest in E-navigation initiatives projects in maritime navigation.
- Maritime Cyber security solutions to strengthen critical information infrastructure.
- Satellite communications. Future integration of 5G, Wi-Fi and new generation marine networks.

Recommended market approaches

- Develop data-driven intelligent solutions most relevant for Singapore's industry needs, e.g. ship chartering, ship operations, automation solutions.
- Showcase distinctive safety and efficiency features, business development potential within Singapore and Southeast Asia using Singapore as base.
- Develop maritime cyber security technologies and solutions together with smart shipping products or systems as a holistic package.
- Focus on offering solutions that offers reliability and cost effective solutions towards the needs of global navigation satellite systems.

4.0

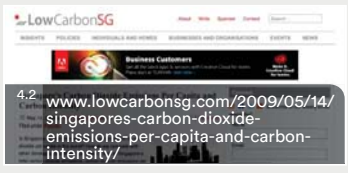
Green Shipping



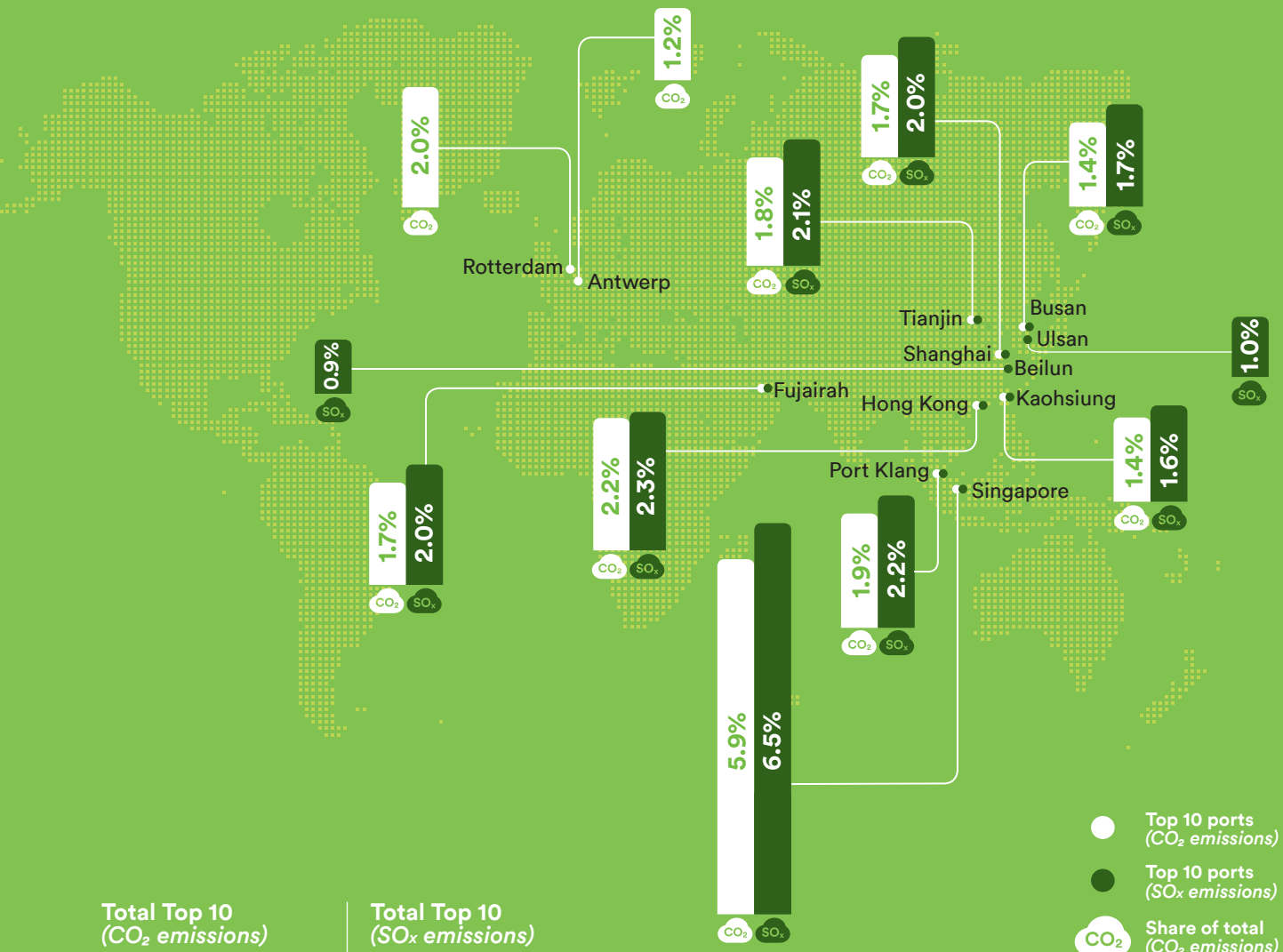
The Singapore government is putting much emphasis on developing and preserving the city-nation as a “Clean and Green City” and has to large extent succeeded in this endeavor. Singapore has ratified the “Paris Agreement”, and although the country does not commit to a fixed emission reduction target, the pledge is to reduce its greenhouse gas emissions intensity[4.1] by 36% from a 2005 baseline by 2030; and to reach the maximum gross emission within 2030.

Although Singapore ranks among the countries with lowest emission intensity[4.2], the national, CO2 emission budget do not include emissions related to the energy balance from marine bunkering, nor emission from international vessel traffic in the Singapore maritime territory. In fact, the port of Singapore tops the list of the major ports in terms of CO2 emission as illustrated by the infographic next page.

4.1 Emission intensity is defined as amount of emission per gross national product. As long as GDP grows, total emission is also allowed to grow.



4.2 www.lowcarbonsg.com/2009/05/14/singapores-carbon-dioxide-emissions-per-capita-and-carbon-intensity/



Total Top 10
(CO_2 emissions)
19.0%

Total Top 10
(SOx emissions)
22.3%

*Source: « **Shipping Emissions in Ports** », 2014, ITF/ OECD, http://www.internationaltransportforum.org/ jtrc/DicussionPapers/DP201420.pdf*

Singapore, as every other maritime nation, is facing the classical dilemma of operating its ports, harbour and shipping industry in an economically competitive manner versus environmental considerations. Singapore has been member of the International Maritime Organization (IMO) Council since 1993 and Party to all annexes of the International Convention for the Prevention of Pollution from Ships (MARPOL). The government pay close attention to the potential environmental impact of its port development projects, and conduct comprehensive environmental impact assessments (EIA) before starting any such projects.

Maritime Singapore Green Initiative (MGSI)

The Maritime and Port Authority is at the helm of promoting clean and green shipping and to reduce the environmental impact of the port activities in Singapore. In 2011 the MPA launched their 5-year, SG$100 million (NOK 600million) Maritime Singapore Green Initiative (MSGI)[4.3]. The initiative has been deemed successful: under the voluntary Green Ship Programme more than 50% of the qualifying ships exceeded the current Energy Efficiency Design Index frame required by the International Maritime Organization (IMO); and under the Green Port Programme (GPP) more than 3,700 vessel calls have switched to marine fuel with sulphur content not exceeding 1%.

Last year, the MGSI was extended for another 5 years until 2020, and enhanced to also encourage LNG as a clean(er) maritime fuel. The MGSI currently contains of 5 major programmes:

The **Green Ship Programme (GSP)**[4.4] encourages Singapore-flagged ships to reduce carbon dioxide and sulphur oxides (SOx) emissions by reducing fees and taxes to vessels with energy efficient and/or emission reducing designs or measures such as scrubber technology. As mentioned above, LNG is encouraged as alternative maritime fuel.

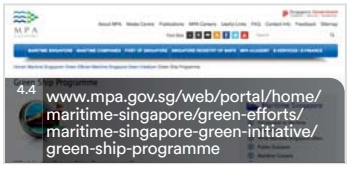
Similarly, the **Green Port Programme (GPP)**[4.5] encourages ocean-going ships calling at the Port of Singapore to reduce the emission of pollutants by offering a 25% reduction in port dues for ships that use approved abatement/scrubber technology or burn clean fuels (LNG).

The **Green Technology Programme (GTP)**[4.6] which encourages Singapore-registered maritime companies such as terminal operators, ship operators and harbour craft operators to develop and adopt green technologies. The GTP provides a grant of up to 50% of total qualifying costs to co-fund the development and adoption of **green technological solutions/systems**. Grants are capped at S$2 million per project, with an increased cap of S$3 million per project for solutions/systems that can achieve more than 20% reduction in emission levels. Since 2011, GTP has seen more than 20 projects involving over 60 vessels. Example of projects funded under this programme include the construction of two dual-fuel diesel LNG harbour tugs by Keppel Offshore & Marine[4.7] and the R&D of a methanol fuel blend system for marine engines by Billion Miles Pte Ltd[4.8].

Added in 2016, the **Green Energy Program (GEP)** is intended to promote adoption of alternative and cleaner maritime fuels in the Port of Singapore. Examples of incentive is the $12mil co-funding support launched by the end of 2015 to support adoption of LNG fuelled vessel[4.9]. Finally, also added in 2016, the **Green Awareness Program (GAP)** focuses on creating awareness on possible avenues towards sustainable shipping.

Although the MGSI is primarily aimed at the Singapore-registered maritime companies, it is expected that these programmes will increase the general demand for scrubber and emission abatement technologies, enhancing the opportunities for business development and technology co-development for Norway-based companies offering scrubber technologies such as Yara Marine Technologies.

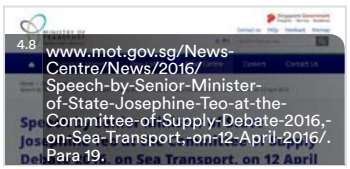

4.3 http://www.mpa.gov.sg/web/portal/home/maritime-singapore/green-efforts/maritime-singapore-green-initiative

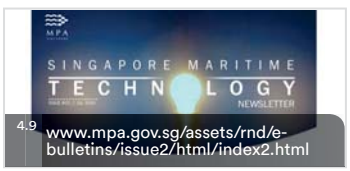

4.4 www.mpa.gov.sg/web/portal/home/maritime-singapore/green-efforts/maritime-singapore-green-initiative/green-ship-programme


4.5 www.mpa.gov.sg/web/portal/home/maritime-singapore/green-efforts/maritime-singapore-green-initiative/green-port-programme


4.6 www.mpa.gov.sg/web/portal/home/maritime-singapore/green-efforts/maritime-singapore-green-initiative/green-technology-programme

4.7 www.straitstimes.com/business/keppel-to-build-2-lng-tugs-explore-use-of-the-gas-as-fuel


4.8 www.mot.gov.sg/News-Centre/News/2016/Speech-by-Senior-Minister-of-State-Josephine-Teo-at-the-Committee-of-Supply-Debate-2016,-on-Sea-Transport,-on-12-April-2016/. Para 19.

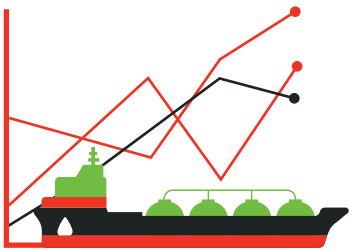


4.9 www.mpa.gov.sg/assets/rnd/e-bulletins/issue2/html/index2.html

4.1 LNG As Maritime Fuel

The opportunities around LNG (Liquefied Natural Gas) as alternative maritime fuel in Singapore is especially interesting and relevant for Norwegian companies, and it's useful to consider Singapore's overall engagement in the LNG value chain.

Singapore's interest in LNG comes from three angles: as a imported energy resource; as a trading commodity and as an alternative fuel for maritime transport sector. Let's look into each of these aspects in order to understands Singapore's increasing interest in LNG.



Diversifying the energy sourcing risk: LNG for own power generation

Singapore depends on imported natural gas for 95% of its electricity generation. Upto now, natural gas has been sources from Malaysia and Indonesia through pipelines, but as Singapore has an strong emphasis on resource independence and supply security, LNG is regarded as an increasingly relevant alternative, as it allows the country to import natural gas from just about anywhere in the world.

Currently, three quarters of the gas import is pipeline gas from Malaysia and Indonesia while LNG covers the remaining quarter of the 10 Mtpa (million tons per annum) gas consumed annually. As the pipeline gas purchase contracts with Malaysia and Indonesia expires towards 2030, LNG import will increase. Bloomberg New Energy Finance analysts forecast the LNG demand to increase from the current 2.3 Mtpa to 3Mtpa in 2020 and further to 10Mtpa in 2030.

Singapore LNG Corporation (SLNG) owns and operates the LNG terminals and storage infrastructure, while BG Singapore Gas Marketing aggregates and distributes the natural gas to power generation companies in Singapore. Since the first import in 2013, SLNG has built three storage tanks with total throughput capacity of 6 Mtpa. Further storage expansion was completed this year and with the completion of a fourth 800,000m3 storage tank by 2018, the annual throughput capacity will increase to 11 Mtpa.

Shell and Pavilion Energy is currently the only external import licensees of LNG to Singapore, each with licence to import 1Mtpa from 2016-19. Beyond the next tranche of LNG imports, which is expected to start in 2017, the Energy Market Authority plans to allow third-party LNG spot imports on a case-by-case basis[4.10].

4.10 http://www.channelnewsasia.com/news/singapore/pavilion-gas-shell-appointed-as-new-lng-importers-for-singapore-7774818

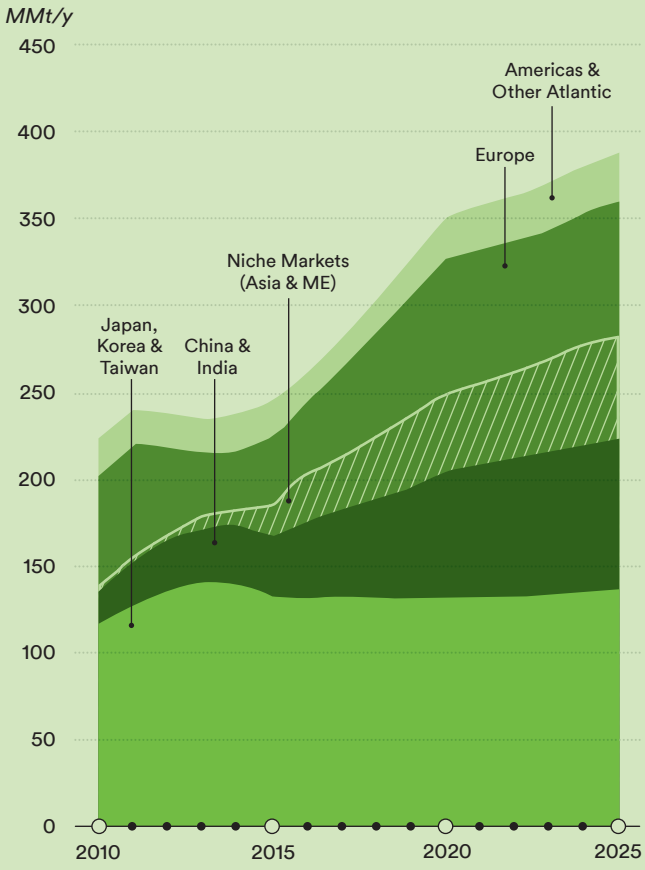
A Global LNG Trading Hub

Global LNG demand is expected to grow substantially over the next decade, with Asia taking a substantial share of demand and trade volume.

Singapore has since 2013 shown clear ambitions to establish itself as one of the leading LNG trading hubs in Asia. According to a survey done by Deloitte in May this year, a majority of senior energy sector leaders finds Singapore likely to become the preferred LNG hub of Asia. Trading infrastructure and institutional structures are in place, and the country has a strong trading talent pool and strategic geographic location which supports this assumption.

However, although the Singapore Exchange is already listing several LNG Index Group (Sling) indices, it is likely that the Platts Japan/Korea Marker would be the most widely adopted benchmark for spot LNG trades in Asia in five years, making it the standard LNG pricing benchmark in Asia.

Global LNG Demand Forecast (2010-2025)



Source: Poten & Partners

LNG as maritime fuel: bunkering and vessels.

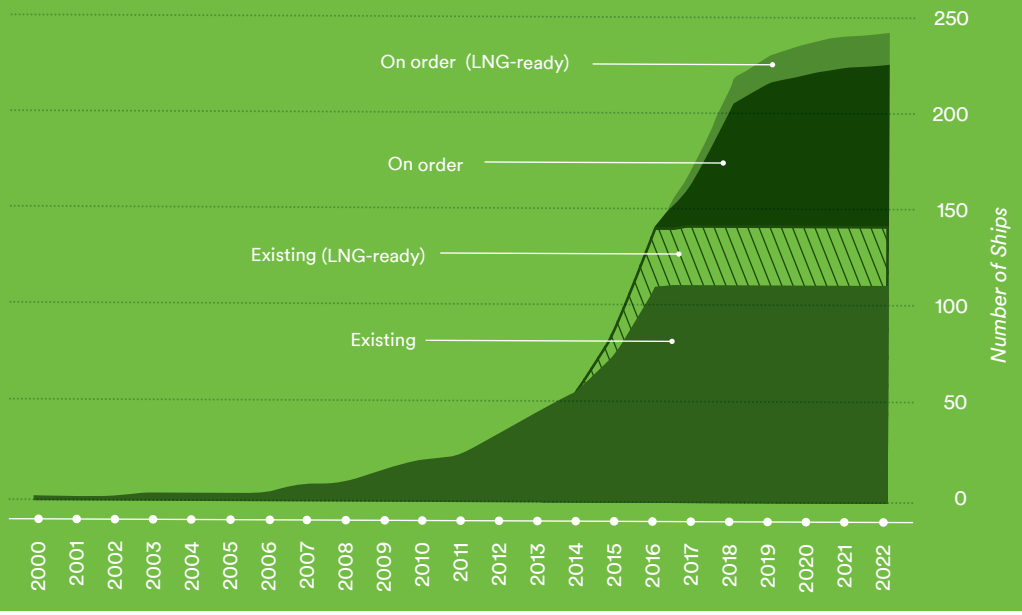
Singapore is building up its LNG bunkering capabilities n i anticipation of the gradual introduction of LNG fuelled vessels, both locally and not at least in international shipping as illustrated in the graph below. This includes investing and developing infrastructure, developing regulatory schemes and ensuring sufficient bunker supply. In 2016, the IMO granted LNG bunkering licenses to Pavillion Gas (who entered into an technology development MoU with French oil & gas major Total in April 2017) and to the Keppel-Royal Dutch Shell joint venture company FueLNG Ltd. Assuming that LNG will replace 11-15% of the conventional bunker oil, Keppel Offshore's managing director Michael Chia forecasts that LNG bunker demand could grow to 3-4 Mtpa by 2030[4.11].

To incentivise the local shipping industry (ferry, port and harbour vessels) to "go greener", MPA has allocated S$12 million through its LNG Bunkering Pilot Programme (LBPP) Grant. A total of S$8 million has been awarded to Harley Marine Asia Pte Ltd, Keppel Smit Towage Pte Ltd and Maju Maritime Pte Ltd to build LNG fuelled harbour crafts, including tugboats and bunker tankers. Keppel Singmarine will build the two **first dual-fuel tug** boats ordered by the two latter tugboat companies, expecting completion by 2018.

While waiting for the first LNG vessels to come into operation, the activity level around LNG bunkering has significantly picked up over the last year:

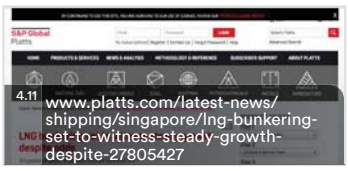
- October 2016: MPA and SLNG signs an MoU to collaborate on an interim truck-loading facility for LNG bunkering.
- October 2016: Port of Singapore signs an MoU for harmonisation of LNG bunkering standards with Ports of Antwerp, Zeebrugge, Rotterdam, Jacksonvill, and port authorities from Ulsan, Japan and Norway.
- April 2017: MPA, Spring Singapore and the Standards Development Organisation @ Singapore Chemical Industry Council launches its first framework for liquefied natural gas (LNG) bunkering operations .
- May 2017: Pavilion Energy demonstrates a **truck-to-ship transfer** of LNG from a shore-side tank to a 40 foot ISO tank on board an off-shore vessel[4.12]
- June 2017: SLNG performs the first **small scale LNG reload** at its terminal on Singapore's Jurong Island[4.13].

LNG-Fulled Ships in service and on order, Q2 2017

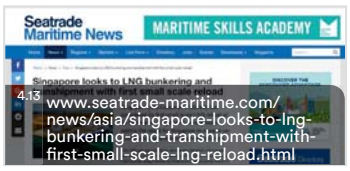


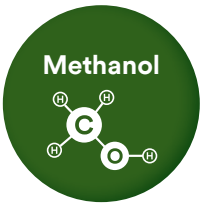
Note: excludes LNG carriers, inland waterway vessels (>200) and LOI; doesn't differentiate exclusive use of LNG vs dual-fuel capacity

Source: Poten & Partners


4.11 www.platts.com/latest-news/shipping/singapore/lng-bunkering-set-to-witness-steady-growth-despite-27805427


4.12 www.pavilionenergy.com.sg/news_the_business_times_3may17.php


4.13 www.seatrade-maritime.com/news/asia/singapore-looks-to-lng-bunkering-and-transhipment-with-first-small-scale-lng-reload.html



There has been some interest in Singapore in methanol as a contender or complement to green marine fuel to LNG. An example is the R&D of a methanol fuel blend system for marine engines by Billion Miles Pte Ltd, co-funded by MPA. As the world's top bunkering hub, along with the presence of a large petrochemical industry, Singapore has not ruled out methanol to be one of the many alternate solutions the marine market will adopt. Recent advances in the use of methanol will continue to keep interests alive for methanol fuel.

There have been considerable interests around the world, especially in Japan and North Europe on the rise of hydrogen as a clean fuel for the maritime industry[4.14,15]. However, there are still many challenges in implementing the hydrogen supply chain to back up the application of hydrogen powered application. In Singapore, most of the discussion in local context is still at R&D (desktop and small prototypes) stage. Larger scale demonstration will take time to realize.

The French energy company Engie SA is experimenting with hydrogen as an intermittent storage solution for power grids at the REIDS (Renewable Energy Integration Demonstrator) operated by ERI@N on the island of Semakau. The partners Engie, Nanayang Technological University (NTU) and Schneider Electric are installing a microgrid on the island to demonstrate integration of wind, solar, tidal and hydrogen storage. The micro-grid is expected to be in operation in October this year, with hydrogen storage added next year[4.16].

While Singapore is actively promoting LNG, the upfront capital and space needed to adopt this fuel is still a challenge. Local owners for smaller crafts that need deck space for transport work are actively seeking alternate solutions.

One possible candidate solution is hybrid diesel-electric. The Energy Research Institute @ Nanyang Technological University has seen an increase in enquiries of such solution from local harbour craft owners (e.g. passenger ferries) and solution providers. Though there are genuine interests to demonstrate these types of solutions in Singapore water, the local community has yet to see a working hybrid diesel-electric solution in local context. Generally risk-adverse, they would like to see actual demonstration before adopting the solution.

For full electric option, possible local adopters are the ferries and fix-route vessels. With a few exemptions, such as Siemens[4.17] (with its core expertise on maritime electrification residing in Norway), there are limited local expertise in this space in Singapore. However, the interest for electrification of transport in Singapore is generally increasing, and this space should offer opportunities for Norwegian companies within electric land and maritime transport solutions.

IMO's Ballast Water Management Convention[4.18] (BWMC) will enter force on September 8, 2017, forcing many ship owners and operators to make important decisions to comply to the regulations. Although Singapore is not yet a party to the BWMC and do not have national legislation to authorise their ship-owners to issue International Ballast Water Management Certificate (IBWMC) and/ or Statement of Compliance (SoC)[4.19] , tthe Maritime and Port Authority of Singapore is promoting ballast water handling on its own fleet.

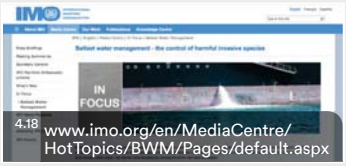
According to company register Shipserve.com, there is 14 Singapore and international companies offering technology and services for ballast water management in Singapore. The Norwegian technology companies Optimarin AS and OceanSaver AS are established through sales offices or agents, and the maritime insurance firm Gard are engaged in ballast water management advisory.

4.14 www.nedo.go.jp/content/100580338.pdf

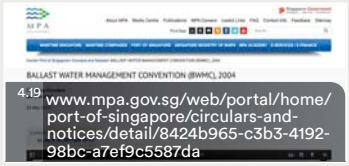
4.15 www.fch.europa.eu/event/workshop-maritime-and-port-applications

4.16 www.bloomberg.com/news/articles/2017-05-24/a-tiny-island-off-singapore-may-hold-answers-to-energy-s-future

4.17 www.siemens.com.sg/drive/stories/



4.18 www.imo.org/en/MediaCentre/HotTopics/BWM/Pages/default.aspx



4.19 www.mpa.gov.sg/web/portal/home/port-of-singapore/circulars-and-notices/detail/8424b965-c3b3-4192-98bc-a7ef9c5587da

Opportunity space: Green Shipping

Market Drivers:

- Heralded and encouraged by the government, the maritime industry is subject to ever stricter environmental conditions; limits of local ship emission (SOx, NOx, particles, noice, ballast water), greenhouse gas emission and energy efficiency requirements.
- IMOs Maritime Singapore Green Initiative (MSGI) gives the directions, incentives and to some extent financial support for the industry to develop, acquire and adapt technologies to meet new environmental requirements.
- In addition to Singapore's substantially increasing demand of LNG for own energy use, Singapore is establishing its port to be one of the major LNG trading and bunkering hubs in Asia.

Problem Statements *(challenges and technology needs):*

Harbour and port emission reductions:

Singaporean ship-owners, port operators, harbour craft and ferry operators are subject to stricter emission regulations:

- Need for scrubber and abatement technologies.
- Need for cleaner fuel alternatives: LNG, bio-fuel, electrification
- Need for technology and ICT solutions related to energy saving, operation optimisation, monitoring, surveillance, etc.
- Port operations: alternative fuel for vehicles, cranes, vessels; energy efficiency, power system integration; data analytics, sensoring, automation etc.
- Technology and solutions for ballast water treatment/ management
- International cooperation on emission regulations

LNG bunkering and trading:

- Technologies for LNG bunkering and small scale distribution (truck, ship, ship-to-ship etc.)
- Technology, standards, best practices related to safety

Ship design, modelling:

- International cooperation on "greener" ship and design. Modelling, numeric simulation, ocean basin testing.

Norwegian strengths and opportunities:

Norway has over the last two decades introduced strict emission control regulations, including CO2 tax, NOx tax/ fund and climate pledges, driving Norway to be world leader in:

- Design, class and operation of LNG tankers, FSRU etc. since 1960s
- Use of LNG as maritime fuel since 2000 – 50% of all LNG vessels is in Norway waters
- Use of full-electric ferries and other vessels since 2015
- Leading in research on utilisation of hydrogen for maritime sector
- The maritime governmental relations between Norway and Singapore is excellent: for example, excellent working relationship between MPA and the Norwegian Coastal Administration and the Norwegian Maritime Directorate on a wide range of maritime topics.

Norwegian companies and institutions can offer solutions to Singaporean maritime companies for:

- Emission abatement technologies (scrubbers, engines, software..)
- Technology and knowledge across the LNG value chain: bunkering and small-scale distribution, engines, regulations and standards on operations and safety.
- Technology and knowledge for maritime sector electrification: vessels design/modifications, motors and electric systems, charging and operations, regulations and safety, impact on the national power system.
- Research cooperation across several areas on Green Shipping: design, material technology, propulsion, operation optimisation etc.
- International and bilateral cooperation within regulations, standards, and best industry practices.

Summary

Recommended market approaches:

Local emission:

- We assume that the market needs and available solutions in the market is well known among the stakeholders. However, Norwegian SMBs with unique technologies for emission abatement but no experience from Asia may consider the Singapore and Asian market opportunities. Innovation Norway and local partners in Singapore can assist to understand the market needs and make connections to relevant Singaporean companies (ship-owners, yards, suppliers, engineering firms).

LNG value chain:

- Technologies and solutions across the entire LNG value chain (transport, storage, bunkering, handling, small-scale distribution and downstream utilisation) is generally attractive in Singapore, and Norway has a very strong standing here.
- Building and strengthening relations with the key stakeholders:
  - Utilize and build the excellent governmental and agency relations between Norway and Singapore: MPA vs Norwegian Coastal Administration, Norwegian Maritime Directorate.
- Innovation Norway has taken the initiatives to establish various networks of Norwegian companies within the LNG value chain. These networks represent a huge accumulated insight and experience in technology and market opportunities globally. To be part of such networks reduces the market entry risk and costs:
  - The Network LNG Norway (www.networklngnorway.com) is a formal organisation of Norwegian companies engaged in the LNG value chain. Many of them with establishment and experience from Singapore and southeast Asia. Members include ConnectLNG, DNV GL, Kanfer Shipping, Liquiline, Norconsult, Torgy, Statoil, Gassnor, BW Gas, Awilco LNG, Sund Energy and Clarksons Platou.
  - The more informal Norwegian LNG network in Singapore includes BW LNG, DNV GL, Fearnleys, Høegh LNG, Kongsberg Maritime, Norgas Carriers, PGS, Rolls-Royce Maritime, Statoil, TechnipFMC, Wartsila Moss, Poten & Partners, MHWirth, TTS etc.).
  - Norwegian Energy Collaboratorium (NEC) in Singapore is another cluster of companies and research institutions with focus on energy, including clean maritime and LNG: Norwegian University of Science & Technology, SINTEF, Institute for Energy Technologies, Elkem, Multiconsult, Tronrud Engineering, eSmart Systems). NEC is closely connected to leading Singaporean research institutes at Nanyang Technological University, National University of Singapore, A*STAR and National Research Foundation.

Maritime Electrification:

- The Singapore market for maritime electrification is currently immature as there is no clear incentives. , but expected to grow within 2-5 years. Companies with relevant technologies could consider an early entry thorough the research institutes in Singapore. Introductions can be done through Innovation Norway contacts to e.g. MPA, SMI, ERI@N, NUS, A*STAR etc.
- Some larger companies are looking into maritime electrification in Singapore and may be approached from the "Norwegian side": Siemens, Rolls-Royce, Wartsila, etc.

General market approach:

- Innovation Norway has been very active in promoting Norwegian LNG solutions in Singapore and south-east asia, and has built up an extensive network versus government institutions and companies in Singapore, Myanmar, Thailand, Vietnam and Indonesia. Through the LNG networks listed above, Innovation Norway are regularly facilitating meeting and networking arenas which new companies can utilize. See below for relevant meetings arenas.
- Singapore shipyards and engineering firms are actively seeking to acquire technologies through investments and acquisitions abroad. Examples include Sembcorps recent acquisition of Gravifloat and LMG Marine.
  - Innovation Norway and its "sister organisation" International Enterprise Singapore is cooperating to support in finding and matching technology offering companies with market needs across the two countries.
- Utilize advisors at the local Innovation Norway offices to discuss strategies and support instruments for international market approach. www.innovasjonnorge.no
- Attend and present solutions at conferences and trade shows in Singapore – see below.

Relevant marketing and networking arenas

The Asian Conference on Energy, Power and Transportation Electrification (ACEPT 2017) in Singapore October 24-26 is part of the Singapore International Energy Week. Although not explicitly addressing the maritime industry, there will a strong Norwegian/Nordic presence during that week, and there will be events related to LNG, energy efficiency and electrification of the transport sectors on land and sea.

Asia Pacific Maritime 2018 in Singapore 16-18 March 2018 is "the premier event in Southeast Asia where 15,000 owners, builders, procurers, end-users of products/service from Asia and 1,500+ international suppliers in the shipbuilding & marine, workboat and offshore industry come together across three days to buy, sell and network". Innovation Norway is every year organizing a special pavilion for Norwegian companies which opens for exhibition, network and presentations.

Singapore Green Shipping Stakeholders:

The main driver for Green Shipping in Singapore is the Maritime and Port Authority with its Maritime Singapore Green Initiative described above. In addition to the IMO programs and incentive schemes, several university and company maritime centres are actively engaged in green shipping.

Singapore Maritime Institute (SMI)

The SMI is a joint effort between the MPA, A*STAR (Agency for Science, Technology and Research) and EDB (Economic Development Board) to develop strategies and programmes related to the academic, policy and R&D aspects of the industry. The SMI has developed a comprehensive Maritime R&D road map where the Green Shipping (Energy & Environment) is one of five core pillars.

SMI plays an important role to facilitate and bridge R&D and technology development cooperation between Norway and Singapore within the maritime sector. As discussed in Chapter 8 on Research and Development, SMI and the Norwegian Research Council has a strong relationship and have established a joint call for research projects.

Maritime Institute @ Nanyang Technological University[4.20]

MI@NTU is one of the four Maritime Institutes @ Institution of Higher Learning under the umbrella of Singapore Maritime Institute (SMI). Leveraging NTU's established interdisciplinary strengths in the field of maritime science and technology development, MI@NTU aims to support the needs of industry and government by working closely with the local maritime sector and national agencies. Relevant for this context, MI@NTU has R&D focus areas including:

- Improved Ship Design for Better Fuel Efficiency
- Propulsion and Power Generation Concepts Using Alternative Energy Source
- Clean Technologies for Treating Emission Streams to Air and Water

Maritime Institute at National University of Singapore[4.21]

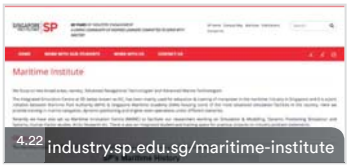
MI@NUS is a collaborative effort between the National University of Singapore (NUS) and the Singapore Maritime Institute (SMI), led by Executive Director Professor Chow Yean Khow. As compared to the more technical focus at MI@NTU, the various maritime centres under NUS has more focus on Maritime Policy & Management and Maritime Operations & Modelling. MI@NUS investigates on the impact of adopting the green shipping related policy and technologies.

Maritime Institute @ SP[4.22] & Maritime Institute @ NP[4.23]

Singapore Polytechnic (SP) and Ngee Ann Polytechnic (NP) both have established maritime institutes. Leveraging their vocational and theoretical training capabilities, both institutes have maritime research centres such as the Singapore Maritime Academy Research and Training Centre (SMART) and Marine and Offshore Technology Centre of Innovation (MOTCOI) to support their research and education on green shipping.

4.20 mi.ntu.edu.sg/Pages/Home.aspx

4.21 maritimeinstitute.nus.edu.sg/directorsmessage.html



4.22 industry.sp.edu.sg/maritime-institute

4.23 www.np.edu.sg/coimot/mi/Pages/default.aspx

A number of the Corporate Laboratories and Research Centers in Singapore are engaged in green maritime, including DNV GL's Technology Centers, Keppel's KOMTech and Sembcorp Maritme Centers. Please refer to chapter 8 for further description of these centres.

Key Singaporean and Norwegian companies engaged in the LNG value chain is listed below.

Business area

Website

MPA

Regulation, facilitation, funding

www.mpa.gov.sg

SLNG

LNG infrastructure

www.slng.com.sg

Shell Eastern Petroleum

LNG import, bunkering.

www.shell.com.sg

Pavilion Energy

LNG import, infrastructure, bunkering, downstream operation.

www.pavilionenergy.com.sg

Sembcorp Marine

Downstream (power plant). Gravifloat LNG-to-power.

www.sembcorp.com

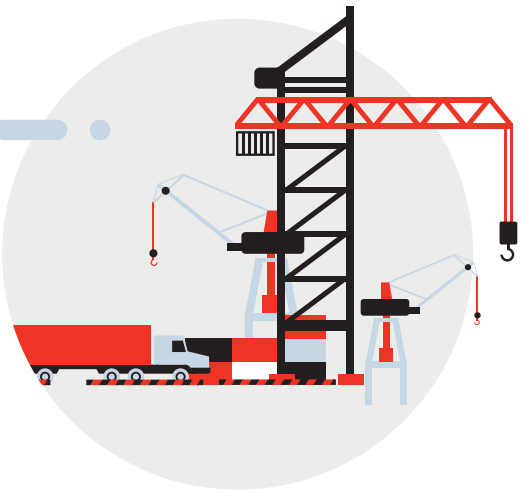
Keppel Offshore & Marine Gas Technology Development Pte. Ltd.

Wide range: Yard, ship owner. Technology. Research lab KMOTech.

www.keppelom.com

5.0

Port Technologies



5.1 Port of Singapore

The growth of Singapore's seaports has been instrumental to the country's survival and overall economic welfare ever since Sir Stamford Raffles established a trading post and the first port in 1819. Today, Singapore is the second largest port in the world and the world's busiest transhipment hub, accounting for almost one seventh of the world's total container transhipment throughput and more than 4% of global container throughput.

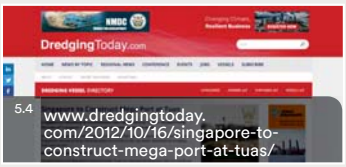
Singapore and its main port stakeholders have since the 1970 been in world class for developing and deploying modern technology. The Port of Singapore Authority deployed the electronic data interchange software BOXNET/PORTNET as early as 1984; and with the 1989 Computer Integrated Terminal Operations System (CITOS) could handle the highest vessel rates in the world then despite the complexity, number and speed of box connections between vessels. PSA also introduced Remote Crane Operations and Control (RCOC) system at Pasir Panjang in 2000[5.1] .

The Port of Singapore includes terminals located at Tanjong Pagar, Keppel, Brani, Pasir Panjang, Sembawang and Jurong. They can accommodate all types of vessels, including container ships, bulk carries, ro-ro ships, cargo freighters, coasters and lighters. The terminals are managed by two commercial port operators – **PSA Singapore Terminals**[5.2], which manages the major share of container handling in Singapore and **Jurong Port Pte Ltd**, which is Singapore's main bulk and conventional cargo terminal operator[5.3]. The Pasir Panjang Terminal expansion, which is estimated to cost about $3.5 billion, has increased PSA Singapore's maximum draft from 16 to 18 meters to accommodate a new wave of mega-sized containerships that can carry over 20,000 20-foot containers. By 2018, both phases will add 15 million TEUs of capacity, bringing the port total to 50 million TEUs[5.4].

5.1 "Singapore, a port city : the case of port development and its impact on the city", Kai Yeng Wong Expert, Centre for Liveable Cities Singapore, Singapore, paper at 15th World Conference Cities and Port Crossover, 2016.

5.2 The operation of Singapore harbour and ports was regulated by handled by the Port of Singapore Authority (PSA) from 1964 until 1997, when PSA Corporation Ltd was corporatized. The regulatory functions was transferred to the MPA. In 2003, PSA again restructured with PSA International Pte Ltd, becoming the holding company for the PSA Group of companies, including PSA Singapore Terminals.

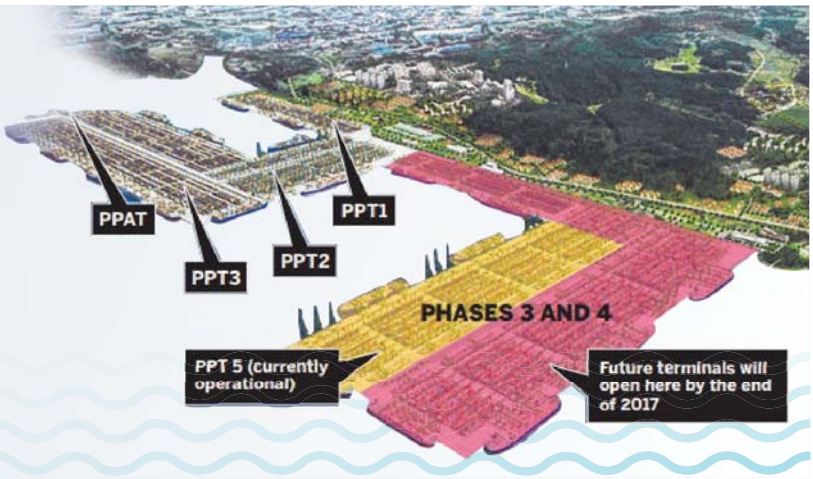
5.3 www.mpa.gov.sg/web/portal/home/port-of-singapore/port-operations/port-infrastructure/terminals

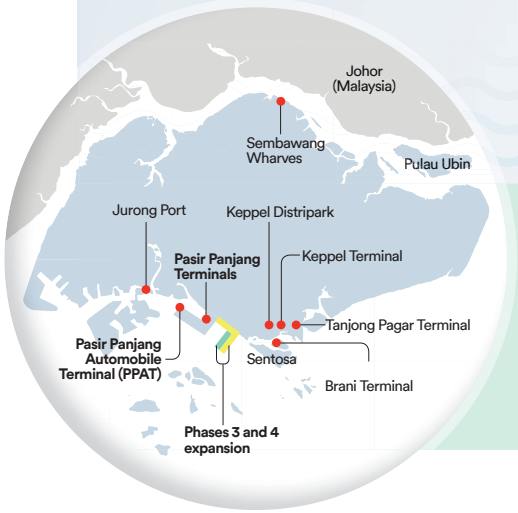


5.4 www.dredgingtoday.com/2012/10/16/singapore-to-construct-mega-port-at-tuas/

Shoring up status as leading shipping hub

The Phases 3 and 4 expansion of Pasir Panjang Terminal (PPT) will add 15 million TEUs (20-foot equivalent units) to Singapore's handling capacity, boosting it by 40 per cent to 50 million TEUs each year.





Features of phases 3 and 4

- Cost : **$3.5 billion**
- Quay length : **Almost 6km**
- Berths : **15**
- Draft : **Up to 18m**
- **Container yard with automated rail-mounted gantry cranes**
- **Handling capacity of 15 million container units per annum**

ST GRAPHICS PHOTO: PSA SINGAPORE TERMINALS

Source: PSA International

The new port in Tuas

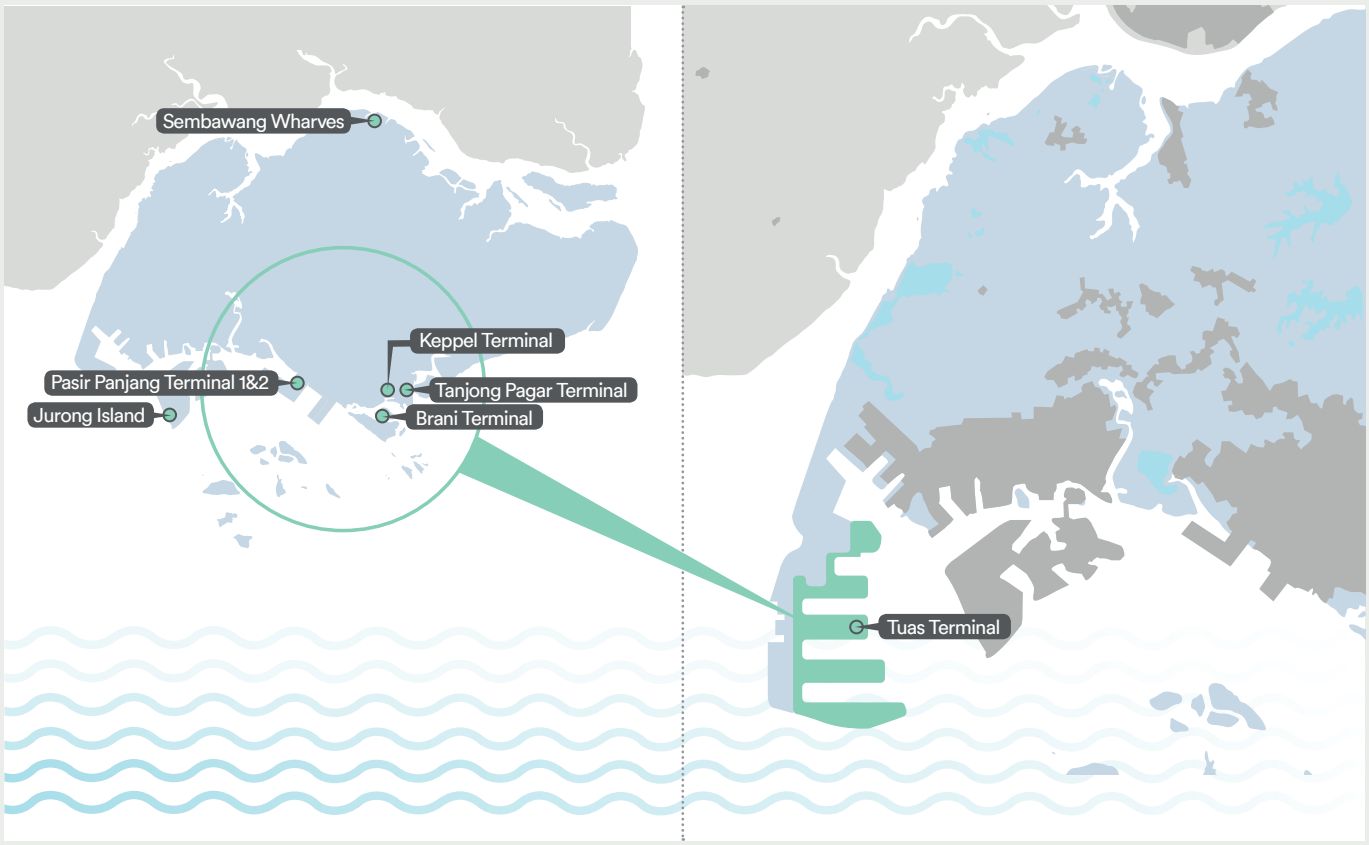
The work on the Tuas Terminal, the new mega port of Singapore, started April 2016[5.5]. The Tuas Terminal will be developed in four phases over the span of some 30 years, and all the current terminals in Singapore will eventually be relocated at the Tuas Terminal.

The first phase of Tuas is expected to be operational in the early 2020s, in time for the 2027 expiration of the leases for Singapore's city terminals at Tanjong Pagar, Keppel, and Pulau Brani. When completed, the 20 deep-water berths in Phase 1 of Tuas Terminal development will be able to handle about 20 million twenty-foot equivalent units (TEUs) per annum.

The entire mega-terminal will have a total capacity of up to 65 million TEUs, double the total current capacity of Singapore port.

Source: Westwood Residence

5.5 www.mpa.gov.sg/web/portal/home/media-centre/news-releases/detail/ec45e87e-656d-4848-b08b-7c1c80fabeab



Source: Westwood Residence

> *The first set of berths at the new Tuas Port is expected to be operational in about ten years' time.*

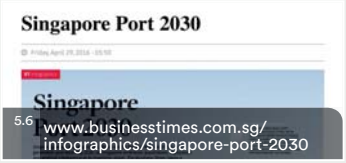
All container port activities to be consolidated at Tuas in future....

By relocating container terminals from Pasir Panjang to Tuas where the multi-purpose Jurong Port and most maritime logistics providers are based, Singapore can design and build a maritime port for the future from scratch, incorporating new ideas and technologies. Consolidating port operations at one location will also improve connectivity and economies of scale, thus reducing costs by eliminating inter-terminal haulage.

Another challenge for Singapore is building a ***maritime-future ready workforce***[5.6]. By 2030, it is envisaged the labour mix at the Port of Singapore will encompass more highly skilled technicians and engineers with specialised training.

The next generation port will feature digital technology that will boost **efficiency and productivity, improve safety and security.**

The technology developments and needs can be categorized into four interconnected broad areas – **safety and security; efficiency; "intelligence";** and **environmental sustainability**[5.7]



5.6 www.businesstimes.com.sg/infographics/singapore-port-2030

5.7 unboxed.globalpsa.com/cp4/

The VTMS will be developed to handle increased shipping traffic and larger ships in the future. The system will leverage data analytics to predict traffic hotspots and decision support tools to assist vessels in planning and optimizing their sea passages.

Smart ships communicate vital information to the port operators via on board sensors. Smart buoys, satellites and radars detect ships due to arrive. If arrival times are predicted to be later or earlier than scheduled, predictive analytics will advise ships to slow down or accelerate. This helps the port to better manage its anchorage space and plan ahead for loading or unloading.

The core technology in the present VTMS system in Singapore is provided by Norwegian Kongsberg Norcontrol and developed in close collaboration with the Maritime Port Authority. The Norwegian Coastal Administration and MPA have recently completed the “Sesame Straits” project aimed at developing next generation e-navigation systems.

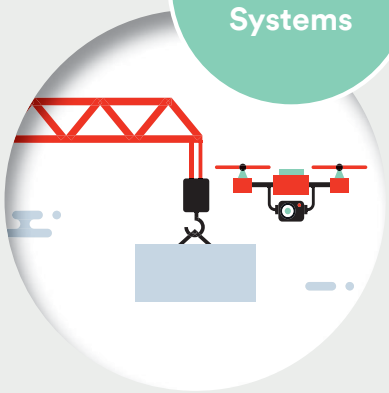
Systems, sensors and wearables that can address Health, Safety and Security issues in an integrated manner.

- Surveillance system using a whole range of sensors with advance analytics capability to detect, recognize and respond to abnormal and potentially dangerous situations involving human and physical assets.
- Apps that promote Health, Safety and Security among individuals through social interaction and gamification.
- Barrier-free access control systems utilizing contactless verification of moving assets and intruder detection in such barrier-free zones.
- Location tracking of personnel and equipment in the port.

Efficiency – automation and autonomy

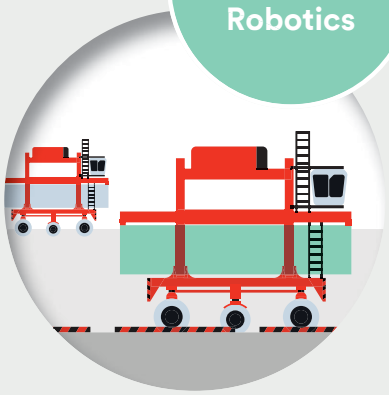
Terminal operations and machinery will be automated, and technologies such as automated guided vehicles (AGV) and truck platooning are being explored and developed to increase the efficiency of port operations. Automation will reduce manpower needs and boost productivity of port operations.

Smart Machines & Systems



- New sensor capabilities allowing new Internet of Things (IoT) applications to be explored.
- Sensor-equipped autonomous machines that can survey port and marine equipment (such as cranes) and infrastructure (such as underdeck marine structures) that are relatively inaccessible to humans for maintenance and fault detection.
- Holistic maintenance solutions for port equipment enabled by sensors, predictive analytics, job scheduling and supply of parts.
- Smart inventory management solutions for spares and parts including innovative storage, supply solutions and 3D printing.
- Remote, virtual, augmented reality or telepresence applications in areas such as training, supervisor-assisted maintenance and operations management.

Autonomy and Robotics



Terminal operations and machinery will be automated, and technologies such as automated guided vehicles and truck platooning are being explored and developed to increase the efficiency of port operations. Automation will reduce manpower needs and boost productivity of port operations.

- Solutions that improve the safety and user experience of all man-machine interfaces.
- Machine-assisted coning/ deconing operations and lashing solutions to enhance the safety and productivity of the stevedores.
- Autonomous cargo handling machines relying on marker-less navigation systems that are able to operate in inclement weather and able to effect swift, automatic and precise hand-offs between equipment.
- Contactless or near-contactless solutions for power transmission to heavy container handling equipment and refrigerated containers.

5.2

Intelligence: Digitalization and Data Management:

An unprecedented amount of data – from world meteorological and oceanographic data, traffic data, material and machinery performance data, data on cargo flows across the world, maritime accident data and even passenger and seafarers' personal data – will be shared among the next-gen ship owners, port operators and other players in the maritime eco-system.

Real-time information from multiple smart sensors and sources will be used to provide data for analysis. The data will then be fed through advanced maritime sense-making systems that can process, mine and extract useful information for decision and policy making, along with contingency planning.

Holistic maintenance solutions for port equipment enabled by sensors, predictive analytics, job scheduling and supply of parts. Smart inventory management solutions for spares and parts including innovative storage, supply solutions and 3D printing. Remote, virtual, augmented reality or telepresence applications in areas such as training, supervisor-assisted maintenance and operations management.

Built-in algorithm detects "anomalies" when two vessels are coming together at the wrong place or the wrong time, alerting port operators to possibilities of illicit activities such as illegal bunkering. A separate algorithm can detect vessels suddenly slowing down or changing directions and alert port operators of possible hijacking or piracy.

- Real-time availability of information and documents, secured by access control and cybersecurity, to all supply chain actors instead of dissemination through a chain one at a time.
- Collaborative workflow around key processes such as freight arrangement and vessel stowage planning to reduce iterative processes.
- Crowd-sourcing and asset-sharing business solutions to improve asset utilization and service scalability.
- Use of Big Data, Analytics and Artificial Intelligence to improve predictability and planning of supply chain events.
- Integration within port communities of the various activities and transactions among actors such as authorities, pilots, tugs, shipping agents and service providers to achieve better coordination.

5.3

Energy And Environmental Sustainability:

The use of clean energy will be heavily promoted – especially liquefied natural gas (LNG) as a ship fuel – for day-to-day port operations. More community spaces will be built around the port fringes for public access to allow the maritime sector to stay connected with the masses.

Real-time availability of information and documents, secured by access control and cybersecurity, to all supply chain actors instead of dissemination through a chain one at a time. Collaborative workflow around key processes such as freight arrangement and vessel stowage planning to reduce iterative processes. Crowd-sourcing and asset-sharing business solutions to improve asset utilisation and service scalability. Use of Big Data, Analytics and Artificial Intelligence to improve predictability and planning of supply chain events. Marketplaces to expand procurement options for supply chain services.

Integration within port communities of the various activities and transactions among actors such as authorities, pilots, tugs, shipping agents and service providers to achieve better coordination.

Specific problem statements and technology needs include:

- Smart grid systems to track and manage peaks and lulls in energy consumption and achieve the lowest cost-combination of energy sources for peak operation levels.
- Multi-purpose sensors and IoT to track and detect leakages of utilities.
- Recover, reuse and recycle materials, consumables and utilities.

Apps to reduce wastage and promote recycling among individuals through social interaction and gamification.

PSA International

As one of the leading global port groups, PSA participates in around 40 terminals in 16 countries across Asia, Europe and the Americas with flagship operations in PSA Singapore Terminals and PSA Antwerp. PSA strives to continue growing its port network alongside its shipping line customers and become the preferred partner to port stakeholders across the world. Employing the finest talents in the industry, PSA delivers reliable and best-in-class service to its customers and develops win-win relationships with its partners. As the port operator of choice in the world's gateway hubs, PSA is "The World's Port of Call".

PSA unboXed

PSA unboXed is PSA International's corporate venture capital arm that invests in start-ups with innovations that bring strategic value to PSA. PSA unboXed aim to create new value for the stakeholders in the container logistics industry by exploring new opportunities through collaborative integration of LogTech with trade and FinTech (financial technology) solutions.

PSA unboXed Incubator Program

This incubator program seeks to invest in and nurture start-ups that are keen to create innovative logistics solutions fusing information and communications technology including IoT (Internet of Things), cloud, data analytics, AI (Artificial Intelligence) and optimisation, as well as engineering solutions including robotics and automation in container and cargo handling operations, and transaction solutions for the maritime trade and finance ecosystems.

Selected start-ups will receive up to S$50,000 in seed funding, and be provided with incubator facilities at PSA's Pasir Panjang Terminal in Singapore. They will have access to an unparalleled live port environment to develop and test-bed ideas for the real market at PSA Singapore Terminals – one of the world's largest hub centres for container movement. In addition, they will receive the mentorship of seasoned PSA port professionals and other business leaders, and be provided with the opportunity to springboard their innovations to the global maritime logistics chain through PSA's network of terminals worldwide.

PSA unboXed launched its second call for action for its incubator program on March 3rd 2017, inviting start-ups and potential partners to propose technology solutions in support of PSA's technology vision for the Port of the Future – CP4.0TM (Container Port 4.0TM) .
Application website here:

https://unboxed.globalpsa.com/application/

Jurong Port

Jurong Port operates the only multi-purpose port in Singapore, handling bulk, break-bulk and containerized items from about 15,000 vessels annually. The company operates ports in China and Indonesia.

To prepare for the « Port of the Future », the SG$ 3 million Jurong Port Academy was launched in January as part of the port's efforts to transform the multipurpose port industry, by leveraging new technology and innovation to enhance capabilities, increase productivity and upskill port workers. Jurong Port's Offshore Marine Centre is a facilitation for companies engaged in fabrication of marine and offshore equipment.

www.jp.com.sg

Port Technologies

Summary

Market Drivers:

- Singapore to develop the world's largest and most advanced container port in Tuas.
- Pressure on energy efficiency, automation and environmental considerations

Problem Statements *(challenges and technology needs):*

Detailed listing in the sections above.

- Safety and security
- Efficiency
- Digitalization and smart systems
- Environmental sustainability

Norwegian strengths and opportunities:

Norwegian strength further discussed under "Smart Shipping" and "Green shipping" chapters:

- Strong competence in marine navigation and communication: Kongsberg Norcontrol/ Seatex
- Automation and autonomous vessels/ vehicles: Kongsberg Maritime, DNV GL, Sintef Ocean, Rolls-Royce Marine, Kleven shipyard, Fjord 1 etc.

  Digital shipping: established partnerships through R&D projects.

  Environmental: world lead on LNG, electrification, surveillance/drones
- Energy management / energy efficiency.

Recommended market approaches:

- Updated on tenders, calls and announcements from key stakeholders PSA and MPA
- Connect to agencies like IE Singapore, IPI, SBF etc. to stay updated on the market's needs – and promote solutions offering.
- Actively attend meeting places: conferences such as Asia Pacific Maritime, Singapore Maritime Week
- Connect to PSA unboXed, consider their incubator program
- Utilize Innovation Norway Singapore to connect to Singapore maritime eco-system (Global Growth, business network etc.)

6.0

Ocean Technologies

"As a national Centre of Excellence for M&OE research, TCOMS will be accessible to Institutes of Higher Learning (IHLs), public R&D agencies and the industry, and serve as a focal point for M&OE R&D activities in Singapore. It will also partner the Singapore Maritime Institute to engage in maritime research."

Mr S Iswaran
Minister for trade and industry – speech at the inauguration of TCOMS, Oct 31, 2016.

Over the last two decades, the Singapore government agenda is to evolve its economy from manufacturing-centred industries to "knowledge-based innovation-driven economy and society". Through their six 5-years research, innovation and enterprise plans[6.1] (RIE), the government will invest a total SGD60 billion (360 billion NOK) to establish Singapore in the world class R&D hubs within 4 dedicated verticals: Advanced Manufacturing and Engineering (AME) Health and Biomedical Sciences (HBMS); Urban Solutions and Sustainability (USS) and Services and Digital Economy (SDE).

The government will invest SG$3.4 billion in the AME vertical, where the Marine & Offshore Engineering (M&OE) industry plays an important role. The Technology Centre for Offshore and Marine, TCOMS, is intended to be the national integrator for research and development in Ocean Technologies, including advanced shipbuilding, aquaculture and other floating structures, deep sea ocean technologies and ocean energy technologies.

6.1 https://www.nrf.gov.sg/rie2020

6.1

Technology Centre For Offshore And Marine, Singapore

A key differentiator in TCOMS is the development of a simulation system featuring the integration of basin modelling, numerical modelling, smart-sensing, and real time data analytics. This novel approach will not only enhance the value-added services for the clients, but also unleashes new opportunities to better understand non-linear fluid structure interactions in complex sea states. It will also pave the way for the development of intelligent systems that would help transform the M&OE industry, especially in the enhancement of efficiency, safety and reliability in harsh environments.

Professor Chan Eng Soon
Chief Executive Officer of TCOMS and Provost's Chair Professor in the Faculty of Engineering, NUS.

The idea of establishing a national maritime technology centre in Singapore started around 2010 on the recommendation of the Marine and Offshore Taskforce, a multi-agency group co-led by A*STAR and EDB, for an ocean basin to be built to help the Marine and Offshore industry through Singapore's public sector research efforts.

The Technology Centre for Offshore and Marine, Singapore (TCOMS) TCOMS was thus established on October 2016 as a joint venture between the Agency for Science, Technology and Research (A*STAR) and the National University of Singapore (NUS) and supported by the Singapore Economic Development Board (EDB) and the Maritime and Port Authority of Singapore (MPA). TCOMS is intended to be the national integrator for research and development in Ocean Technologies and to co-create innovative solutions in cooperation with university and industry. Thematically, TCOMS will engage in advanced shipbuilding, aquaculture and other floating structures, deep sea ocean technologies and ocean energy technologies.

The Deepwater Ocean Basin

A key feature of TCOMS is a next-generation Ocean Basin with forefront simulation capabilities, including smart sensing and integrated physical modelling and numerical simulation. The Ocean Basin is under construction and expected to be in operation within first half of 2018. The initial capital expense of the construction of the Deepwater Ocean Basin and associated buildings and infrastructure is in the order of S$107 million, and fully covered by the Singaporean government through the National Research Foundation.

Initially, one of the main objectives for establishment of TCOMS was to build capacity in the offshore oil and gas industry – especially for deep and ultra-deep operations. However, with the recent slowdown of the oil and gas industry and associated maritime industry, the focus is increasing in other ocean space areas:

- Advanced shipbuilding technologies – smart vessels, autonomous vessel, maritime robotics etc
- Ocean and offshore renewable energy, for example offshore wind
- Aquaculture and fisheries – enhancing the domestic production of seafood
- Large scale and multi-purpose floating structures – storage tanks, bridges etc.

Key Features of TCOMS Ocean Basin

	TCOMS	MARIN	MARINTEK	Lab Oceano
Horizontal dimensions	60m x 48m	45m x 36m	80m x 50m	40 × 30m
Depth	12m	10.2m	10m	15m
Deep Pit	Yes	Yes	No	Yes
Diameter and depth of pit (from water surface)	10m, 50m	5m, 30m	-	5m, 25m
Multi-directiona; wave generation system	Yes	Yes	No	Yes
Range of wave height	0.3-4.0s	0.3-3.0s	>0.6s	0.3-5.0s
Max. wave height	1.0m	N.A.	0.9m	0.5m
Max. Significant wave height	0.5m	0.4m	0.5m	0.3m
Current Generation system	Yes	Yes	Yes	Yes
Max. near-surface velocity	0.5m/s	0.5m/s	0.25m/s	0.25m/s
Depth-averaged velocity	0.25m/s	0.2m/s	N.A.	N.A.

Table: Comparison between some leading ocean basin facilities in the world. TCOMS (Singapore); MARIN (Maritime Research Institute Netherlands); MARINTEK (Sintef Ocean, Norway); Lab Oceano (Rio de Janeiro Federal University, Brazil). Source: NUS.

TCOMS is connected to the National Super Computing Centre Singapore[6.2] for combining sensoring, modelling, computations and virtual prototyping for physical testing and model calibration. The Ocean Basin will be able to support integrated physical tests with numerical simulation in collaboration with academia, research institutes and industry.

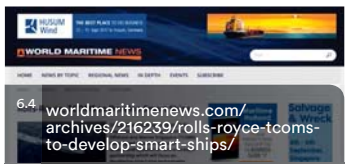
Singapore has joined the ranks of countries with petascale supercomputing capabilities with the National Supercomputing Centre Singapore's (NSCC) Advanced Supercomputer for Petascale Innovation, Research and Enterprise or ASPIRE 1. ASPIRE 1 serves both academic and industry high performance computing (HPC) users, including TCOMS. The TCOMS core powers the next-generation Deepwater Ocean Basin research facility which uses advanced wave and current generation systems to simulate ocean environments.[6.3]

The users/customers of TCOMS will be both domestic and international companies and institutions. Within the Singapore maritime cluster, the more relevant users of TCOMS would include companies and institutions engaged in shipbuilding technology and design; local ship yards; industry research entities;shipping companies (owners and operators); universities and research institutions such as A*STAR and not at least internal TCOMS researchers.

On the international arena, TCOMS will attract suppliers to the Singaporean maritime industry; international shipbuilders, owners, operators; foreign government entities without own capacities and foreign research institutions in cooperation with Singaporean counterparts.

6.2 www.a-star.edu.sg/ihpc

6.3 www.asianscientist.com/2016/12/topnews/singapore-unveils-petascale-supercomputer/



6.4 worldmaritimenews.com/archives/216239/rolls-royce-tcoms-to-develop-smart-ships/

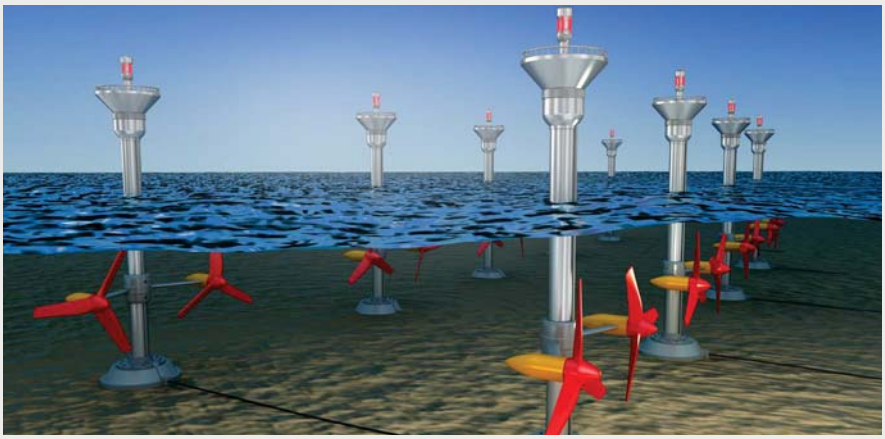

6.5 www.lr.org/en/news-and-insight/news/LR-to-collaborate-with-Singapore-centre-of-excellence.aspx

6.6 www.gov.sg/resources/sgpc/media_releases/mpa/press_release/P-20170427-2

Some key clients have already signed MoUs with TCOMS:

- October 2016: DNV GL and TCOMS will jointly carry out research to develop innovative designs for future marine and offshore systems, including research to increase the understanding of extreme wave effects. Using digital technology is a key part of the agreement including use of digital twins, smart sensors and integrated modelling.
- March 2017: **Rolls-Royce** and TCOMS announced a MoU to form a strategic partnership which will focus on developing smart ship technologies[6.4]. The partners will work on world leading research to develop fundamental technologies, such as smart sensing, digital twinning and integrated modelling which are essential to the development of future marine data based solutions.
- April 2017: **Lloyd's Register** (LR) and TCOMS agreed to jointly develop technology, infrastructure and skills necessary for future marine and offshore systems, digital and data innovation, and robotic autonomous systems in a marine environment[6.5].
- April 2017: A four-party collaboration MoU between **MPA, Alpha Ori, LR and TCOMS** to jointly establish a Centre of Innovation. The parties will conduct joint research in the areas of Data Analytics for Smart Shipping, use of Robotics and Unmanned Systems in port and shipping for operations, maintenance and inspections in hazardous zones, and maritime cybersecurity[6.6].

6.2 Ocean Energy



Ocean energy potential is very limited in Singapore. The available sea territory is small and congested and energy conditions for e.g. wind, current, wave and ocean thermal energy conversion (OTEC) are rather poor. Tidal is generally regarded the ocean energy source with highest potential, estimated by Energy Research Institute at NTU to some 200MW (technical availability). Again, competition on sea space with port, anchorage and traffic lanes makes any sizeable ocean energy farms unfavourable within foreseeable future.

That being said, some corporate and university research laboratories are conducting research and technology development on ocean energy. Their motivation is a combination to explore opportunities of ocean energy harvesting inside Singapore waters and to develop technology and solutions to be exported to other markets in Southeast Asia and beyond. As mentioned above, TCOMS regards research and testing of ocean energy (wind mills etc.) as part of their strategic focus.

Energy Research Institute at Nanyang Technological University:[6.7]

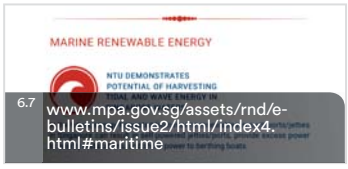
The Energy Research Institute @ NTU (ERI@N) embarked on a project to investigate the potential marine renewable energy sources available at Singapore's jetties. Together with Singapore Cruise Centre (SCC) which operates a number of ferry terminals including TMFT, ERI@N's Wind and Marine Renewables Team performed a resource assessment of the marine renewable energy that can be harnessed in a typical terminal/ jetty setting.

ERI@N also designed, prototyped, and installed a Wave Energy Converter (WEC) for harnessing the jetty berth's pontoon movement due to tides and waves and converting the mechanical power into electrical power. The developed WEC works with existing pontoon rollers and will eventually replace some of them to function both as pontoon movement guides but with energy extraction features.

The Maritime Clean Energy Interdisiplinary Research Programme covers Green Shipping and Green Ports including alternative fuels, emission management, energy efficiency offshore and in ports.

- Keppel O&M Technology Center (KOMTech) is doing research on offshore wind energy research on self-installing platforms for substations, turbine foundations, wind turbine installation vessels and cable laying vessels. As mentioned earlier, Keppel invested in the Norwegian offshore wind foundation company OWEC Tower in 2012.
- The Japanese Class NK launced in 2013 the Global Research and Innovation Center (GRIC) which includes a marine energy R&D test site for energy storage systems, biofouling materials, energy converters, prototype design testing, and creating possibilities to provide energy for maritime industry usage like in ports and harbours.

ERI@N is managing a Joint Industry Project (JIP) on Offshore Renewable Energy. More than 20 docoral projects are in progress on energy resource forecasting, grid and integration issues and substructure/generation topics. Commercial firms in this consortium are: Lloyds, Vestas, Gamesa, DNV, Keppel Corporation, Ceentek, IBM, DHI and CIMNE. In addition, the research is supported by leading research partners such as National Renewable Energy Labs (NREL) in USA, the Norwegian University of Science and Technology (NTNU), the University of Colorado, and Danish Technology University (DTU).



6.7 www.mpa.gov.sg/assets/rnd/e-bulletins/issue2/html/index4.html#maritime

Ocean Technologies

Summary

Market Drivers:

- Singapore aims to develop its maritime industry by moving from manufacturing-centric to more knowledge-driven maritime industry, including ship design, naval architecture, advanced technology development, innovation and research.
- The establishment of TCOMS as the integrator between companies, research institutions and universities demonstrates the governments commitment.
- International partnership, knowledge transfer and joint development are essential enables to lift Singapore to "Maritme 4.0". This opens for market opportunities and research collaboration with Norwegian entities – but could also mean that Singapore will move in as an strong competitor to Norwegian centres of excellence.

Problem Statements *(challenges and technology needs):*

- Undertake prototyping and design to develop emerging concepts such as remote operations for offshore platforms, underwater robotics, platforms for renewable energy and aquaculture.

Norwegian strengths and opportunities:

Norway has a very strong global position in ocean technologies:

- World class competence and experience in ocean technologies centred around the maritime clusters in Sintef/NTNU in Trondheim and Ålesund; the subsea clusters in Bergen and the oil and gas clusters in Stavanger.
- World leading ocean basin facilities at Marintek (now Sintef Ocean).
- Internationally recognised universities and maritime and offshore research centres in e.g Trondheim, Stavanger, Bergen, Oslo., Ålesund etc.

Recommended market approaches

Market entry through network and research relations:

- TCOMS is an integral part of the extensive maritime cluster in Singapore; including world-class shipyards and their technology supply chain; the worlds most advanced port (under development) and a strong academic and research community. Clear technology needs and an inherent international inclination opens a potentially huge market for Norwegian technology and solutions providers. TCOMS would offer facilities and competence to adapt, test, verify and demonstrate Norwegian technologies for Asian markets.
- For immature but emerging technology areas, such as large-scale aquaculture, ocean energy and deep sea exploration; early relations with research and university groups, such as TCOMS, could present effective bridges into the Singaporean commercial maritime community.
- Innovation Norway has established networks between Norwegian energy and maritime companies/ institutions vs Singaporean counterparts that newcomers can plug into:
  - Norwegian Energy Collaboratorium (NEC) in Singapore is another cluster of companies and research institutions with focus on energy, including clean maritime and LNG: Norwegian University of Science & Technology, SINTEF, Institute for Energy Technologies, Elkem, Multiconsult, Tronrud Engineering, eSmart Systems). NEC is closely connected to leading Singaporean research institutes at Nanyang Technological University, National University of Singapore, A*STAR and National Research Foundation.
- Leveraging on existing research relations - Sintef OCEAN has already well-established research collaboration projects with e.g. NUS, A*STAR, JTC and other key entities in Singapore. DNV GL is active and proactive in all ocean technology initiatives in Singapore. Join market approaches in new areas (such as for example floating offshore wind) could be make through Joint Industry Projects supported by Innovation Norway/Research Council.

Active marketing:

- Attending conferences and trade shows in Singapore. See below.

Relevant marketing and networking arenas

Singapore International Energy Week (SIEW). Although not explicitly addressing ocean energy, several events during SIEW will be relevant for ocean energy; including the ACE conference and the Nordic Green Conference, organized by the 4 Nordic embassies.

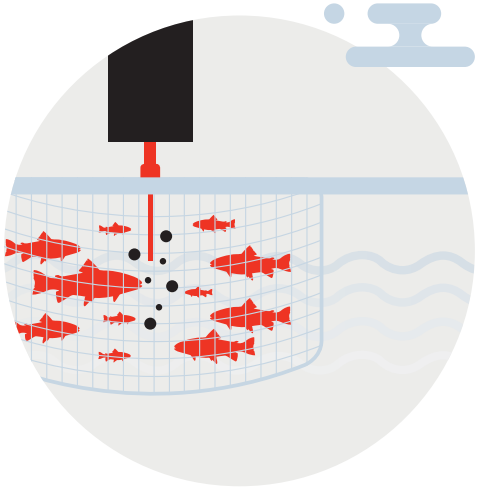
www.siew.sg

Asia Pacific Maritime 2018 in Singapore 16-18 March 2018 is "the premier event in Southeast Asia where 15,000 owners, builders, procurers, end-users of products/ service from Asia and 1,500+ international suppliers in the shipbuilding & marine, workboat and offshore industry come together across three days to buy, sell and network". Innovation Norway is every year organizing a special pavilion for Norwegian companies which opens for exhibition, network and presentations.

www.apmaritime.com

7.0

Aquaculture Technology



7.1

Aquaculture In Singapore

Singapore's consumption of fish is estimated to be 100,000 tonnes per year. Given Singapore's limited size, only about 4% of the fish demand and 8% of overall seafood demand is covered by domestic aquaculture.

The current Singaporean aquaculture industry consist of:

- coastal fish farms in floating net cages along the northern coast of Singapore producing marine food fish species like groupers, sea bass, snappers and milkfish as well as green mussels and crustacean (shrimp/mangrove crabs);
- freshwater food fish farms producing snakeheads, tilapia, catfishes and carps and other cyprinids[7.1], and
- a few land-based fish farms culturing species like tilapia, marble goby and snakehead.

The largest commercial fish farm, Barramundi Asia[7.2] produces 500 tonnes of barramundi (Asian sea bass) a year at its 7.5 hectar European Union-certified farm off Pulau Semakau, which has a maximum capacity of 3,000 tonnes of fish. Although Barramundi Asia has a large export to Australia, and has the option of fish farming in other Southeast-Asia waters, it prefers Singapore waters as these are sheltered from tsunamis, earthquakes and typhoons[7.3].

7.1 AVA Website: www.ava.gov.sg/

7.2 www.barramundi.asia/index.html

7.3 wildshores.blogspot.sg/2009/12/what-goes-on-at-singapores-largest.html#.WVuaVk0UmUk

Development and challenges for the Singaporean aquaculture industry

In line with Singapore's general policy of national security and minimising dependency on imported resources, the governments objectives are to increase local fish production from 4% to 15% of the demand – i.e. the order of 15,000 ton p.a. This will require massive expansion of both ocean-based and land-based aquaculture infrastructure and allocation of coastal waters.

Most of the local fish supply is produced by farms using the open net cage systems, made of net cages submerged in the sea to house fish. These fish stocks are exposed to environmental changes which farmers have no control over. In recent years, fishing operations were affected by massive die-offs due to severe plankton blooms. Algae blooms, local pollution and parasite/disease spreading are serious challenges for the ocean-based aquaculture in Singapore. As example, algae blooms wiped out 500 tonnes of fish stocks in 77 fish farms in 2015, and an oil spill from a ship collision in March this year polluted 12 fish farms between Singapore and Johor[7.4]. AVA has been working with coastal fish farmers to develop mitigating measures against these occurrences in the long run[7.5].

To address these challenges, Singaporean government and the industry is developing ***Closed Containment Aquaculture Systems (CCAS)*** and ***Recirculating Aquaculture Systems (RAS)*** as alternative production method in Singapore for coastal farms. Agri-food and Veterinary Authority of Singapore (AVA) commissioned in 2015 five companies to develop CCAS prototypes that cater to different types of coastal farm operations. These systems, along with technical advisory provided by AVA, allow farms to boost production by mitigating the adverse impact of environmental conditions. Such land-based aquaculture system maintains the water at an optimum condition, allowing the company to grow more fish while reducing water consumption by up to 90 per cent.

There is furthermore focus on increasing hatchery production using RAS. AVA worked with Swee Chioh Fishery, a local land based fish hatchery, to set up a RAS and develop accompanying culture protocols for large-scale indoor sea bass larviculture. With RAS technology, a high level of bio-security can be maintained by reusing treated water. This project is the first known record of successful larviculture of Asian sea bass using RAS on a commercial level.

With AVA's assistance, a recirculation aquaculture system was set up at a local fish farm.

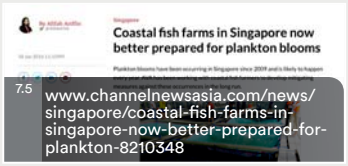
The Singapore government is stating that "Embracing new technology is crucial for fish farm sustainability"[7.6] and are specifically pointing out areas of need for innovation:

- Novel use of biological technology for treatment in seawater environment.
- Sustainable, cost-effective and environmentally-friendly system for water treatment in coastal fish farming.
- Identification and optimisation of parameters for closed containment system.
- Monitoring systems to enhance high density sea fish production output.

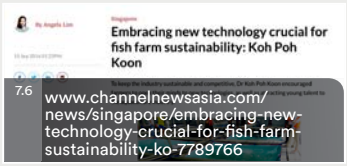
At a meeting between AVA and Innovation Norway on June 26th, more specific technological opportunities and challenges (Problem statements) were identified:

- Design and manufacturing of large, ocean-based cages
- Efficient technology for production of nets and solutions for net cleaning,
- Automated feeding systems with pipe delivery
- Effective aquaculture policy and regulations which balances economic efficiency with environmental concerns
- Technologies for automated, cost-effective and energy-efficient land-based facilities
- Solutions to meet energy challenges: primarily within cooling and water conditioning

7.4 http://www.channelnewsasia.com/news/singapore/oil-spill-off-johor-affected-fish-farms-plan-to-seek-compensatio-7532660



7.5 www.channelnewsasia.com/news/singapore/coastal-fish-farms-in-singapore-now-better-prepared-for-plankton-8210348



7.6 www.channelnewsasia.com/news/singapore/embracing-new-technology-crucial-for-fish-farm-sustainability-ko-7789766

Opportunities For Norwegian Companies

This report is addressing technology and service companies within the aquaculture industry as opposed to fish farming and seafood processing companies.

Market opportunities in this context arises on two arenas: meeting technology needs for domestic aquaculture activates in Singapore; and approaching the aquaculture industry in South-east Asia using Singapore as a base.

Within the Singapore aquaculture market:

The Singaporean aquaculture industry is minuscule compared to the neighbouring countries in the region. However, the governments ambitions is to significantly expand Singapore seafood self-sufficiency through advanced and high-technology land-based and ocean-based fish farms. Government and industry recognizes that the experience is limited compared to e.g. European industries, and are actively seeking technology and advice for expanding their industry.

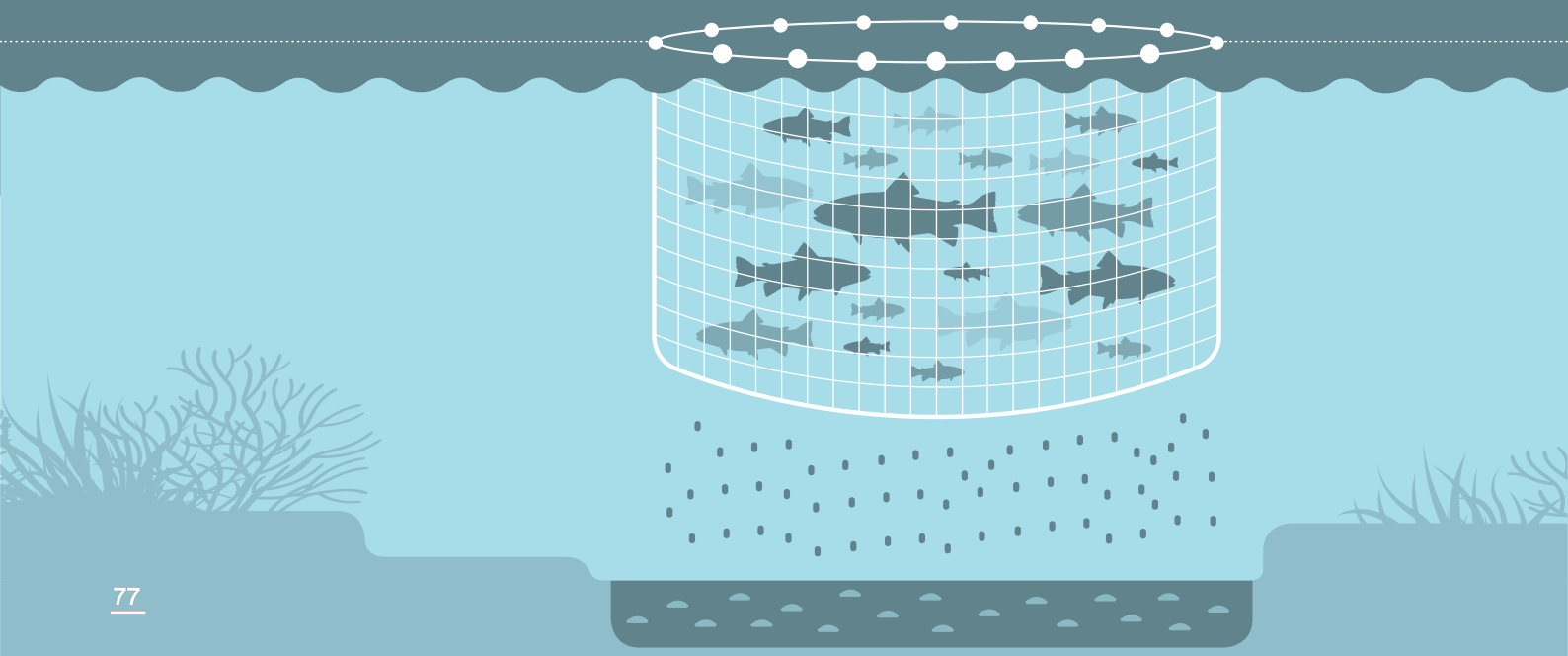
For land-based aquaculture facilities:

- Design and construction of closed tanks and associated infrastructure
- Water treatment and conditioning
- Automation, sensoring, data analytics, modelling etc.
- Energy use, energy efficiency. In Singapore, this is mainly related to water and air cooling.

For ocean-based aquaculture facilities:

- Design and construction of larger-scale cage structures and associated infrastructure
- Automated and efficient feed systems
- Autonomous and automated operations of fish farms.
- Monitoring, sensoring, data analytics

On a non-technical side, exchange of experience on governance, sea farm planning and regulations, handling of diseases and parasites etc. are areas of possible cooperation for Norwegian and Singaporean cooperation.

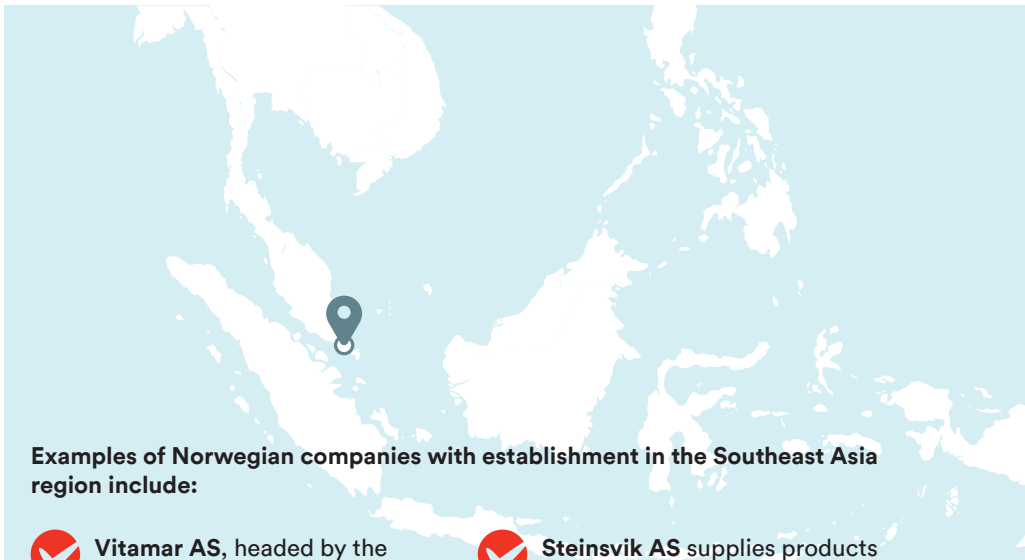


Singapore as base for south-east Asian markets:

Singapore excellent geographical location provides easy access to the South China Sea, and the Indian and Pacific Oceans. It also has the necessary infrastructure essential for successful marine research and development. Singapore and its eco-system of high level technology companies, shipyards, investors and financers, could be a relevant and attractive "base camp" for developing and deploying aquaculture technologies for the Southeast Asian markets.

There are clear signals that the Singaporean maritime industry – yards, technology supply firms – are actively looking for new areas with the ocean technology space – including large scale aquaculture infrastructures. Companies like Keppel and Sembcorp are showing interest in this area, including study tour to Norway. Furthermore, maritime research institutions and centres such as TCOMS lists aquaculture technology as one of the new focus areas.

Several Norwegian companies have shown interest in the aquaculture value chain in SE Asia. However, the majority have mainly spent efforts in markets screening for selling their products. Some few have invested in production or services in the region, while other companies have assessed the region for shorter or longer periods possibly in connection with market screening: AkvaGroup, Smartfarm, OxyVison, AqVisor, AFGC (tilapia).[7.7]

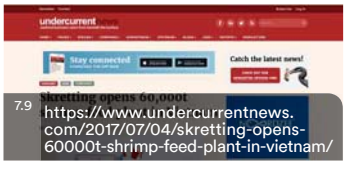


Examples of Norwegian companies with establishment in the Southeast Asia region include:

- **Vitamar AS**, headed by the pioneer and expert on global fish farming Bjørn Myrseth, has announced a US$24 million investment in a very first fish farm in Cambodia, with start-up this year[7.8].
- Bjørn Myseth has furthermore investments in Vietnamese aquaculture farms though his **Marine Farms AS**, specializing on cage farming of Cobia species in Nha Trang.
- **GenoMar AS** is the world's leading tilapia breeding company. They operate their Breeding nucleus and main multiplier in the Philippines. In partnership with Trapia Malaysia Sdn Bhd, they use world-class cage farming and processing facilities to test and document the performance of Genomar Supreme Stocks with regards to several traits including growth and fillet yield.
- **Skretting AS** is the world's largest producer of feeds for farmed fish. Skretting entered Vietnam in 2010 through the acquisition of Tomboy Aquafeed, a Vietnamese fish and shrimp feed company. Skretting Vietnam now conducts research, raw material procurement, as well as provides products and services for aquaculture in the country. A new 60,000t shrimp feed plant in the Mekong Delta was opened July this year[7.9].
- **Steinsvik AS** supplies products for fish farming, ships, subsea and rigs. Steinsvik Vietnam is a engineering- and software office, and opened in 2014 a factory in Nha Trang to produce parts for Steinsviks products.
- **Pharmaq AS** is the global leader in vaccines and innovation for aquaculture. Pharmaq was first engaged in development of fish vaccines for Vietnam in 2006. Since 2008 the company has been present through its own subsidiary, Pharmaq Vietnam, with a total of 18 employees today.

7.7 Source: «A Study of Market Opportunities for Potential Investors in Aquaculture Production, Technology and Services in Myanmar with a Focus on Marine Aquaculture Sector in the Rakhine and Tanintharyi Regions.», Prepared by RR Consult for Norad, June 2016.

7.8 https://www.cambodiadaily.com/business/first-large-scale-marine-fish-farm-in-works-2-122914/

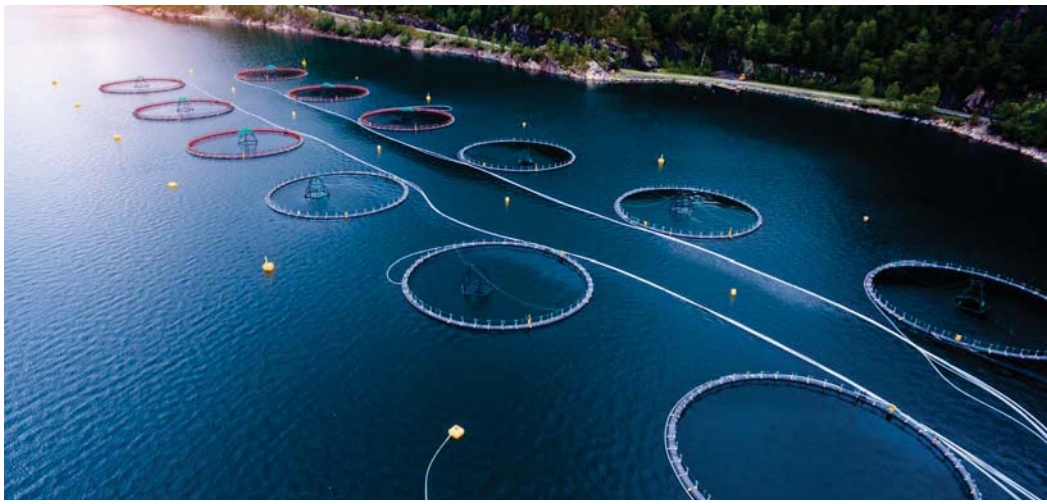


7.9 https://www.undercurrentnews.com/2017/07/04/skretting-opens-60000t-shrimp-feed-plant-in-vietnam/

Research collaboration

There is furthermore a good basis for research cooperation between leading Norwegian and Singapore institutes and agencies on all the aspects listed above.

There is established relations between Temasec Lifesciences Laboratories and the Norwegian University of Life Sciences withain Aqua-genomics, Gut microbiome, Microbiomes as bioresources for application to biomass valorization and Development of selected food crop via molecularassisted breeding.



Market entry strategies

AVA and their Technology and Industry Development Group would be a good starting point to identify opportunities and to connect to the industry.

The Singaporean government and industry has shown strong interest in Norwegian aquaculture industry and technologies, and is organizing a study tour to Aquanor in Trondheim in August. The delegation includes high level representatives from Ministry of National Development (minister attending); AVA (director level), Economic Development Board and SPRING and fish farm companies.

The one week study tour includes meetings with Sintef Ocean and local technology companies; participation at the Aqua Nor expo and conferences[7.10], meetings with Norwegian maritime authorities and a visit to Marine Harvests fish farm at Hitra. This study tour will provide excellent opportunities to connect the Norwegian companies and research institutions to the policy makers and industry representatives from Singapore.

Innovation Norway Singapore and Trondheim office and the Norwegian Seafood Council is facilitating the study tour and will follow up on opportunities for developing cooperation on institutional and company level.

Based on the finding and interest from Singapore delegation; and on interest from the Norwegian side, Innovation Norway Singapore will work with the key stakeholders - AVA, EDB from Singapore side - and research institutions and industry clusters from Norwegian side – to line up a strategy to establish business and research development. One possible meeting arena is the AquaSG 2017 in Singapore in October.

7.10 www.aqua-nor.no

AquaSG'17 Aquaculture Singapore

3-7 October 2017

Organized by Temasek Polytechnic

Premium Sponsor: BLUE AQUA

Supported by: AVA

Silver Sponsor: FISHANCE

Official Media: AQUA Practical

Media Partner: AQUA FEED, IntraFish, World Aquaculture Society

Aqua Singapore 3-7 october 2017

For third year running, the AquaSG 17 brings together stakeholders in research, nutrition, farming technology and investment for the aquaculture industry. Selected topics for AquaSG 17 will cover various aspects of aquaculture including latest trends in research findings to bring value to conference participants.

AquaSG'17 is an ideal place to learn, discuss, exchange, and connect. It is for every area of profession expertise in aquaculture: Farmers / Entrepreneurs; Researchers / Scholars; Investors; and Feed manufacturer.

The Industry Roundtable on Oct. 7th would be of special interest for Norwegian aquaculture technology companies, under the title "Aquaculture Industry Development Across Economies" and subtitle "Innovation in Aquaculture - explore the growth and potential of the aquaculture industry in Singapore and across the globe, with expert and practical views from valuable players of the industry".

http://www.aquasg.com/

Opportunity space: Aquaculture Technologies

Summary

Market Drivers:

- Singapore aim to increase national fish production from 4% to 15% of demand through expansion of ocean-based and land-based farms, increasing efficiency and new technology.
- Cost reduction, energy efficiency and stricter environmental regulations will require development and deployment of advanced technology and solutions.
- The massive projected growth of aquaculture industry in the South-east Asia countries will require a wide range of effective and environmentally sustainable technical solutions and good governance.

Norwegian strengths and opportunities:

- Norway has world-class aquaculture industry covering the entire value chain for ocean-based (recently also land-based) fish farming and can offer solutions within design and construction, operation and maintenance and on governance and regulations.
- Norwegian companies can offer technology products directly to stakeholders in Singapore, or partner with Singaporean technology providers to address the Singaporean and SEA markets.
- Norway research institutions and universities are in world class on aquaculture and aquatic bio economy areas.

Problem Statements *(challenges and technology needs):*

Singapore centric:

- Land based aquaculture: need for technology for tanks and associated infrastructure
- Labour costs: need technology related to automation, efficient maintenance etc.
- Energy and environmental issues: need technology for energy efficiency, surveillance and emission control
- Ocean based aquaculture: need technology for large-scale cages and associated infrastructure, automated feeding, maintenance, vessels etc.
- Need to build academic and research capacities on industrial scale and effective aquaculture.

South-east Asia centric:

- Technology for large-scale ocean sea farms – design and construction; feed and energy efficiency; environmental aspects;
- Experience and advice on governance and regulations.

Recommended market approaches - Singapore:

Norwegian "offer" screening:

- Identify the Norwegian industry clusters and companies that have relevant technologies and are "able, ready and willing" to approach the Singaporean and South-East Asian aquaculture markets.
  - Communicate with Norwegian industry clusters, associations and single companies
  - "Sell in" the Singaporean and Southeast Asia market opportunity space to relevant companies and clusters in Norway.

Market intelligence – supported by institutions such as Innovation Norway:

- In-depth study of Singapore's objectives, road maps, challenges and problem statements within aquaculture industry.
- In-depth studies of selected South-east Asia markets (see later)
- Analyse and understand where Norwegian technology is applicable and where it is not (different species, methods, regulations, culture, economic constraints etc.)
- Analyse and understand economic drivers, market mechanisms, funding and investment structures, various markets risks.

Relations and network building:

- For Singapore: AVA and the government does probably offer the most effective avenue to approach both the industry and research institutions in Singapore.
- Study tours to Norway for key decision makers to present and promote technologies and solutions:
  - Study tour from Singapore to Norway in August 2017. Aqua Nor/Trondheim and bilateral meetings with companies.

Promotion and networking in Singapore

- Visit from Norwegian stakeholders to AquaSG'17 and other events.
- Innovation Norway Singapore facilitate
- b-to-b meetings and/ or business networks if sufficient interest.

Identify partnership opportunities between Singaporean and Norwegian entities:

- Innovation Norway Singapore cooperates with agencies like IE Singapore, Singapore Business Federation, IPI Singapore etc. to establish and support business-to-business relations.

Research collaboration:

- Leverage on existing cooperation agreements such as the MoU between the Norwegian University of Life Sciences (NMBU) and Temasec Life Sciences Laboratory (TLL).

Singapore stakeholders.

AQUACULTURE & HORTICULTURE SERVICES

Marine Aquaculture Centre

Marine Aquaculture Center[7.11]:

Located at St John's Island, the Marine Aquaculture Centre (MAC) was set up to develop and harness technology to facilitate the development and expansion of large-scale hatchery and fish farming production in Singapore and the region. The main focus is on tropical marine fish aquaculture technology development in order to develop fast-growing and good quality fish fry for intensive farming.

AVA Agri-Food & Veterinary Authority of Singapore

AVA – Agri-food and Veterinary Authority of Singapore

AVA is the main authority overlooking food production and food safety in Singapore, including aquaculture. AVA consists of a multidisciplinary team to support professional development, innovation, cross-boundary exchange and interdisciplinary co-operation within the agri- and aquaculture industries. The objectives is to diversify Singapore's food sources worldwide, while simultaneously developing Singapore into a regional hub of excellence for agrotechnology and agri-business.

AVSA regulated the aquaculture industry. For marine food fish farms, the farm licensee must abide by good farm management guidelines to maintain the farm in good condition and ensure that the farm does not engage in activities that would impact the farming environment. For land-based farms, there are also guidelines that address infrastructure layout, farming system and water treatment facilities. The latter requires that sedimentation ponds, reservoir ponds/tanks, supply/drainage systems and trade effluent treatment plant are included in the farm set-up.

AVA performs research and development at its Marine Aquaculture Centre, while freshwater R&D is performed at Sembawang Research Station.

7.11 www.ava.gov.sg/explore-by-sections/farms/aquaculture-and-horticulture-services/marine-aquaculture-centre


7.13 www.nmbu.no/en/news/node/28901

7.15 arl.nus.edu.sg/twiki6/bin/view/ARL/Research#PlatformTech

7.12 www.tll.org.sg/


7.14 www.tmsi.nus.edu.sg/

7.16 www.singaporetech.edu.sg/

TLL – Temasec Lifescience Lab[7.12]:

Temasek Life Science Laboratory is a small, but prestigious laboratory in biotechnology that conducts research on plant diseases, plant science, animal science and aquaculture science. In addition, the laboratory conducts research within genetics, food, and genetic engineering.

TLL signed a MoU with the Norwegian University of Life Sciences in October 2016[7.13], intended to facilitate a collaborative joint research programme, which will include training, dissemination of information and exchange of faculty, students and staff and commercialization of research outcome. The thematic focus is mainly on biotechnology such as aqua-genomics; gut microbiome and microbiomes as bio-resources, but also on sustainable food future. This relation can be developed as a platform for further research collaboration into more general aquaculture technologies and techniques.

National University of Singapore: Tropical Marine Science Institute (TMSI)[7.14]:

The Tropical Marine Science Institute (TMSI) began as a research initiative of National University of Singapore (NUS) in December 1996. It was officially formed in April 1998 in response to a need for a centre of excellence in tropical marine science.

The most relevant research programme in this context is on Marine Aquaculture, including Hatchery Production; Reef Ranching and Fish Health; and the Acoustics Research Laboratory (ARL)[7.15].

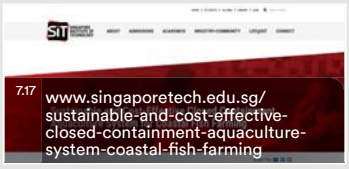
The ARL is conducting research on **autonomous vehicles and platform technologies; underwater communication and sensing networks** which is of relevance for Norwegian maritime technology community, especially the research and industry community around autonomous vessels in the Trondheim region.

Singapore Institute of Technology (SiT)[7.16]:

SiT has an ongoing research project on “Sustainable and Cost-Effective Closed Containment Aquaculture System for Coastal Fish Farming”[7.17].

Institution of Aquaculture of Singapore[7.18]:

The Institution of Aquaculture[7.19] was formed in 2014 by twelve experienced professionals with the vision to assist members advance the art science and practice of aquaculture. In partnership with Temasek Polytechnic. LMC Training and others, this institution plays a significant role in the training of aquaculture manpower resource to support the members’ operations. As a non-profit organisation, the Society is expanding to enrol new members both locally and internationally. This institution could be a gateway for educational and training cooperation between Norwegian and Singaporean universities and companies engaged in aquaculture operations.


7.17 www.singaporetech.edu.sg/sustainable-and-cost-effective-closed-containment-aquaculture-system-coastal-fish-farming


7.19 www.aquaculturesg.org/


7.18 thefishsite.com/articles/new-aquaculture-institution-set-up-in-singapore

Selection of relevant aquaculture companies in Singapore

Danish Water Technology House

Industry association representing water management technologies

www.dwth.dk

SIF Technologies

Water treatment technologies for aquaculture industry

www.dpasys.com/aquaculture

Wieland

German producer of semi-finished copper and copper alloy products like strips, sheets, tubes, rods, wires and extrusions.

www.wieland.com.sg

BioGill Asia Pte Ltd

Australian biotechnology company for growth bioreactors and biofilters.

www.biogill.com/aquaculture

Jebsen & Jessen

Engineering, manufacturing and distribution company

www.jjsea.com

Singapore Aquaculture Technologies Pte Ltd (SAT)

SAT has an offshore fish farm consisting of fish culture tanks on floating platforms. The farm employs close-containment aquaculture technology with advanced water treatment system to optimise fish culture conditions.

www.apollogroup.com.sg

Fishance

Aquaculture business specialized in outdoor, cage system fish farming

www.fishance.com

Marine Life Aquaculture Pte Ltd

Aquaculture company

www.mla-fish.com

Barramundi Asia Pte Ltd

Largest aquaculture company in Singapore

www.barramundi.asia

Apollo Aquaculture Group

Aquaculture processes and solutions

www.apollogroup.com.sg

Metropolitan Fishery Group (MFG)

Operates four fish farms and is one of the bigger players in Singapore.

www.thefishfarmer.com

Rong-Yao Fisheries Pte Ltd (RYF)

Operates an offshore grow-out fish farm with fingerlings supplied from their own land-based fish hatchery/ nursery facility.

Oceanus Group Limited

Crustacean and seafood farmer

www.oceanus.com.sg

Industry

Website

7.2

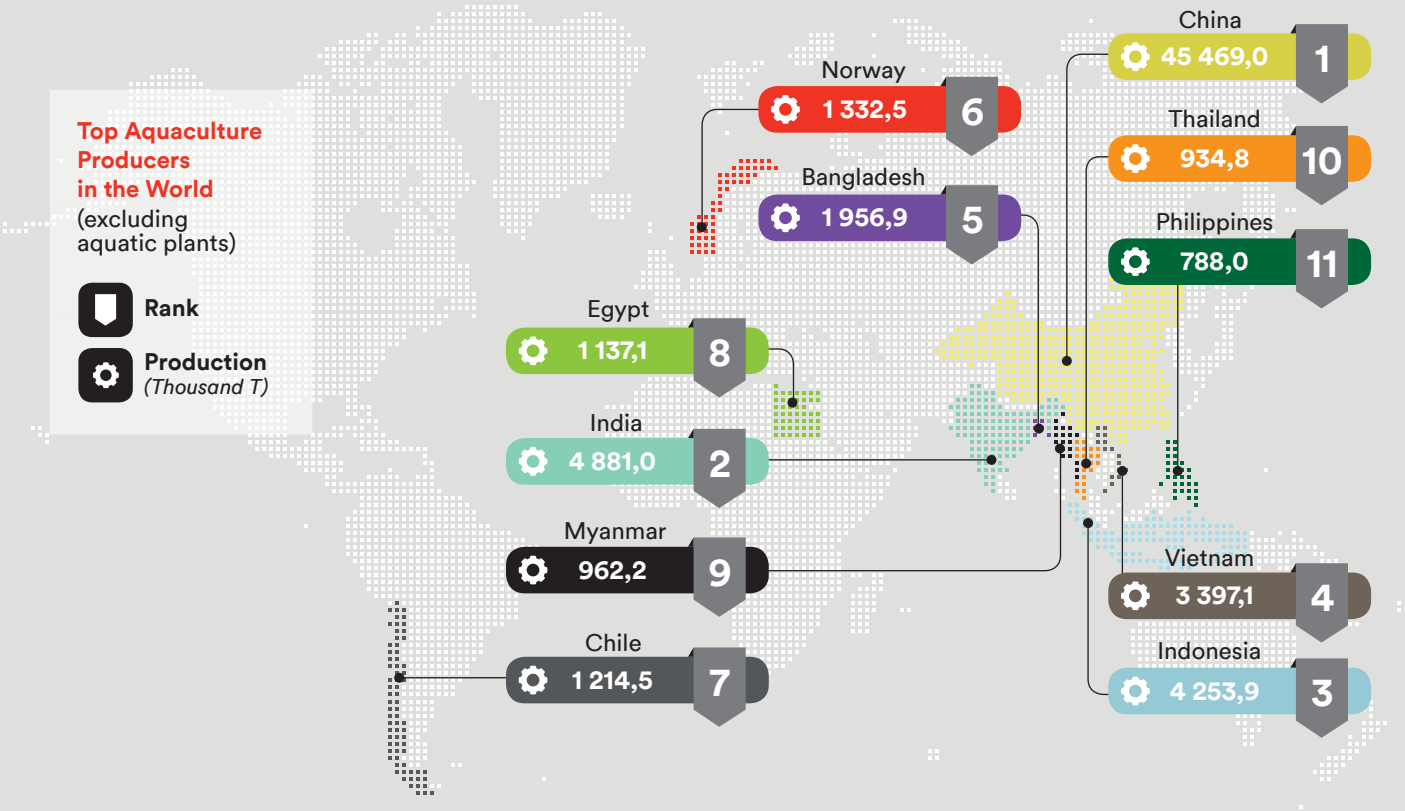
Aquaculture in Southeast Asia

South-east Asia is the global centre of marine biodiversity, and yet the coastal zone of the region also supports over 70% of the human population. Asia is the home of aquaculture, a practice which dates back to thousands of years, and represents 87% of the world's total production and 94% of the people engaged in aquaculture.

Aquaculture in Asia has traditionally and up to the last decade been low-technology and small-scale. However, as countries such as Thailand and Vietnam become more economically and technically developed, the nature of aquaculture has become more intricate, intertwining with other food production sectors under the influence of political, social, economic, technological and cultural factors.

With advancement of technology, the involvement of more aquatic species and farming practices has become possible, and more choices can be offered to the consumers. Population growth, economic growth and the development of disposable income and higher purchasing power, and social factors such as traditional fish consumption patterns, is now rapidly shaping the demand for fish and fishery products. To meet these demands, there will be significant requirement for technology and solutions for industry-scale, cost-efficient and environmentally sustainable aquaculture.

This is an arena that Norwegian aquaculture technology companies should be able to play and increasing role. Innovation Norway and the Norwegian embassies has conducted and commissioned in-depth analysis of the aquaculture industries in three south-east Asian countries: Vietnam, Indonesia and Myanmar.



Vietnam

Vietnam is the 9th largest fishery nation and 4th largest aquaculture producer in the world. 73% of the production is on fresh water species from land-based farms, mainly pangasius and shrimps. Ocean based aquaculture has up until very recently been small, but the Vietnamese government aims to boost this segment. The newly established Vietnamese Seaculture Association is actively seeking close cooperation with e.g. Norwegian technology providers to develop the ocean aquaculture capacity in Vietnam.

The governments ambitions is to reach a production of 4.5Mton farmed fish (at a value of 11 billion US$) by 2020. However, challenges related to lack of technological solutions, diseases and pollution needs to be solved, combined with the fact that the exposed coast of Vietnam is not ideally suited for ocean fish farms. This is where Norwegian technologies and experience can play a huge difference. Source: "Norsk Fiskerinæring" – issue 1/2016[7.20] (in Norwegian).

The Norwegian foreign aid organisation Norad[7.21] has contributed to establishment of a pilot farm for pompano at the RIA research station in northern Vietnam. Innovation Norway, the Norwegian Embassy in Hanoi and Vietnamese government is currently actively facilitating Norwegian technology transfer and business opportunities in Vietnamese aquaculture industry.

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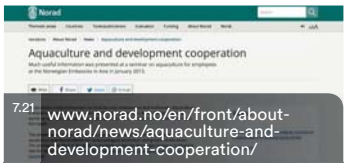
Lien.Phuong.Dang@innovationnorway.no


7.20 digital.findexaforlag.no/i/762948-utgave-11-2016/114



7.21 www.norad.no/en/front/about-norad/news/aquaculture-and-development-cooperation/

Indonesia

Indonesia is well-known as the largest archipelago on earth, consisting of more than 17,000 islands and boasting a coastline of over 81,000 kilometres. Yet Indonesia's seafood industry is still in its infancy compared to its Asian neighbours. Indonesia is currently the ninth largest fish producer in the world. Given the country's extensive coastline, abundant marine resources, and a tropical climate that lends itself to aquaculture production all year round, the country has tremendous potential to be a leading global seafood player.

Already well-connected in distribution markets, Indonesian aquaculture products are exported to more than 200 countries with main markets in Japan, Hong Kong, Taiwan and the United States. Nonetheless, local players yearn for greater access to European markets in particular.

A comprehensive market report on the "Value Chain Analysis of Marine Fish Aquaculture in Indonesia – Business Opportunities for Norwegian Companies" was commissioned by Innovation Norway to Spire Research and Consulting in 2014[7.22].

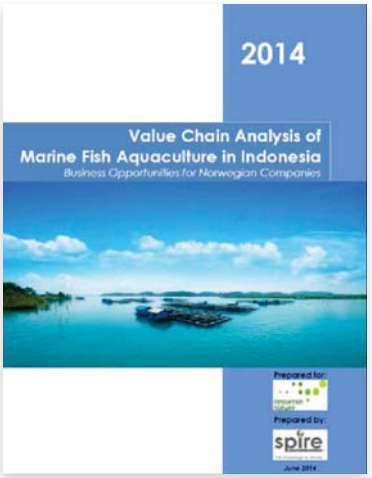
The main recommendations for market entries for Norwegian companies are:

General:

- Huge potential for fish farming in a country with 250 million.
- Focus on east Indonesia and Tiger Grouper and Barramundi as prioritized species
- Business integration: Norwegian companies avoid converging into a single segment since profitability would be problematic.
- Partnership with local companies highly recommended.

Nursery/aquafarming:

- Norwegian companies could initiate operations in Inner Ambon Bay, North of Bali or Jeneponto.
- Focus on developing Tiger Grouper and Barramundi as stand-out species.
- Extensive research into aquaculture cultivation method for upcoming species in the Indonesian mariculture sector such as Yellow-fin Tuna and Tilapia Zilli.
- Develop diversified coastal systems for smaller scale production, with cooperative support (training and knowledge transfer).



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[7.22] Can be obtained from Innovation Norway Jakarta office:Ms. Peggy.Gaspersz@innovationnorway.no

Myanmar

Although Myanmar reports aquaculture production of close to a million ton p.a., the use of the natural aquatic resources has over the last decades been based on a pure exploratory approach, and the government sector only focused on getting a share by collecting fees or leases. Nothing was reinvested into research and development or competence building of staff within science-based fisheries and aquaculture management for the last 36 years. As a result, the research and development capacity within fisheries and aquaculture in the country is nearly absent[7.23].

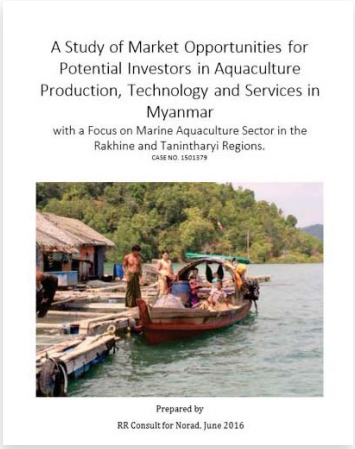
According to the report from RR Consult, Myanmar has very large coastal area resources, but the potential has not been exploited for aquaculture apart from one small, corporate marine fish farm and a few small-scale 'holding' cages for live fish. Thus, it is a good opportunity for Myanmar to avoid the mistakes made in other countries and get things right from the start. One strategy for 'getting things right' is to attract a Norwegian investor in marine fish farming with operational and management experience, who could make the technology transfer. As an investor, there will be ample and highly potential areas available and little biosecurity risk from small-scale marine fish farms, as they are absent, which is different from other countries in the region.

Even when it will be possible to hold 100% foreign ownership, a foreign competent investor may be in control of the production performance of the company, but Myanmar has a very challenging and changing legal and administrative environment, and there will be many issues, where a foreign investor would depend on a local network and legal advices to appreciate, how to administrate the company towards the public sector.

Tanintharyi region is bordering Thailand and has an archipelago of more than 800 medium and larger islands. It is a fast-developing region.

It is highly recommended to the foreign investor in large-volume marine fish farming due to the following reasons:

1. there are no history of cyclones making landfall in Tanintharyi,
2. monsoon impact is less i.e. less wind and rainfall,
3. the archipelago holds a very large number of potential large-volume cage sites, protected and with suitable depths,
4. most of the sites are more than 20 km from the mainland, and turbidity will be minimal,
5. good market access being close to Yangon and Thailand, processing plants, port facility and local airports and
6. no ethnic unrest or security threat.


A Study of Market Opportunities for Potential Investors in Aquaculture Production, Technology and Services in Myanmar

with a Focus on Marine Aquaculture Sector in the Rakhine and Tanintharyi Regions.

CASE NO. 1501379

Prepared by

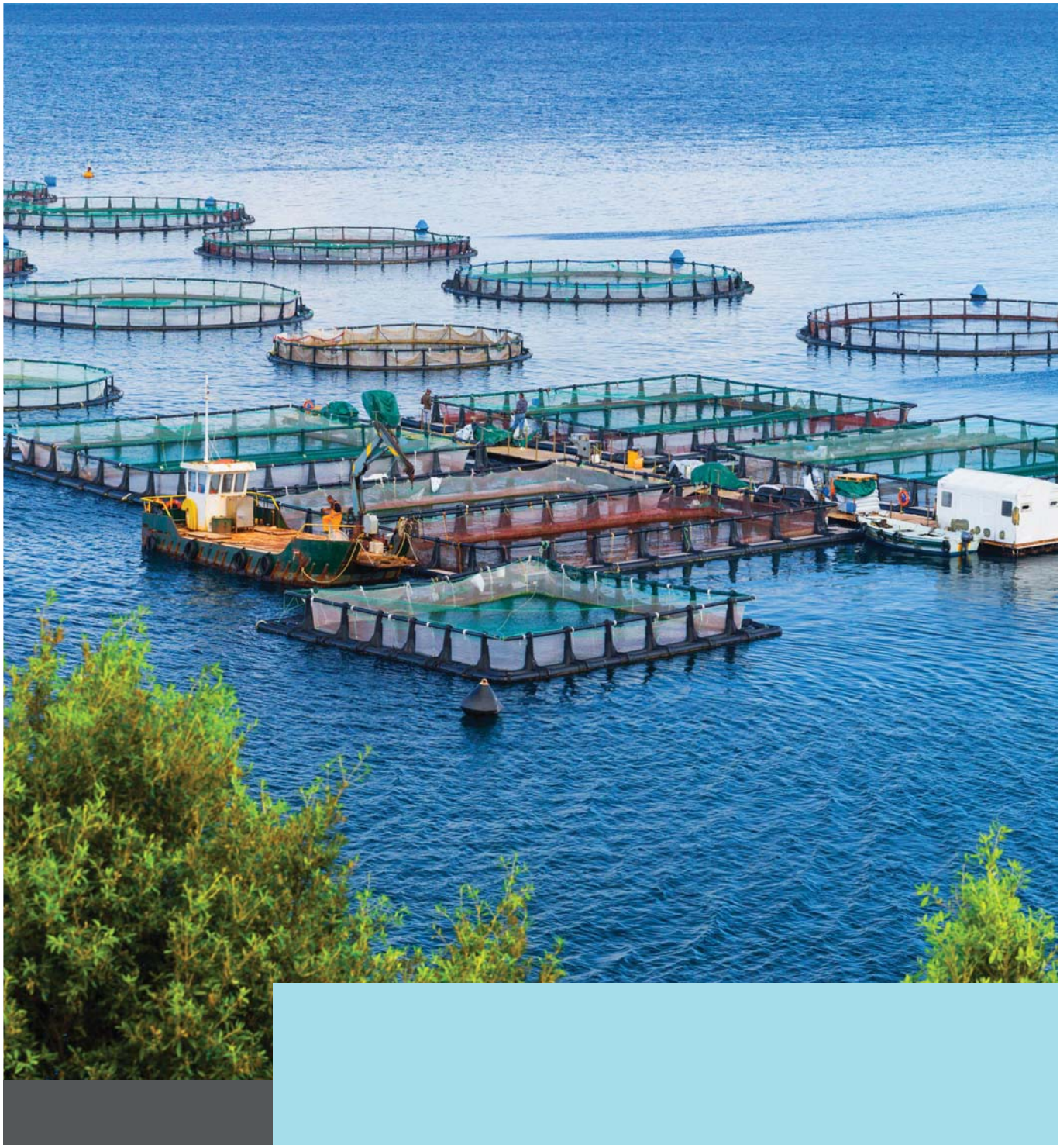
RR Consult for Norad. June 2016

Contact:

Per Christer Lund
Counsellor
Innovation Norway Singapore

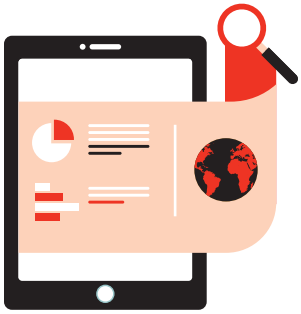
Per.christer.lund@innovationnorway.no

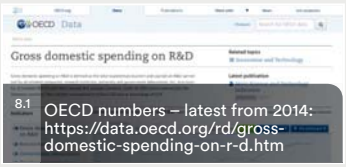
7.23 Source: «A Study of Market Opportunities for Potential Investors in Aquaculture Production, Technology and Services in Myanmar with a Focus on Marine Aquaculture Sector in the Rakhine and Tanintharyi Regions.», Prepared by RR Consult for Norad, June 2016.



8.0

Marine, Maritime and Offshore R&D





8.1 OECD numbers – latest from 2014: https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm

8.2 https://www.nrf.gov.sg/rie2020

Singapore is spending around 2,2 % of its gross GDP on R&D[8.1], of which about half is government investment. Through their SG$19 billion RIE 2020 (Research, Innovation and Enterprise) Plan8.2 the government is singling out four main industry segments as future pillars in Singapore's knowledge-driven economy: Health & Biomedical Sciences; Urban Solutions and Sustainability; Services and Digital Industries; and Advanced Manufacturing and Engineering. The Shipping, Maritime and Offshore Technology industries falls in under the latter focus area.

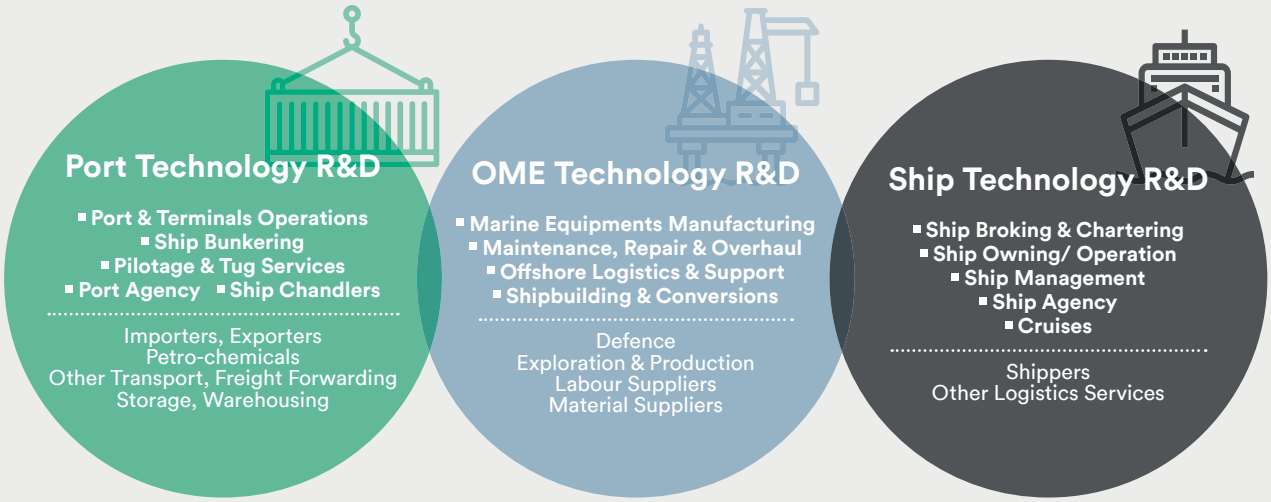
Over the last two decades, Singapore maritime industry is transforming from a transhipment and manufacturing-centric industry to more service and knowledge-driven industries, with more emphasis on design, advanced manufacturing and innovations. To support Singapore's competitiveness as a leading international maritime and offshore centre, the government, academia and industry has realized the necessity of building up national business-centric research, advanced technology development and nourishing of new talent through world-class education institutions are vital pillar. Achieving a dynamic and sustainable maritime technology cluster within Singapore requires strong R&D linkages between research institutions, universities and the maritime industry.

International R&D collaboration is essential to maintain Singapore's ambitions. We will address the Norwegian relations later, but Singapore is growing extensive academic and R&D networks with leading countries and research cluster globally. The universities in Singapore are among the highest ranking in Asia and attracts top-notch leadership, professors and student.

R&D within the Singapore maritime cluster can be categorized into three main areas: Port Technology R&D (addressed in this report in Chapter 5); Ship Technology R&D, which includes "Smart" and "Green" shipping (Chapter 3 and 4); and Offshore & Marine Engineering Technology R&D (chapter 6 and 7).

MARITIME R&D AND ICT

- Class Societies & Marine Surveying Service
- Maritime Logistics & Support
- Maritime Education & Training Government Agencies
- Maritime Finance
- Maritime Legal & Arbitration
- Maritime Insurance, P&I
- Inland Water Transport



The main agencies governing Maritime R&D are the National Research Foundation (NRF) – the funding agency; the Agency of Science, Technology and Research (A*STAR) – combined funding and research institution; and the Maritime and Port Authority (MPA). In 2001, the MPA set up a Maritime R&D Advisory Panel of international and local maritime experts to:

a. develop the vision for maritime technology and R&D,

b. provide comprehensive recommendations based on global trends and

c. to identify significant maritime R&D programmes for Singapore.

The three agencies NRF, A|STAR and MPA established the Singapore Maritime Institute (SMI)8.3 to develop strategies and programmes related to the academic, policy and R&D aspects of the industry. In addition, SMI support cluster and cooperative R&D activities – such as TCOMS discussed in chapter 6, and in general the transformation of Singapore into the global maritime knowledge hub.

As a whole-of-Government approach, the three funding agencies have committed to fund national and international R&D initiatives through the SMI. The joint funding scheme between MPA and Research Council of Norway discussed later in this chapter is administered by SMI. It is also worth mentioning that the Norwegian professor Torger Reve of BI Norwegian Business School sits on the advisory board of SMI.

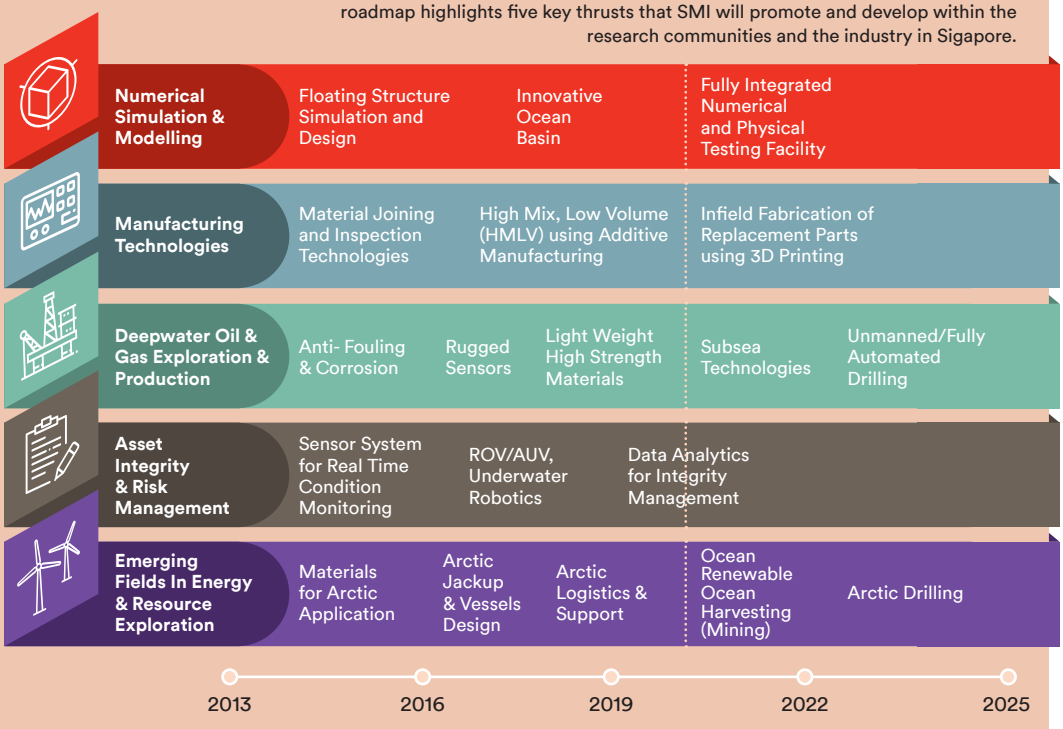
8.3 www.maritimeinstitute.sg

The Maritime R&D road map

In 2013, SMI released their comprehensive Maritime R&D Road Map 2025[8.4] which addresses strategic R&D target and technology needs (problem statements) within Marine and Offshore (M&O); Maritime/Shipping; and the Port of the future.

Marine & Offshore R&D Roadmap

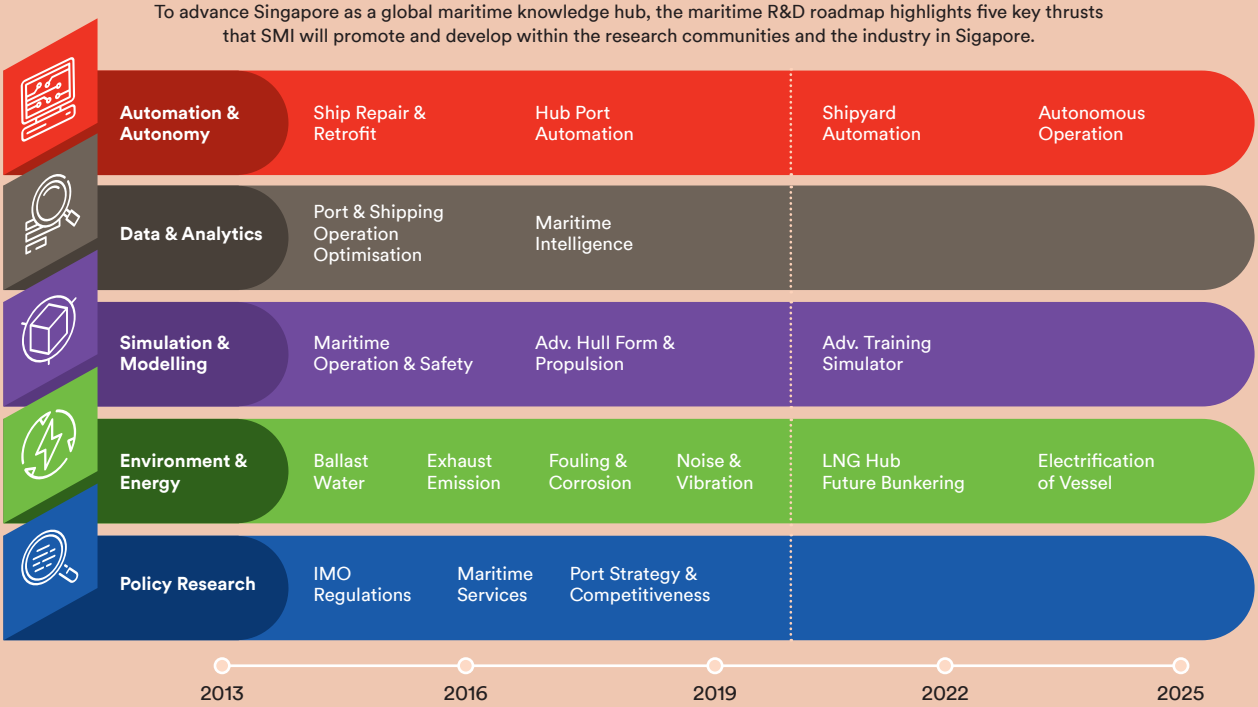
To advance Singapore as a global maritime knowledge hub, the maritime R&D roadmap highlights five key thrusts that SMI will promote and develop within the research communities and the industry in Sigapore.



8.4 https://www.maritimeinstitute.sg/DATA/0/docs/SMIDocuments/SMI-Roadmap-July2014.pdf

Maritime R&D Roadmap

To advance Singapore as a global maritime knowledge hub, the maritime R&D roadmap highlights five key thrusts that SMI will promote and develop within the research communities and the industry in Sigapore.



The figures above; copied from SMI website[8.5], spans out a wide and detailed menu for the Singaporean maritime industry. In the context of this report - identifying research and business opportunities for Norwegian maritime players - the following topics may be most relevant:

Numerical simulation and modelling, especially within floating offshore structures, and integration between numerical models and physical testing/verification (ocean basins) are areas where Norway has very strong capacity, and where Singapore has an expressed interest in cooperation. One example is comprehensive Multi-Purpose Floating Structure (MPFS) project between Sintef, NUS and JTC described later. TCOMS are showing strong interest to attract international R&D cooperation on this topic.

Manufacturing technologies. Novel designs material use for application areas such as ocean energy, aquaculture and deep ocean are areas where Norwegian institutes and companies have long experience from the offshore O&G industry. Additive manufacturing techniques (3D printing) is now looked upon for application such as in-field or event on-board fabrication of spare parts. The Norwegian automotive-parts industry clusters at Raufoss and Kongsberg may have very relevant experience that can be applicable for the maritime industry.

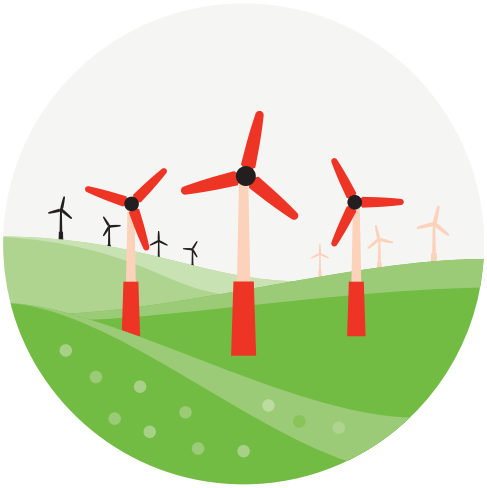
Deepwater exploration. This is perhaps the area where Norwegian research institutes, universities and companies has the most advanced experience and available technologies.

Arctic applications is mentioned in the road map; including materials, O&G rig design, logistics and support etc. Norway is also here in the global lead, and we see alliances such as Sembcorp and Gravifloat addressing business opportunities in the arctic such as LNG fuelled power supply in off grid areas such as Svalbard.

8.5 https://www.maritimeinstitute.sg/DATA/0/docs/SMIDocuments/SMI-Roadmap-July2014.pdf

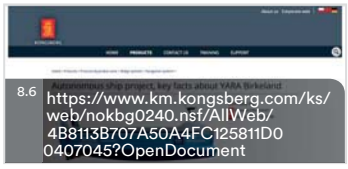
Other emerging fields. Chapter 6 discussed ocean energy such as floating offshore wind and aquaculture technologies, both which are rather immature in Singapore, but with a strong technology and R&D base in Norway.

Automation and Autonomy: As discussed in chapter 3 on "Smart shipping", Norway and Singapore currently share a very strong interest in autonomous vessels. Whereas the first commercial autonomous vessels are realized in Norway (for example MS "Yara Birkland" from Yara and Kongsberg[8.6]), the deployment in Singapore is still at the military and university demo stage. Port and shipyard automation and autonomy may be relevant over time, perhaps within areas such as autonomous port surveillance vessels.



Data analytics, ship simulation and modelling, digitalization. Norwegian research institutions such as Sintef and companies including Kongsberg Maritime, DNV GL, Navtor etc., have over the years build a very strong partnership with Singapore through a number of joint projects related to port and sailing route surveillance, electronic navigation and electronic ship-port communication.

Environment and Energy. As discussed in chapter 4 on Green Shipping, there is substantial potential for R&D cooperation within the LNG value chain – especially within bunkering and small-scale distribution and utilization. Norway has been world-leading on LNG as maritime fuel over the last decade, and are now again leading the way in electrification and use of hydrogen as maritime fuel. With different fuel mix and environmental protection incentive schemes, it is expected that electrification and hydrogen will take time before becoming relevant in Singapore. Ballast water treatment is another area of joint interest.



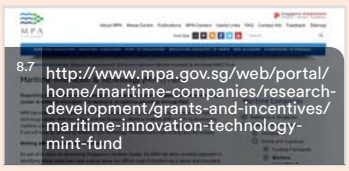
8.6 https://www.km.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/4B8113B707A50A4FC125811D00407045?OpenDocument

The Maritime Innovation & Technology (MINT) Fund[8.7]

MPA has established a SG$200 million (NOK 1.2 billion) MINT Fund to support development programmes for the maritime technology cluster. Through the Singapore Maritime Institute, the MINT Fund will focus on promoting Research and Technology Development in partnership with the industry. The funds are available for Singaporean **or foreign but Singapore-registered companies,** and requires at least 50% own project funding – including man-power. The R&D or test-bedding of new or better products, processes and applications relevant to the maritime industry should be carried out in Singapore.

There are currently 2 funding schemes:

- MINT-Research & Development scheme promotes upstream research and encourages creation of knowledge, capability and IP within the companies, and is relevant to maritime companies and large companies with in-house R&D, as well as marine equipment makers and technology developers.
- MINT-Product Development scheme encourages product and solution development, value creation, and the translation of state-of-the-art technologies from non-maritime industries for use within the maritime domain, and is relevant to maritime companies with engineering design capabilities, engineering companies, system integrators, software / hardware developers, shipyards, and overseas technology companies.



8.7 http://www.mpa.gov.sg/web/portal/home/maritime-companies/research-development/grants-and-incentives/maritime-innovation-technology-mint-fund

The Singapore Maritime Institute Fund[8.8]

The SMI fund covers strategic programs and initiatives within R&D, policy research and education & training across the maritime, port, shipping and O&M sectors. Funding for technology R&D and policy research will be provided through competitive thematic grant calls. The program/ initiative consortia will normally be headed by a Singaporean university or A*STAR institute. The R&D activities much be conducted in Singapore and the principal investigators should also be based in Singapore.

One such program is the ongoing Maritime Research between Norway and Singapore (MNS)[8.9], described later.

Other important stakeholders in the public R&D ecosystem in Singapore include the National Research Foundation, A*STAR and the Economic Development Board.

- **National Research Foundation (NRF)** sets the national direction for research and development (R&D) by developing policies, plans and strategies for research, innovation and enterprise. It also funds strategic initiatives and builds up R&D capabilities for eligible institutions. Marine & Offshore (M&O)[8.10] is one of 5 strategic research programmes and the Offshore Technology Research Programme by MPA; Maritime Research Programme by Institute of High Performance Computing (IHPC); and Infocomm@Seaport Programme[8.11] by MPA and Infocomm Development Authority (IDA).

- **Singapore Economic Development Board (EDB)**[8.12] is the lead government agency for supporting company establishment and growth in Singapore. EDB facilitates foreign investment in the manufacturing and services sectors through grants, tax reduction schemes and advisory services. From and R&D support perspective, the EDB offers Research Incentive Scheme for Companies (RISC) to encourage the development of research and development capabilities and technologies through the support of projects in the areas of science and technology.

- **Agency for Science, Technology and Research (A*STAR)** the lead public agency that drives mission-oriented research to advance scientific discovery and technological innovation in Singapore. In addition to fund research projects at universities, research institutions and companies, A*STAR operates 18 own research institutes and consortia with a staff of 4,400 researchers and engineers.

8.8 https://www.maritimeinstitute.sg/SMI-Fund

8.9 https://www.maritimeinstitute.sg/Programmes-Initiatives#tabs3

8.10 https://www.nrf.gov.sg/programmes/strategic-research-programmes


8.11 https://www.imda.gov.sg/industry-development/sectors/infocomm/logistics/infocomm-at-seaport

8.12 www.edb.gov.sg

8.1

Norway – Singapore Maritime Research Collaboration

Building on century long commercial and decades long academic relations between Norway and Singapore, Singapores Maritime and Port Authority (MPA)and the Research Institute of Norway (RCN) entered in 2000 into a formal research cooperation agreement in areas such as maritime environment, sustainable energy technology, offshore and marine engineering, and maritime operations and infocommunications technology. The 3-year-duration Memorandum of Understanding (MoU) has since been renewed 5 times, the last in April 2015.

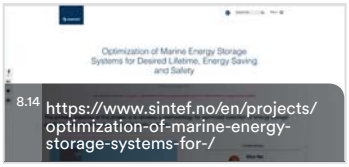
Former president of Research Council of Norway, Arvid Hallen and CEO of MPA, Andrew Tan renews the MoU in 2015. Source: Research Council of Norway.

A key component of the MoU is a joint call for bilateral funded projectss8.13. A total of NOK 15 million is available from RCN for Norwegian partners and up to SG$3 million is available from SMI for the Singaporean partners. The call invites project proposals within Maritime Arctic Research; Maritime Navigation Safety; Ship Operations & Safety; Ship-Port Operations and Green Shipping.

At the first call in March 2016, the following three project application were successful:

- "Optimization of Marine Energy Storage Systems for Desired Lifetime, Energy Saving and Safety", by Sintef Energy Research, Rolls-Royce Marine and Nanyang Technological University[8.14].
- "Real Energy Efficiency in the Seaway (REEalSea)", by Nanyang Technological University (NTU) and Center for Applied Research (SNF), Norwegian School of Economics (NHH)[8.15]
- "Design Considerations and Performance Evaluation of Energy Saving Devices for Deep Sea Vessels toward Green Shipping", by A*STAR Institute of High Performance Computing, SINTEF Ocean, Odfjell Tankers, MAN Diesel & Turbo and Sembcorp Marine.

8.13 https://www.maritimeinstitute.sg/Programmes-Initiatives#tabs3



8.14 https://www.sintef.no/en/projects/optimization-of-marine-energy-storage-systems-for-/

8.15 http://www.transport-research.info/project/real-energy-efficiency-and-emissions-seaway

The partners are currently evaluating the results of the ongoing projects and will consider a next call in 2018. Research collaboration areas of high common interest include eNavigation; next generation vessel traffic management system and autonomous vessels and drones.

The MoU also includes a Joint Fora in Maritime Thought Leadership, including the International Maritime-Port Technology Conference This conference is held alternately in Singapore & Norway, last in April 2017 in Singapore, and next planned in Trondheim, Norway 2019.

The research cooperation between MPA and RCN has so far spun off 20 research and development projects, 4 education initiatives and one training program involving Norwegian stakeholders since 2000.

The **SESAME Straits project** (Secure, Efficient, and Safe maritime traffic Management in the Straits of Malacca and Singapore) aims to utilize the IMO e-Navigation concept in order to reduce the problem of traffic hot-spots. SESAME Straits will make it possible to predict possible vessel traffic hot-spots in congested waterways and offers new strategies to avoid such congestions. This will improve the safety of vessel traffic and enable "Just-in-time" arrival of vessels, improving the efficiency of existing infrastructure, and reducing the environmental footprint. The partner consortium is led by Kongsberg Norcontrol IT and includes Kongsberg Seatex (KSX), Kongsberg Maritime (KM), Sintef Ocean, Navtor, the University College of Southeast Norway. The project is partly funded by the Norwegian Research Council and supported by the Norwegian Coastal Administration, MPA and Singaporean company SimPlus.

Other R&D projects include:

- "C-Sharper: Multi Radar Services from a Single Radar Sensor System" by Kongsberg Norcontrol IT and Kelvin Hughes.
- "Sea Trials and Model Tests for Validation of Shiphandling Simulation Models (SimVal)" by Sintef Ocean, NTNU and Singapore Maritime Academy
- "Development of a Ship Traffic Simulator as a Decision Support Tool" by Kongsberg Norcontrol IT and Simplus

One ongoing marine research and technology development project not under the MPA/RCN umbrella is the Multi-Purpose Floating Structures project MPFS[8.19] between NUS, the Singapore company JTC and the two Sintef institutes SINTEF Ocean and SINTEF Building and Infrastructure. The objective of the project is to develop innovative and optimal structural and foundation solutions as well as construction methods for multi-purpose very large floating structures (VLFS). The R&D activities will be related to two specific applications (case-based approach): Hydrocarbon storage and floating bridges. The SG$ 6.5 million (NOK 40 million) project is fully funded by Singapore's National Research Foundation and JTC.


8.16 www.smtcsingapore.com/mtec

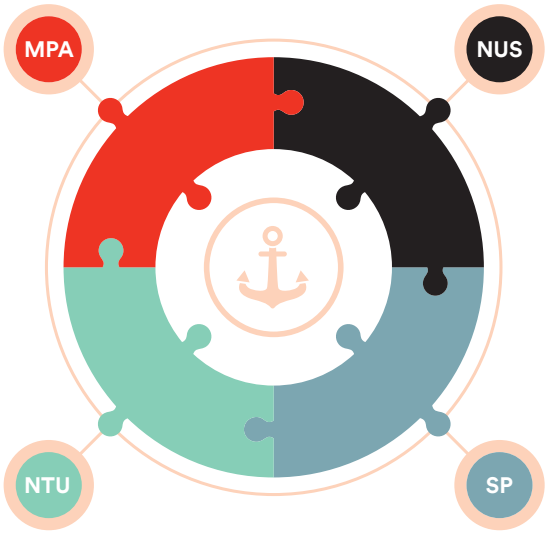

8.17 straits-stms.com/


8.18 www.kongsberg.com/en/kds/kncit/

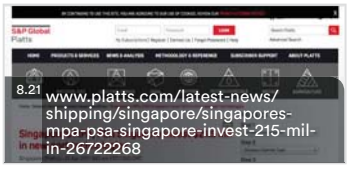

8.19 https://www.sintef.no/en/latest-news/norway-to-help-singapore-with-floating-urban-devel/

8.2

Singaporean Maritime R&D Stakeholders




8.20 www.mpa.gov.sg/web/portal/home/media-centre/news-releases/detail/b8947c16-bd25-4499-a115-4ca1f8333f82


8.21 www.platts.com/latest-news/shipping/singapore/singapores-mpa-psa-singapore-invest-215-mil-in-26722268

Maritime and Port Authority

MPA launched their Living Lab in March 2017 to help technology providers and industry partners for development and piloting of innovations.

The MPA Living Lab[8.20] will focus on developing capabilities in the following areas:

- **Data analytics & intelligent systems.** A maritime data hub will be set up for industry and technology partners to co-develop innovative applications, such as just-in-time vessel arrivals or predictive analytics to forecast traffic conditions and potential collision for the next-generation vessel traffic management system.
- **Autonomous systems & robotics.** MPA will work with industry partners to provide framework conditions for the development and testing of autonomous vessels, drones and other autonomous systems. Sea spaces and regulatory guidelines will be provided for such testing activities.
- **Smart & innovative infrastructure.** MPA will optimize land and sea space by taking advantage of innovative engineering and technologies. For instance, the use of multi-purpose floating platforms for ship mooring and berthing, and timely supply of marine services will be employed.
- **Safety & security.** MPA will make use of technologies such as smart sensors for detection of intrusions and monitoring of marine incidents.

Furthermore, MPA will be partnering with Singapore Maritime Institute to set up three maritime research Centres of Excellence (CoEs) within local Institutes of Higher Learning (IHLs) over the next five years. The first centre focusing on maritime environment & energy will be launched by MPA and Nanyang Technological University by the second quarter of 2017.

The MPA and PSA Singapore announced in April 2017 they will under the Port Technology Research and Development Programme invest a combined S$30 million ($21.5 million) to boost research and test-bedding of new technologies for Singapore's future Tuas Terminal as well as **automation and robotics in the maritime sector**[8.21].

The National University of Singapore (NUS)

The leading university in Singapore has 5 centres related to maritime activities:

- The Centre for Maritime Studies (CMS)[8.22] is specializing in maritime affairs: Maritime Policy & Management and Maritime Operations & Modelling Cluster. The latter research cluster is presumably most relevant in this context of maritime technologies: covering topics like Shipping and Logistic Transportation; Port Operations Modelling & Analysis; Maritime Infrastructure Systems & Management; Marine Cluster Planning & Operations Management; Maritime Information Technology; Maritime Communications; Maritime Vessel and Navigation Simulation; Maritime Environment Management. The centre is headed by Director Prof. Bernard Tan.

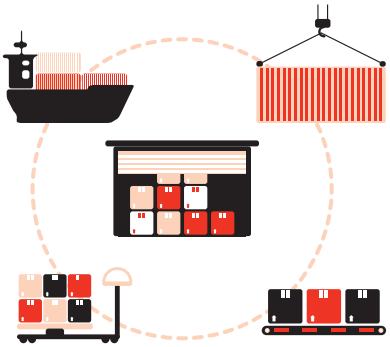
- Centre for Offshore Research and Engineering (CORE)[8.23] was established in October 2003 to be a leading centre in research & development, and education & manpower training for the advancement of the offshore and marine industry. CORE is performing research and development; runs education and manpower training and actively promote R&D collaboration with industry, A*STAR research institutes and tertiary institutions within the maritime sector. CORE is closely engaged with TCOMS and Keppel-NUS Corporate Lab. The centre is headed by Executive Director Prof. Yean Khow (YK) Chow.

- Tropical Marine Sciences Institute[8.24] is engaged in Physical Oceanography, Acoustics, Marine Biology, Marine Mammals, Biofuels, Water Resources and Climate Change and discussed in Chapter 7 on Aquaculture Technologies. The centre is headed by Prof. Sek Man Wong.

- Centre for Maritime Law (CML)[8.25] is focusing on research in commercial maritime law, broadly on international trade, transport and shipping law related issues. Not very relevant for maritime technology, the CML is establishing relations with the Arctic University of Norway (former Tromsø University), which also incudes topics like shipping, ocean technologies and energy. Director is Prof. Stephen D Girvin.

- Maritime Institute at National University of Singapore[8.26] is collaboration between between NUS and SMI to coordinate the maritime and offshore education, training and R&D activities within NUS.

As an subjective observation, it appears that as compared to the more technology-focused Maritime Institutes at Nanyang Technological University (below), the maritime centres at NUS has more focus on policy, management, education and maritime operations.



8.22 www.maritimestudies.nus.edu.sg

8.23 www.eng.nus.edu.sg/core


8.24 www.tmsi.nus.edu.sg

8.25 law.nus.edu.sg/about_us/news/2015/CMLLaunch.html


8.26 maritimeinstitute.nus.edu.sg/directorsmessage.html

Nanyang Technological University (NTU)

The Maritime Institute at Nanyang Technological University[8.27] is one of the four Maritime Institutes at Institution of Higher Learning under the umbrella of Singapore Maritime Institute. The institute aims to establish a broad-based maritime education and research platform at NTU. The centre's R&D programmes include: Naval Architecture and Marine Engineering; Maritime Clean Energy; Maritime Technology and Environment; Maritime Logistics and Operations; Maritime Policy and Security and Maritime Business and Economics. Acting Executive Director is Prof. Lua Aik Chong.

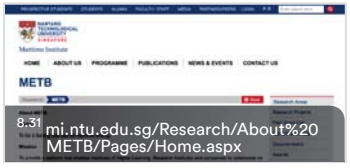
- The Maritime Studies program[8.28] at NTU stated in 2004 and is conducted jointly by the School of Civil and Environmental Engineering and the BI Norwegian Business School and leads to the award of the Maritime Studies BSc degrees by NTU[8.29]. In addition to internship to the maritime industry as well as field visits , the programme focuses primarily on tertiary education in shipping, business, management, and maritime science and technology.
- The Energy Research Institute @ NTU (ERI@N) was established in 2010 to spearhead the university's effort in the area of sustainable energy research. ERI@N consists of seven major groups, including Solar Energy & Solar Fuels, Energy Storage, Sustainable Building Technologies, Wind & Marine Renewables, Electromobility, Fuel Cells and Maritime Energy. The maritime energy efforts at ERI@N are championed by the Maritime Clean Energy (MCE) group.
- The first highlight of the MCE efforts was the launch of the Maritime Clean Energy Research Programme (MCERP), jointly by the Maritime and Port Authority of Singapore and NTU in 2010. MCERP aims to leverage on the diverse energy platform of ERI@N to promote green, carbon neutral and energy management solutions for the port and shipping. Since the first MCERP grant call in 2010, the programme has awarded a total of 22 R&D projects, with participation of 29 industry partners from the diverse value chain of maritime industry. Examples of the key awarded projects are land-based energy management system, highly efficient waste heat driven plant on board, desulphurisation process for ship exhaust, etc. MCE group continued to champion the maritime energy research at ERI@N with the setup of SMI in 2011. From 2013 onwards, 7 projects initiated and/or supported by the MCE group were awarded, of which three projects were selected as the top projects under the SMI Research Showcase.
- The second highlight of the MCE efforts was the establishment of the Maritime Energy Test Bed (METB). METB[8.30 31] was set up in November 2015 to support RD&D activities for Singapore Maritime industry over the next ten years. METB consists of a marine engine (1.5 MW), a resistive load (1.5 MWe) and facility for testing of exhaust gas cleaning system. The test bed is suitable for RD&D projects relating to energy and emissions, which include alternative fuels, fuel additives, exhaust gas cleaning & emissions monitoring, waste heat recovery and energy storage. SMI provided the S$ 4.7 million grant for the set-up of the METB.

8.27 mi.ntu.edu.sg/Pages/Home.aspx

8.28 www.cee.ntu.edu.sg/Programmes/undergraduate/MS/Pages/Home.aspx

8.29 www.cee.ntu.edu.sg/Programmes/undergraduate/MS/Pages/Curriculum/AY1617_MSB_ITP.aspx

8.30 erian.ntu.edu.sg/Research/Facilities/MCE/Pages/Maritime-Energy-Test-Bed.aspx



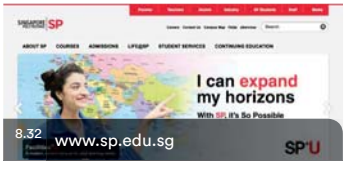
8.31 mi.ntu.edu.sg/Research/About%20METB/Pages/Home.aspx

SMA
Singapore Maritime Academy
SINGAPORE POLYTECHNIC

Singapore Polytechnic (SP)[8.32]

Singapore Polytechnic (SP) has been one of the leading institutions on maritime education and training since 1957. Their Singapore Maritime Academy (SMA) is at the forefront in the areas of navigation, marine engineering and maritime transportation management with about 900 full-time students and 60 teaching staff.

One of the existing flagship facilities in SMA is the Integrated Simulation Centre (ISC). The equipment is provided by Norwegian Kongsberg and includes a 360-degree field-of-view Full Mission ship-handling Simulator (FMSS) and a 240 degree field-of-view Tug Simulator.



8.3

Corporate Maritime Laboratories

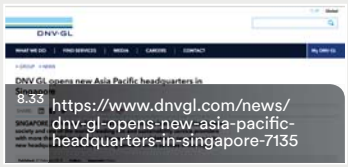
DNV GL's Deepwater Technology Centre (DTC), Clean Technology Centre (CTC) and ECO Research Centre[8.33]

The Norwegian class and advisory company DNV GL runs Deepwater Technology Centres (DTC) in Oslo, Houston, Rio de Janeiro and in Singapore. The Singapore centre, established in 2012, has more than tripled its staff strength and delivered several key innovative projects covering the entire value chain from sea surface to the reservoir.

In addition, the Clean Technology Center (CTC) in Singapore has a broader spectrum of activities covering the whole cleantech sector, renewable energy, smart grid and energy storage. Singapore was chosen as the ideal place for the state-of-the-art clean technology centre due to its geological location that was easily connected to the rest of Southeast Asia and a safe, stable political climate. The FutureShip ECO Research Centre was set up in 2013 to conduct research to strengthen FutureShip's energy efficiency solutions for its Asian clients.

"DNV GL's deep-water technology centre together with our newly enhanced lab facilities opened early 2014 is a great example for the common ambition of Singapore and DNV GL to create an environment where innovation and technology are exchanged and a proof of DNV GL's strong commitment to a sustainable development in Singapore"

Brice Le Gallo
Managing Director
DNV GLs deep-water technology centre in Singapore.



8.33 https://www.dnvgl.com/news/dnv-gl-opens-new-asia-pacific-headquarters-in-singapore-7135

Keppel Offshore & Marine Technology Centre (KOMtech)[8.34]

Established in December 2007KOMtech is responsible for research and development, product development as well as process technology aimed at improving productivity in Keppel O&M yards. The centre activities include:

- Offshore Technology Development - technology and techniques in the design of new generation jack-up rigs and critical systems.
- Deepwater Technology Group - design and engineering solutions spanning semisubmersibles and various floating structures such as drilling tenders, accommodation semisubmersibles and drill ships. The joint venture with J.Ray McDermott, FloaTEC LLC, specialises in floating production systems.
- Marine Technology development - design and development of offshore support and maintenance vessels for a variety of operating conditions.

Being the R&D arm of the Keppel Offshore & Marine, KOMtech is driven by the commercial viability to meet the industry needs. In the aspect of green shipping, KOMtech has R&D focus in LNG, renewable energy system, efficient deep water and shallow water structure design.

In November 2013, Keppel Corporation, National University of Singapore set up the SG$75 million Keppel-NUS Corporate Lab[8.35] to develop innovative solutions for offshore industry:

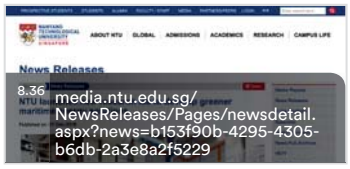
- **Future Systems** with focus on
  - a Deepwater Technology, and
  - b Arctic Technology which aim to develop innovative systems for deep & ultra-deep water, and the Arctic for oil & gas exploration and production.
- **Future Yards** with focus on Productivity Enhancement of Yard Operations.
- **Future Resources** with focus on the theme of Deepsea Seabed Nodule Harvesting.

Sembcorp Marine

Sembcorp Marine Lab at Nanyang Technological University[8.36] was opened in December 2016 with a fund of SG$10 million from Sembcorp Marine and support from EDB. The lab is focusing on ship retrofitting and modification for maritime dual-fuel. The lab is equipped with the region's first dual-fuel marine engine, burning diesel and liquefied natural gas (LNG). The lab will also serve as a testbed, and work with various industry partners and government agencies such as the MPA on maritime-related research projects.

8.34 www.keppelom.com/en/content.aspx?sid=3609

8.35 www.eng.nus.edu.sg/core/



8.36 media.ntu.edu.sg/NewsReleases/Pages/newsdetail.aspx?news=b153f90b-4295-4305-b6db-2a3e8a2f5229

Appendix

Maritime and O&M equipment and engineering companies

Aibel Pte Ltd	Engineering, EPC	www.aibel.com
Asia Offshore Group Pte Ltd	Supply to O&G	www.asia-offshore.sg
Deep Sea Supply	Supply ships.	www.deepseasupply.com
DOF Management PTE LTD	Subsea services, ROV, diving	www.dofsubsea.com
Dualog Singapore Pte Ltd	Digital communication platform on ships	www.dualog.com
Eltorque Asia Pacific Pte Ltd	Valve control	www.eltorque.no
Endeco Marine Engineering Pte Ltd	Maritime engineering	
Fire Fighting Systems (Far East) Pte Ltd	Fire protection systems	www.fifisystems.com
FMC Technologies - Technip FMC	Ship equipment	www.technip.com
Frank Mohn Singapore Pte Ltd	Pumps	www.framo.com
Glamox Far East Pte Ltd	Lighting solutions	www.glamox.com
Goltens Trading and Engineering Pte Ltd	Engineering, diesel	www.goltens.com
Havyard Far East	Yard. Fishing ships, engines	www.havyard.no
IMS & TeamTec Pte. Ltd	Incinerators, ship equipment	www.imsgroup.no
IOT SINGAPORE PTE LTD	Oil equipment	www.iotgroup.com
iSURVEY Pte Ltd	Oilfield surveillance	www.isurvey-group.com
Jotron Asia Pte Ltd	Communication systems	www.jotron.com
Jotun Singapore Pte Ltd	Maritime paint	www.jotun.com
Karmsund Maritime Singapore Pte Ltd	Maritime equipment	www.karmsund.no
Kongsberg Maritime Pte Ltd	Maritime equipment	www.km.kongsberg.com
Kongsberg Norcontrol IT Pte Ltd	Maritime equipment	www.km.kongsberg.com
Marinetrans Singapore Pte Ltd	Marine spare parts	www3.marinetrans.com
Maritime Partner Asia Pte Ltd	Ship equipment	www.maritime-partner.com
Marlink Pte. Ltd.	Satelite communication	www.marlink.com
MHWirth (Singapore)	Drilling equipment	www.mhwirth.com
Miros Pte Ltd	Monitoring and sensing	www.miros.no
Modex Energy Rentals Singapore Pte. Ltd	Offshore containters	www.modexenergy.com
Navico Marine Singapore Pte Ltd	Marine electronics	www.navico.com
Navtor Singapore	Electronic maps	www.navtor.com
Norsafe Singapore	Shipbuilding, rescue boats	www.norsafe.com
OHT Management AS	Offshore heavy transport	www.oht.no
Optimarin Singapore PTE Ltd	Ballast water treatment	www.optimarin.com
PGS (Singapore)	Geophysical survey	www.pgs.comw
Rustibus Pte Ltd	Corrosion removal	www.rustibus.com
Scana Singapore Pte Ltd	Marine equipment	www.scana.no
Seadrill Deepwater Units Pte Ltd	Drilling, ship management	www.seadrill.com
Sinor Marine Technologies Pte Ltd	Vessel control systems	www.marine-technologies.com
SIS Marine Pte Ltd	Maritime software solutions and services	www.sismarine.com

Songa Offshore Pte. Ltd	Oil & gas equipment	www.songaoffshore.com
Sperre Asia	for ships	www.sperre.com
TESS Singapore	Maritime equipment, hoses	www.tess.no
TTS Singapore Pte Ltd	Marine equipment, aftersales	www.tts-marine.com
Ulstein Asia Pte Ltd	Shipbuilding, equipment	www.ulstein.com
Vard Singapore Pte Ltd	Ship building, repairs	www.vard.com
Viking Engineering Pte Ltd	Maritime equipment	www.viking.com.sg
Viking Inert Gas Pte Ltd	Oil and gas equipment	www.viking.com.sg
Wartsila Moss AS	Maritime equipment	www.wartsila.com
Zenitel Marine Asia Pte Ltd	Communication, safety, maritime	www.zenitel.com

Shipping, brokering and ship owners

BW Offshore Singapore Pte Ltd	Shipping, ship mgmt, oil & gas	www.bwoffshore.com
Dolphin Drilling Pte. Ltd	Drillship	www.dolphindrilling.no
Farstad Shipping Pte Ltd	Supply ships.	www.solstadfarstad.com
Gearbulk Shipping Singapore Pte Ltd	Bulk carriers	www.gearbulk.com
Gram Car Carriers	Car carriers	www.gramcar.com
Grieg Star Shipping	Shipping	www.griegstar.com
Hoegh LNG Asia Pte Ltd	LNG Trading	www.hoeghlng.com
JK Offshore Pte Ltd	Shipping	
KGJ Cement (Singapore) Pte Ltd	Cement carriers	www.kgjcement.com
Klaveness Asia Pte Ltd	Shipping	www.klaveness.com
Masterbulk Pte Ltd	Ship owner	www.masterbulk.com.sg
Norgas Carriers Pte. Ltd. (I.M. Skaugen)	LNG and gas carrier	www.norgascarriers.com
Nor-Ocean Offshore Pte. Ltd	Shipbroking and consultancy	www.nor-ocean.no
Nortrans Shipping Agencies Pte Ltd	Ship agency	www.nortrans.com
Norwegian Oil Trading	Bunker trading	www.norwegianoiltrading.no
Odfjell Asia II Pte Ltd	Shipping, bulk operator	
Oslo Bulk Holding Pte Ltd	Shipping	www.oslobulk.com

Primepoint Holdings Pte Ltd	Drilling contractor	www.primepoint.sg
Skadi Maritime Pte Ltd	Ship brokering	www.skadimaritime.com
Solstad Offshore Asia Pacific Pte Ltd	Supply vessels	www.solstad.com
Steem1960	Shipsbroker	www.steem1960.com
Stolt Nielsen Singapore Pte Ltd	Bulk carriers	www.stolt-nielsen.com
Thome Group	Shipping	www.thome.com.sg
Thome Oil & Gas Pte. Ltd	Oil and gas, shipping	www.thome.com.sg
Western Bulk Pte Ltd	Bulk carriers	www.westernbulk.com
Westfal-Larsen Shipping Pte. Ltd	Shipping	www.wlco.no

Ship management

AJM Ship Pte Ltd	Management services - ships	
DOF Management PTE LTD	Subsea services, ROV, diving	www.dofsubsea.com
Eastern Bulk Shipmanagement Pte. Ltd	Shipping, bulk operator	www.easternbulk.com
Hoegh Autoliners Management AS	Ship management	www.hoeghautoliners.com
Leth Agencies Singapore Pte LTD	Ship services	www.lethagencies.com
Mintra Group Singapore	Staffing	www.mintragroup.com
Nordic Maritime Pte Ltd	Shipping services	www.nordic.com.sg
Odfjell Singapore Pte Ltd	Ship management	www.odfjell.com
OSM Ship Management Pte Ltd	Ship management	www.osm.no
Sevan Management Services Pte Ltd	Rig/tank	www.sevanmarine.com
Skaugen OSM Ship Management Pte. Ltd	Ship management, gas	www.skaugen.com
Songa Shipping Pte Ltd	Ship management	
Thome Ship Management Pte Ltd	Ship management	www.thome.com.sg
Wallem Shipping (S) Pte Ltd	Hong Kong based. Ship management	www.wallem.com
Wilhelmsen Ships Services Pte Ltd	Ship services	www.wilhelmsen.com

Finance, insurance, advisory etc

Accensus Pte Ltd	Management consulting	www.ascensus.com
Beri Maritime AS	Ship brokering	www.bery.no
Clarksons Platou Asia Pte Ltd	Shipping services, brokering	www.clarksons.com
Cleaves Asia Pte Ltd	Ship brokering	www.cleaves.no
Continental Maritime Pte. Ltd	Ship brokering	www.continental-maritime.com
DNB Asia Ltd	Bankingww	www.dnb.no
DNV GL Singapore Pte Ltd	Class, advisory	www.dnvgl.com
Dovre Group	Project management	www.dovregroup.com
Edge Insurance Brokers (Singapore) Pte Ltd	Insurance	www.northedge.no
Fearnleys Asia (Singapore) Pte Ltd	Ship brokering	www.fearnleys.com
Frontline Shipping Singapore Pte Ltd	Ship brokering	www.frontline.bm
G Travel	Travel - maritime	
Gard (Singapore) Pte Ltd	Insurance	www.gard.no
Lorentzen & Stemoco	Ship brokering	www.lorstem.com
Marine Solutions Pte Ltd	Oil and gas advisory	www.marinesols.com
MDE Consultants Pte Ltd	Recruiting	www.mde-group.com
Metizoft Asia Pte Ltd	Consulting, software, hazardous material	www.metizoft.com
Mint Maritime	Financing	www.mint-maritime.com
Nordea Bank AB Singapore Branch	Banking	www.nordeaprivatebanking.com
Nordisk Legal Services Pte Ltd	Legal services	www.nordisk.no
NorthCape Pte. Ltd.	Financing, advisory	www.northcapecapital.com
Omega PS Singapore Pte Ltd	Personell and project mgmt	www.omega.no
Reid Engineering Pte Ltd	Project management/engineering	www.reid-eng.com
Rommen Pte Ltd	Legal services	www.rommen.com
Seagull Maritime Information Technology Pte Ltd	Training and competence building	www.seagull.no
Simonsen Vogt Wiig Services Pte Ltd	Legal services	www.svw.no
Skaugen Marine Investments Pte. Ltd	Maritime investment	www.skaugen.com
Skuld (Gjensidig) Singapore Branch	Insurance	www.skuld.com
Statoil Asia Pacific Pte Ltd	Oil and gas trader, deverloper, energy company	www.statoil.com
TradeWinds	Newspaper, shipping	www.tradewindsnews.com
Viking Innovations Pte Ltd	Oil and Gas advisory	www.vikinginnovations.com
Wikborg Rein Singapore Pte Ltd	Legal services	www.wr.no

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