WHEN TRUST MATTERS

INSIGHTS INTO SEAFARER TRAINING AND SKILLS NEEDED TO SUPPORT A DECARBONIZED SHIPPING INDUSTRY

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Content

1 Objective and background 4
2 Executive summary 6
2.1 Key findings 7
2.2 General conclusions 8
3 Abbreviations 9
4 Key terms 10
5 Introduction 11
6 Need for additional seafarer training to support shipping's decarbonization 12
7 Quantitative analysis 13
7.1 Findings derived from 'IMO 2018 Scenario' 14
7.2 Findings derived from 'Decarbonization by 2050 Scenario' 16
7.3 Findings derived from 'Zero Carbon by 2050 Scenario 17
7.4 Expected number of seafarers working on ships equipped with alternative fuel technologies and gas engines 18
7.5 Summary – number of seafarers working on ships equipped with alternative fuel technologies 20
8 Skills and competencies for future seafarers 22
8.1 Skills and competencies enabling the implementation of new technologies 22
8.2 Seafarer skills and competencies for the decarbonization of shipping 24
8.2.1 Decarbonization skills known in some parts of industry 24
8.2.2 Meeting decarbonization goals coupled with fastmoving technological developments, including increased automation, requires careful monitoring and reflects a general trend towards a 'higher-skilled' seafarer 24
9 Safety challenges following the uptake of alternative fuel technologies 26
9.1 Hydrogen 27
9.2 Ammonia 27
9.3 Methanol 28
9.4 Alternative fuel technologies' effect on training needs 28
10 Challenges in providing seafarer training for the transition 29
10.1 Training constraints 29
10.1.1 Slow regulatory development makes investment in seafarer training challenging 29
10.1.2 A need to invest in training facilities and up to date equipment 30
10.1.3 The availability of competent trainers 31
10.1.4 Shortage of experienced seafarers 31
10.2 Future training models 31
10.2.1 Basic seafarer education and education systems 31
10.2.2 Fuel and equipment specific specialised training module courses 32
11 Inability to attract and retain seafarers pose a significant challenge to the maritime industry`s transition 33
12 References 34
13 Appendices 36
13.1 Appendix 1: DNV GHG Pathway Model 36
13.1.1 Converter options, maturity and combability 38
13.1.2 Energy-efficiency measures 38
13.1.3 Speed reduction 39
13.1.4 Logistics 39
13.1.5 Regulations 40
13.1.6 Fuel prices 40
13.1.7 Seaborne trade demand 42
13.2 Appendix 2: Lloyd's Register and UMAS Pathway Model 43
13.3 Appendix 3: Method to estimate number of seafarers 46
13.4 Appendix: 4 Individual views exp-ressed by a range of stakeholders, including seafarers and shipowners 47

1 Objective and background

This initial study was commissioned by the Maritime Just Transition Task Force Secretariat to explore how best to support the maritime workforce in making the shift to a decarbonized shipping industry.

The objective of this study has been to offer an initial assessment of the impacts decarbonization of the international shipping industry will have on crewmembers. It should be noted that this study is not intended to serve as an exhaustive overview, but rather as a means to provide an initial indication of and insight into the training seafarers will need to support the decarbonization of shipping.

The scope of this study is two-fold.

1. Quantitative:

- To estimate the number of seafarers that will need additional training in connection with the introduction of alternative fuels. In this study, the alternative fuels include: Dual Fuel Methanol ICE, Dual Fuel Ammonia ICE, Dual Fuel Liquid Hydrogen ICE, Hydrogen Fuel Cell, Ammonia Fuel Cell, Battery.

2. Qualitative:

- To present an overview of the skills needed for the decarbonization of shipping.
- To present an overview of the challenges that training seafarers for the transition will entail.

Collaboration and engagement between stakeholders involved in the Maritime Just Transition Task Force and its Global Industry Peer Learning Group contributed to the development of this study. This included interviews and dedicated workshops in the context of maritime just transition. Some of the views expressed by different stakeholder groups during these engagements are reflected in Appendix 5 of this study.

This qualitative component was supported by a literature review. Please see the 'References' section of the study for further details.

DNV's GHG Pathway model and a Lloyd's Register and University Maritime Advisory Services model were used to model three different decarbonization scenarios, as well as to assess the effect on the number of seafarers in need of additional training to support shipping's decarbonization. Further explanation about the models and the associated scenarios can be found in section 7 of this study and in the appendices.

It is expected that alternative fuel technologies will prompt new training requirements for seafarers.

Three shipping decarbonization scenarios were part of the scope:

1. At least 50% GHG reduction by 2050 (International Maritime Organization, 2018) – hereinafter referred to as the 'IMO 2018 scenario'
2. Decarbonization by 2050 (DNV Maritime Forecast, 2021) – hereinafter referred to as the 'Decarbonization by 2050 scenario'
3. Zero Carbon by 2050 (Lloyd's Register and University Maritime Advisory Services (UMAS), 2019) – hereinafter referred to as the 'Zero Carbon by 2050 scenario'

Disclaimer

It should be noted that the information and views contained in this report do not necessarily represent the views or opinions of the Maritime Just Transition Task Force or those of the Global Industry Peer Learning Group. The report has been made available for informational and educational purposes only. The Maritime Just Transition Task Force has prepared a separate position paper – Mapping a Maritime Just Transition for Seafarers – which presents a 10-point action plan informed by the findings in this report.

The objective of this study has been to offer an initial assessment of the impacts decarbonization of the international shipping industry will have on crewmembers.

2 Executive summary

2.1 Key Findings

Key finding 1: All three potential decarbonization scenarios point towards an immediate need to train seafarers. However, the timing and type of training provided will depend on the ambition of decarbonization trajectories and the future fuel mix.

Key finding 1a: In the 'IMO 2018 scenario' modelled by DNV, the number of seafarers working on ships with alternative fuels and technologies would peak at 310,000 in 2050.

Key finding 1b: In the 'Decarbonization by 2050 scenario', modelled by DNV, 750,000 seafarers would require additional training to handle alternative fuels and technologies by 2050.

Key finding 1c: In the 'Zero Carbon by 2050 scenario', modelled by Lloyds Register and University Maritime Advisory Services (UMAS), 450,000 seafarers would require some additional training by 2030, while 800,000 seafarers would require some additional training by the mid-2030s. This scenario assumes a sharp ramp-up of alternative fuels in the 2020s.

Key Finding 2: In the 'IMO 2018 scenario' and the 'Decarbonization by 2050 scenario', modelled by DNV, there is expected to be a significant rise in the number of seafarers needing training on alternative fuel technologies in the 2040s, between 310,000 and 750,000. In the 'Zero Carbon by 2050 scenario', the number of seafarers requiring some kind of additional training rises steeply from the 2020s until 2050.

Key finding 3: The number of seafarers expected to work on ships fuelled by LNG/LPG would increase by approximately 100,000 new seafarers every second year until 2038, in both the DNV modelled 'IMO 2018 scenario' and the 'Decarbonization by 2050 scenario'.

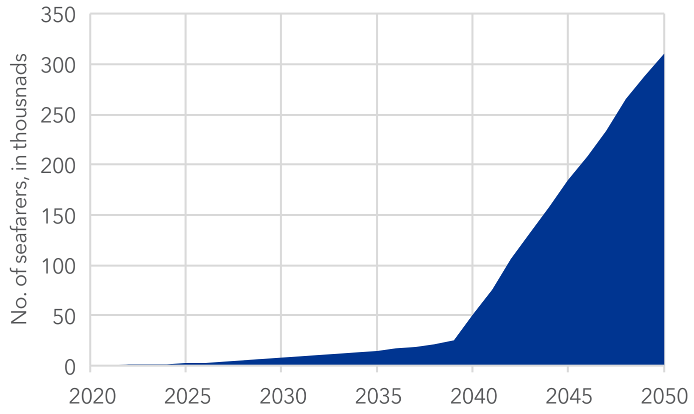
Key Finding 4: There are a number of safety challenges related to alternative fuels in shipping. These include pressurized storage, low flashpoint and toxicity. Hydrogen, for example, is substantially more flammable than diesel. Ammonia, a method of chemically storing hydrogen for propulsion, is toxic to humans and the marine environment. With the exception of hydrogen, which was until recently only transported in packaged form, most of the alternative fuels are currently carried as bulk marine cargo. The shipping industry is therefore both knowledgeable and experienced with regard to their handling. However, seafarers will need additional training concerning the particular risks associated with using these fuels for propulsion in order to ensure not only their safety but the safety of the environment and local communities.

Key Finding 5: Training seafarers to support shipping's decarbonization is already subject to several constraints. These include: slow pace of regulatory development and lack of clarity surrounding the viability and uptake of alternative fuel options and decarbonization trajectories, which makes investment in seafarer training challenging; a need to increase investment in training centres and up-to-date equipment; a lack of competent trainers; and a shortage of experienced seafarers.

CHAPTER 2 Insights into seafarer training and skills needed to support a decarbonized shipping industry

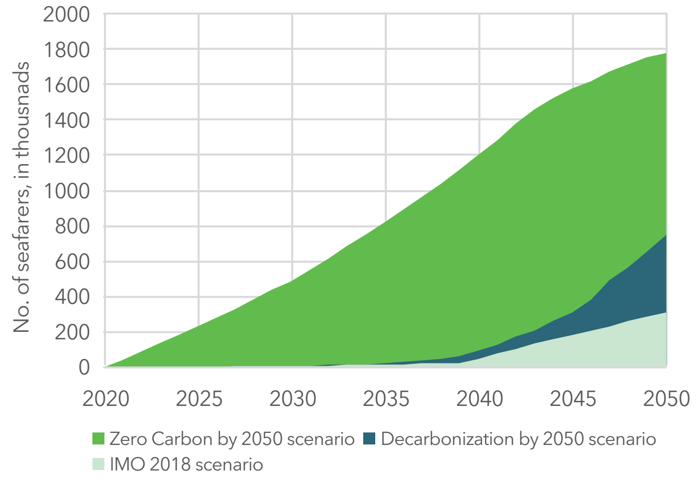
KEY FINDING 1A

Estimated number of seafarers working on ships using alternative fuel technologies in the DNV modelled 'IMO 2018 scenario'



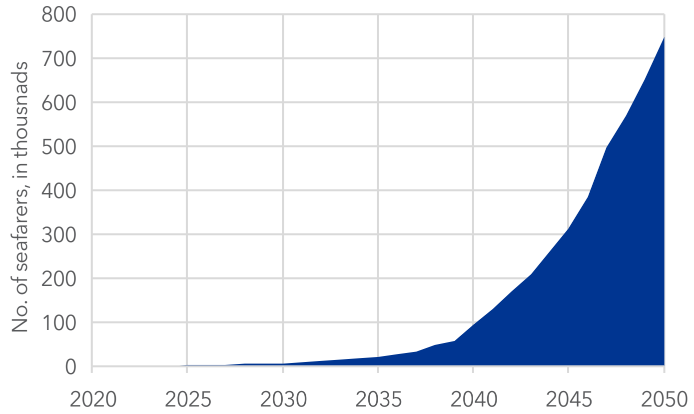
KEY FINDING 2

Estimated number of seafarers working on board ships equipped with alternative fuel technologies, all scenarios



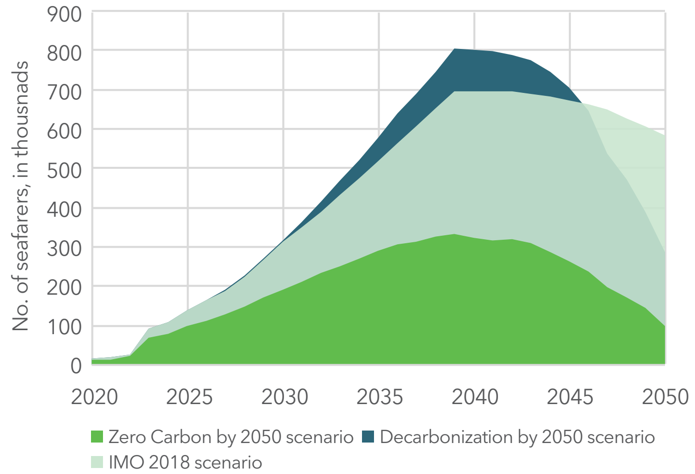
KEY FINDING 1B

Estimated number of seafarers working on ships using alternative fuel technology in the DNV modelled 'Decarbonization by 2050 scenario'



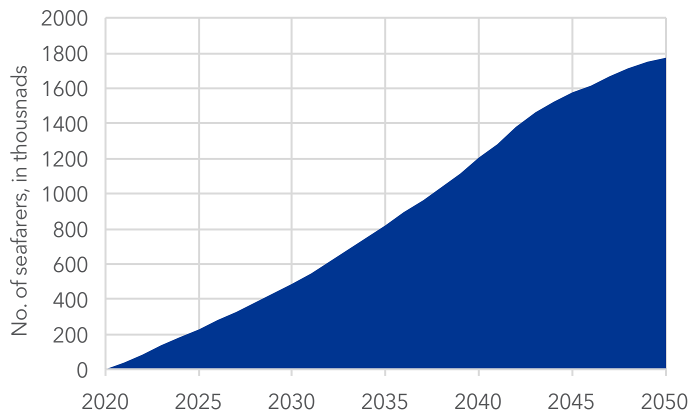
KEY FINDING 3

Estimated number of seafarers working on ships fuelled by LNG/LPG, all scenarios



KEY FINDING 1C

Estimated number of seafarers working on ships using alternative fuel technologies in the LR and UMAS modelled 'Zero Carbon by 2050 scenario'



KEY FINDING 5

Training seafarers to support shipping`s decarbonization is already subject to several constraints

1. Slow regulatory development makes investment in seafarer training challenging
2. A need to invest in training facilities and up to date equipment
3. The availability of competent trainers
4. Shortage of experienced seafarers

2.2 General conclusions

Conclusion 1: A lack of clarity surrounding the viability and uptake of alternative fuel technologies and decarbonization trajectories, coupled with uncertainty surrounding regulatory developments and financing, is making it difficult to plan for the further training of the maritime workforce and attract investment in skills programmes compatible with the industry's future needs.

Conclusion 2: Guidelines for alternative fuel technologies are already under development by the International Maritime Organization (IMO). Once developed, the model for IGF Code compliance, consisting of basic and advanced model courses at an approved training facility, plus minimum seagoing experience (including familiarization), could be adapted by the IMO for training on alternative fuel technologies. This would serve as a minimum training framework. Training requirements for seafarers with regard to LNG/LPG have already been set out in the STCW International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code).

Conclusion 3: Maritime schools and training centres would be able to use the IMO model courses once developed, forming part of the education for all seafarers. Specific training and familiarization onboard are seen as an important part of future training models to ensure seafarers are competent to make use of new technology and ensure a safe transition to alternative fuels and technologies. Such specific training for certain ships, fuels and technologies can be provided by the industry closer to the implementation of the new technology.

Conclusion 4: The skills required for safe operation of ships using alternative fuel technologies are known in parts of the maritime industry. However, meeting decarbonization goals, coupled with fast-moving technological developments, including increased automation, requires careful monitoring and reflects a general trend towards a 'higher-skilled' seafarer. Increased IT, digital, technical and organizational competence will be needed in future to meet the demands associated with decarbonization. Special attention should be paid to systems which can equip all relevant seafarers with new skills and help them transfer to new types of jobs created by new technologies. Bridge and engine officers may face higher skill requirements than ratings.

Conclusion 5: A holistic view, taking into consideration human, organizational and technical challenges, when adopting alternative fuels and technologies is important, alongside a strong safety culture and the provision of familiarization periods during the implementation of alternative fuels aboard ship.

Conclusion 6: Attracting and retaining seafarers is a problem in the maritime industry and poses a significant challenge to ensuring that there are sufficient competent seafarers to support shipping's green transition.

> A holistic view taking into consideration human, organizational and technical challenges when adopting alternative fuels and technologies is important.

3 Abbreviations

CCS	Carbon capture and storage
DNV MF	DNV Maritime Forecast
DF	Dual fuel
EEOI	Energy Efficiency Operational Indicator
GHG	Greenhouse gas
HFO	Heavy Fuel Oil
ICE	Internal combustion engine
ICS	International Chamber of Shipping
IoT	Internet of things
ITF	International Transport Worker's Federation
ISM	International Safety Management Code
LH_2	Liquid Hydrogen
IMO	International Maritime Organisation
MGO	Marine Gas Oil (monofuel)
PLC	Programmable logic controllers
STCW	Standards of training, certification and watchkeeping
STEM	Science, technology, engineering and math

4 Key terms

Alternative fuel technologies	An alternative fuel is one not commonly used in the shipping industry today, i.e., a fuel with low commercial availability of both fuel technology and bunkering facilities. Alternative fuel technologies in this study consist of the following: Dual Fuel Methanol ICE, Dual Fuel Ammonia ICE, Dual Fuel Liquid H_2 ICE, H_2 Fuel Cell, Ammonia Fuel Cell, Battery.
Gas engines	Internal combustion engines running on Liquefied Natural Gas (LNG) or Liquefied Petroleum Gas (LPG). If the term LNG/LPG is used in this study, it is used in gas engines.
Traditional fuel technologies	Internal combustion engines running on Heavy Fuel Oil (HFO) or Marine Gas Oil (MGO). Note that MF MGO ICE, which is a traditional technology, can run on both fossil MGO, bioMGO and eMGO.
Competence	In a maritime context, 'competence' is a demonstrable attribute including (but not limited to) a person's knowledge, ability to perform specific tasks, decision-making, analytical ability, problem-solving, etc. The IMO STCW Convention defines levels of competence and provides specific methods for demonstrating competence leading towards certification.
Skills	Specific learned abilities which enable a person to carry out the tasks and duties of a given job (International Labour Organization).
Transferable skills	Skills used in one job or career that can also be used in another (Cambridge Dictionary),
Training	The process of learning or enhancing the skills needed to do a particular job or activity (Cambridge Dictionary)
Upskilling	The process of learning new skills or of teaching workers new skills (Cambridge Dictionary).
Re-skilling	The process of learning new skills so you can do a different job, or of training people to do a different job (Cambridge Dictionary)

5 Introduction

Currently accounting for 3% of global greenhouse gas (GHG) emissions, the global shipping industry is facing major transformations in the decades to come. The industry will go through a period of rapid energy and technology transition, which is expected to have a significantly higher impact on costs, asset values and earning capacity than earlier transitions. The industry is already experiencing increased pressure to reduce its carbon footprint.[1]

For the shipping industry to reach absolute zero emissions, the implementation of alternative fuel technologies will have to be scaled up in the years to 2050. In this period, the shipping industry will have to transition from conventional fuels such as marine gas oil (MGO) and heavy fuel oil (HFO), to low-carbon and zero-carbon alternative fuel technologies (Hydrogen, Ammonia, Methanol, Batteries).

> For the shipping industry to reach absolute zero emissions, the implementation of alternative fuel technologies will have to be scaled up in the years to 2050.

The decarbonization of shipping is, however, not the only major transformation the industry is facing. Alongside decarbonization, it is expected that the digitalization of shipping and increased use of automated ship systems will also continue.

These changes will affect people working in the industry. The introduction of alternative fuel technologies is expected to have a significant impact on maritime operations on board ships and will require seafarers to develop and acquire new skills and competencies to ensure safe and efficient operations in the decades up to 2050 and beyond.

The Maritime Just Transition Task Force was established during COP 26 in November 2021 by the International Chamber of Shipping (ICS), the International Transport Workers' Federation (ITF), the United Nations Global Compact (UNGC), the International Labour Organization (ILO) and the International Maritime Organization (IMO). The Task Force was launched to ensure that no seafarer is left behind as the shipping industry transforms. Underpinned by stakeholder engagement and social dialogue, this initiative is intended to complement the guiding principles of just transition established in the International Labour Organization's Guidelines for a just transition towards environmentally sustainable economies and societies for all.

Social dialogue

Social dialogue is understood as "all types of negotiation, consultation and exchange of information between and among representatives of governments, employers and workers on issues of common interest relating to economic or social policy" (ILO, 2013, 39).

The key role of social dialogue in managing and delivering just transitions towards environmentally sustainable economies and societies is recognized in the International Labour Organization's Guidelines for a just transition towards environmentally sustainable economies and societies for all.

6 Need for additional seafarer training to support shipping's decarbonization

The transition from conventional fuels and technologies to alternative fuels and technologies will lead to a need for new and additional training for current and future seafarers. Three different decarbonization trajectories (scenarios) in the period to 2050 are presented in chapter 7 of this study. Each of these scenarios foresees a varying uptake of gas fuels (LNG/LPG) and low to zero carbon alternative fuel technologies.

The increased uptake of LNG/LPG and alternative fuel technologies expected towards 2050 will require the provision of additional training to seafarers currently working on conventionally fuelled vessels. The number of seafarers working on vessels fuelled by LNG/LPG or alternative fuel technologies, and thus requiring additional training, is presented in the quantitative analysis in chapter 7.

Depending on the scenario, Ship Operators will either:

- Invest in LNG/LPG, or
- Invest in alternative fuel technologies

Training requirements for seafarers with regard to LNG/LPG have already been set out in the STCW International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code). The training for IGF Code compliance consists of:

- Basic and advanced model courses at an approved training facility.
- Minimum seagoing experience (including onboard familiarization).

However, the implementation of alternative fuel technologies by Ship Operators will introduce new technological and operational modes, as well as new safety requirements over the coming years. In addition, decarbonization and the uptake of alternative fuel technologies are expected to bring fast-moving technological developments, including increased automation and digitalization. While the International Maritime Organization (IMO) is already developing alternative fuel guidelines which could form the basis of new training standards relevant to ships using certain fuels, approved training courses covering alternative fuel technologies are not readily available to the industry today.

Consequently, this study investigates which skills and competencies will be required by seafarers to support a decarbonized shipping industry. This includes an overview of the safety challenges that are expected during the transition period, as well as challenges expected with respect to providing seafarer training.

Chapter 10.2 of this report presents possible future training models for seafarers working on ships equipped with alternative fuel technologies.

7 Quantitative analysis

Three decarbonization scenarios were used in this study to provide insights into the number of seafarers who might require additional training and skills to support the decarbonization of the shipping industry:

1. At least 50% GHG reduction by 2050 (International Maritime Organization, 2018) – hereinafter referred to as the 'IMO 2018 scenario'.
2. Decarbonization by 2050 (DNV Maritime Forecast, 2021) – hereinafter referred to as the 'Decarbonization by 2050 scenario'.
3. Zero Carbon by 2050 (Lloyd's Register and University Maritime Advisory Services (UMAS), 2019) – hereinafter referred to as the 'Zero Carbon by 2050 scenario'.

The methodology and assumptions used in the decarbonization scenarios can be found in appendices 1 & 2 to this report.

The different fuels and technologies used in the analysis of this research are categorized as shown in Table 7.2, page 14.

TABLE 7.1

GHG scenario descriptions

Scenario	Key features
IMO 2018 scenario, modelled in 2021 DNV Maritime Forecast 2050[a]	• Reduce GHG emissions by at least 50% by 2050 compared with 2008 • Total emissions below 460 million tonnes of CO2 in 2050 • Energy Efficiency Operational Indicator (EEOI) (gCO2/Tnm) below 5 in 2050 • 'Tank-to-Wake' emissions model • CO_2 reduction trajectory from 2008 levels; 2030: 17%, 2040: 30% 2050: 67%
Decarbonization by 2050 scenario, modelled in 2021 DNV Maritime Forecast 2050	• 95% reduction of total GHG emissions in 2050 compared with 2008 • CO_2 reduction trajectory from 2008 levels: 2030: 17%, 2040: 47% 2050: 95% • 'Tank-to-wake' emissions model • Reference: Additional information regarding this model is provided in Appendix 1
Zero Carbon by 2050 scenario, modelled by Lloyds Register and University Maritime Advisory Services (UMAS) 2019[b]	• 100% reduction in well-to-wake GHG from 2008 levels, using Intergovernmental Panel on Climate Change (IPCC) 1.5 (2018) estimates of wider energy system transition • GHG reduction trajectory from 2008 levels 2030: 33%, 2040: 61% 2050: 100% • 'Well-to-wake' emissions model

a. Reference: "UN body adopts climate change strategy for shipping" (imo.org)
b. "Zero-Emission Vessels: Transition Pathways", Zero-emission vessels: Transition Pathways (lr.org)

7.1 Findings derived from ‘IMO 2018 scenario’

Figure 7.1 shows the modelled percentage of the energy share of traditional technologies, gas engines and alternative fuel technologies in the international shipping fleet towards 2050. The DNV model anticipates a slow uptake of alternative fuel technologies in the current ‘IMO 2018 scenario’. In this scenario it is considered more cost-effective for the industry to use drop-in fuels[c] rather than retrofitting or building new vessels that use alternative fuel technologies.

More information about the IMO 2018 scenario can be found on the IMO’s website: Adoption of the initial IMO strategy on reduction of GHG emissions from ships and existing IMO activity related to reducing GHG emissions in the shipping sector.

Figure 7.2 shows the total number of seafarers expected to be working on vessels equipped with alternative fuel technologies in the ‘IMO 2018 scenario’. In line with an assumed low uptake of alternative fuel technologies in the near-term, the number of seafarers working on ships using these types of fuel technologies only increases slightly until the late 2030s. After this point, the number increases dramatically year by year. In 2050, it is estimated that 310,000 seafarers would be working aboard vessels using alternative fuel technologies.

TABLE 7.2

Categorization of fuel technologies[d]

Traditional fuel technologies	Gas engines	Alternative fuel technologies
MF MGO ICE	DF LNG ICE	DF Methanol ICE
MF HFO ICE	DF LPG ICE	DF Ammonia ICE
		DF Liquid H_2 ICE
		H_2 Fuel Cell
		Ammonia Fuel Cell
		Battery

c. MF = Mono Fuel, DF = Dual Fuel, ICE = Internal Combustion Engine
d. Drop in fuels concern bio or electric fuels that can run on the same converter. Drop in fuels for MF MGO ICE is bioMGO or eMGO.

CHAPTER 7 Insights into seafarer training and skills needed to support a decarbonized shipping industry

FIGURE 7.1

Estimated share of energy technologies in the international shipping fleet, DNV model of the ‘IMO 2018 scenario’

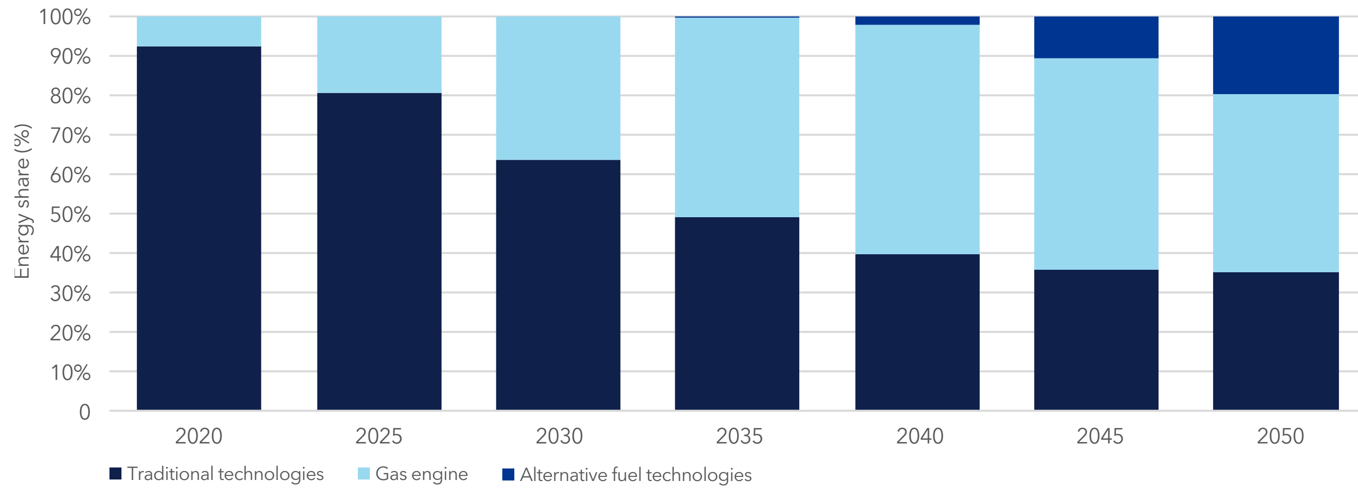
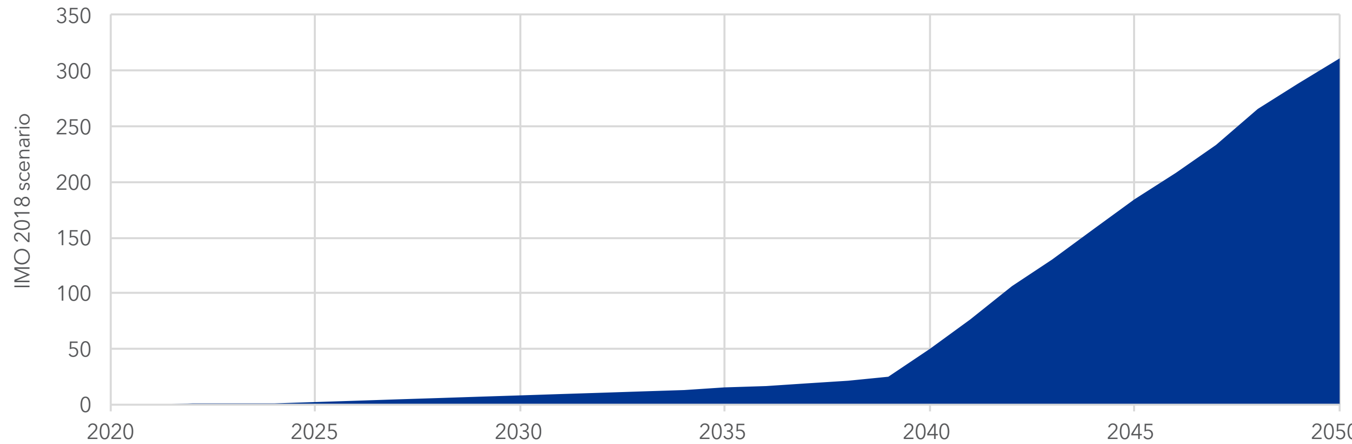


FIGURE 7.2

Estimated number of seafarers working on ships using alternative fuel technologies in the ‘IMO 2018 scenario’



7.2 Findings derived from 'Decarbonization by 2050 scenario'

Figure 7.3 shows the estimated percentage of the energy share of traditional technologies, gas engines and alternative fuel technologies in the international shipping fleet towards 2050. Similar to the aforementioned 'IMO 2018 scenario', the model assumes a slow uptake of alternative fuel technologies in the 2030s, but with a steeper uptake from 2040. It is still assumed that the industry will find it more cost effective to use drop-in fuels, rather than retrofitting or building new vessels that use alternative fuel technologies.

Figure 7.4 shows the total number of seafarers working on vessels equipped with alternative fuel technologies in a 'Decarbonization by 2050 scenario'. The same trends as observed for the 'IMO 2018 scenario' are assumed, with a slower transition of seafarers working aboard ships operating on conventional fuels to ships using alternative fuel technologies in the 2030s. In 2050, it is estimated that about 750,000 seafarers will be working aboard vessels using alternative fuel technologies.

FIGURE 7.3

Estimated share of energy technologies in the international shipping fleet, DNV model of 'Decarbonization by 2050 scenario'

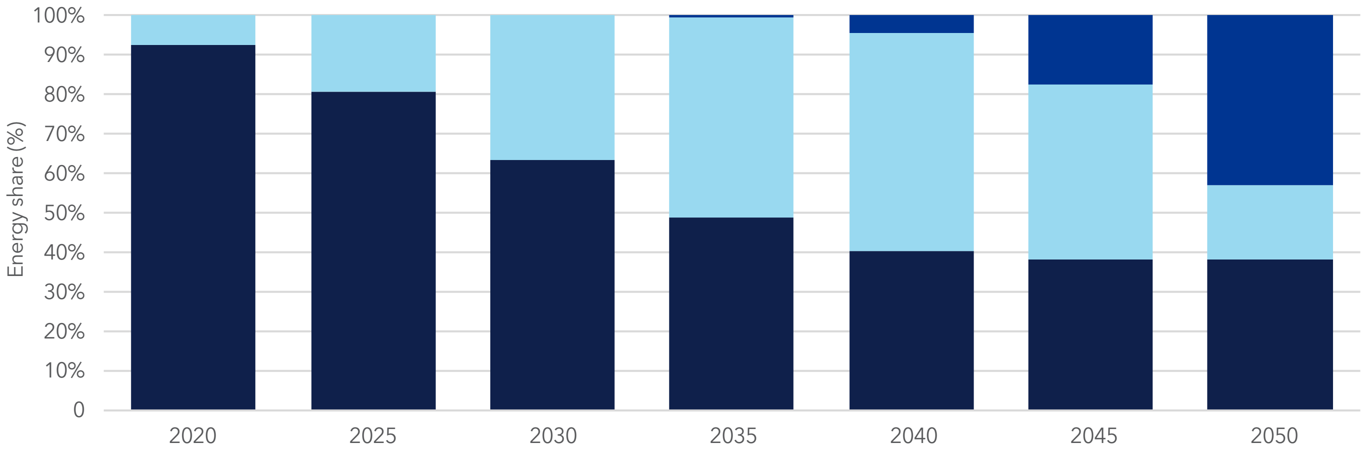
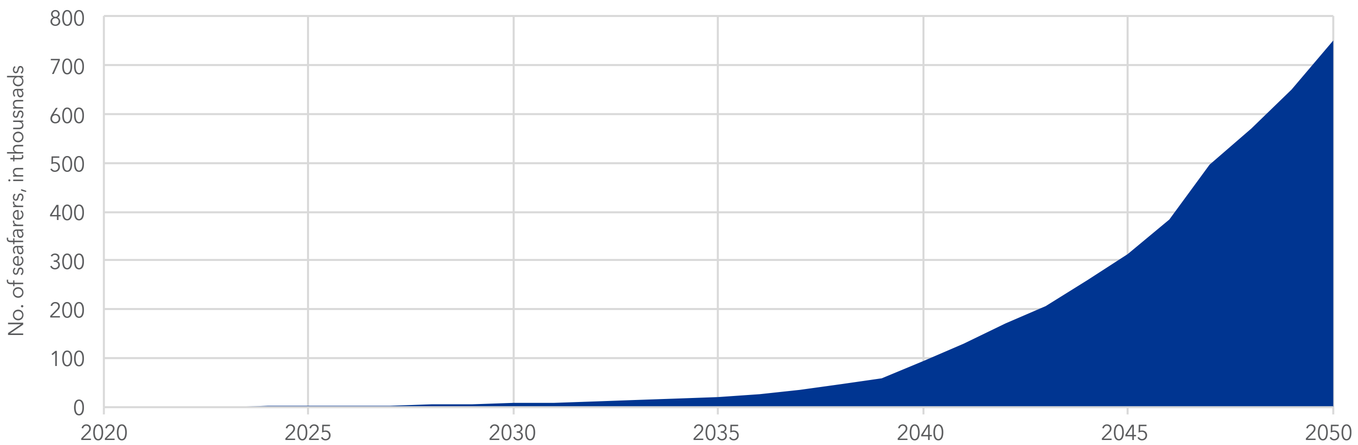


FIGURE 7.4

Estimated number of seafarers working on ships using alternative fuel technology in the DNV modelled 'Decarbonization by 2050 scenario'



CHAPTER 7 Insights into seafarer training and skills needed to support a decarbonized shipping industry

7.3 Findings derived from 'Zero Carbon by 2050 Scenario'

Figure 7.5 shows the modelled percentage of the energy share of traditional technologies, gas engines and alternative fuel technologies in the international shipping fleet towards 2050 in a 'Zero Carbon by 2050 scenario'. This scenario assumes a much earlier uptake of alternative fuel technologies compared to the previous scenarios, from the 2030s onwards.

Figure 7.6 shows the total number of seafarers working on vessels equipped with alternative fuel technologies in the 'Zero Carbon by 2050 scenario'. In this scenario, modelled by Lloyds Register and University Maritime Advisory Services (UMAS), 450,000 seafarers would require some additional training by 2030, while 800,000 seafarers would require some additional training by the mid-2030s. This scenario assumes a sharp ramp-up of alternative fuels in the 2020s.

FIGURE 7.5

Estimated share of energy technologies in the international shipping fleet, LR and UMAS model of 'Zero Carbon by 2050 scenario'

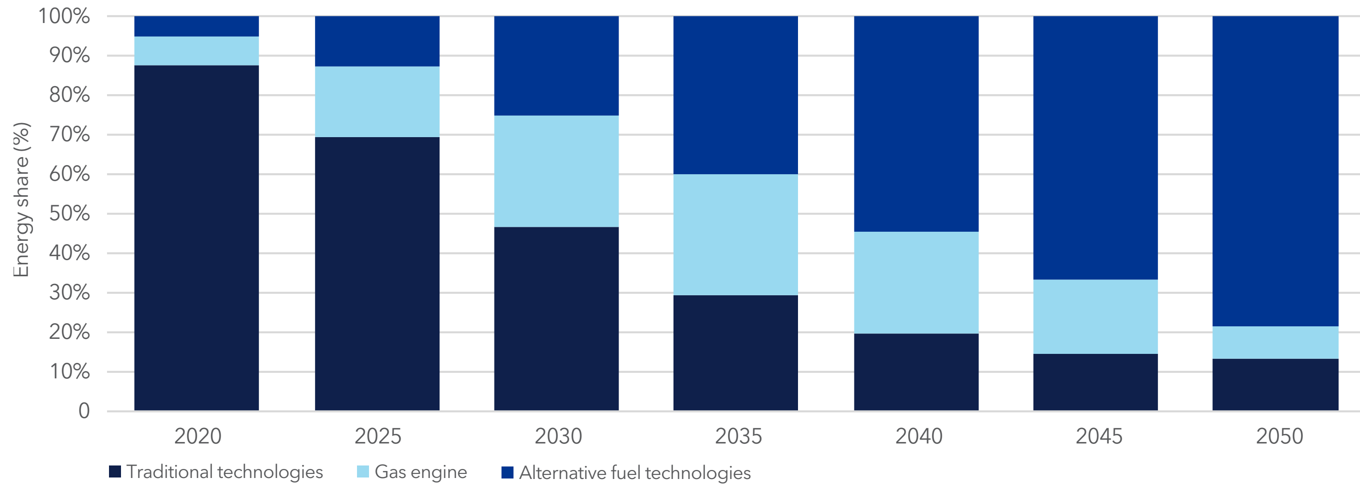
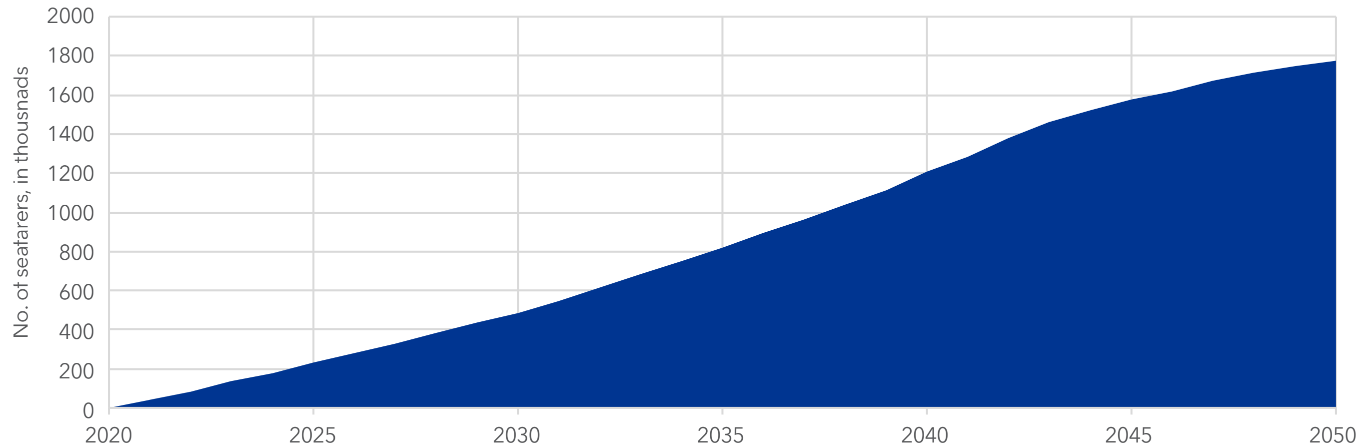


FIGURE 7.6

Estimated number of seafarers working on ships using alternative fuel technologies in the LR and UMAS modelled 'Zero Carbon by 2050 scenario'



7.4 Expected number of seafarers working on ships equipped with alternative fuel technologies and gas engines

In Figure 7.1 and Figure 7.3 it is assumed that LNG/LPG is part of the fuel mix in both the DNV modelled 'IMO 2018' and 'Decarbonization by 2050' scenarios. In the LR and UMAS modelled 'Zero Carbon by 2050' scenario, the uptake of LNG/LPG is considerably less significant.

Figure 7.7 shows the estimated number of seafarers working on ships using alternative fuel technologies and LNG/LPG in the DNV modelled 'IMO 2018 scenario'. This scenario assumes that LNG/LPG, as part of the fuel mix, is adopted immediately, while alternative fuel technologies are introduced slowly in the 2030s.

Figure 7.8 below shows the estimated number of seafarers working on ships using alternative fuel technologies and LNG/LPG in the DNV modelled 'Decarbonization by 2050 scenario'. This scenario assumes that LNG/LPG, as part of the fuel mix, is adopted immediately, while alternative fuel technologies are introduced slowly in the 2030s. In this scenario, the number of seafarers working on ships fuelled by LNG/LPG will decline rapidly between 2045 and 2050 when other alternative fuel technologies are adopted by the industry.

Figure 7.9 shows the estimated number of seafarers working on ships equipped with alternative fuel technologies and LNG/LPG in the LR and UMAS modelled 'Zero Carbon by 2050' scenario. In this scenario the number of seafarers working aboard ships equipped with alternative fuel technologies increases rapidly towards 2050. LNG/LPG does not feature significantly.

FIGURE 7.7

Estimated number of seafarers on vessels equipped with LNG/LPG and alternative fuel technologies in the DNV modelled 'IMO 2018 scenario'

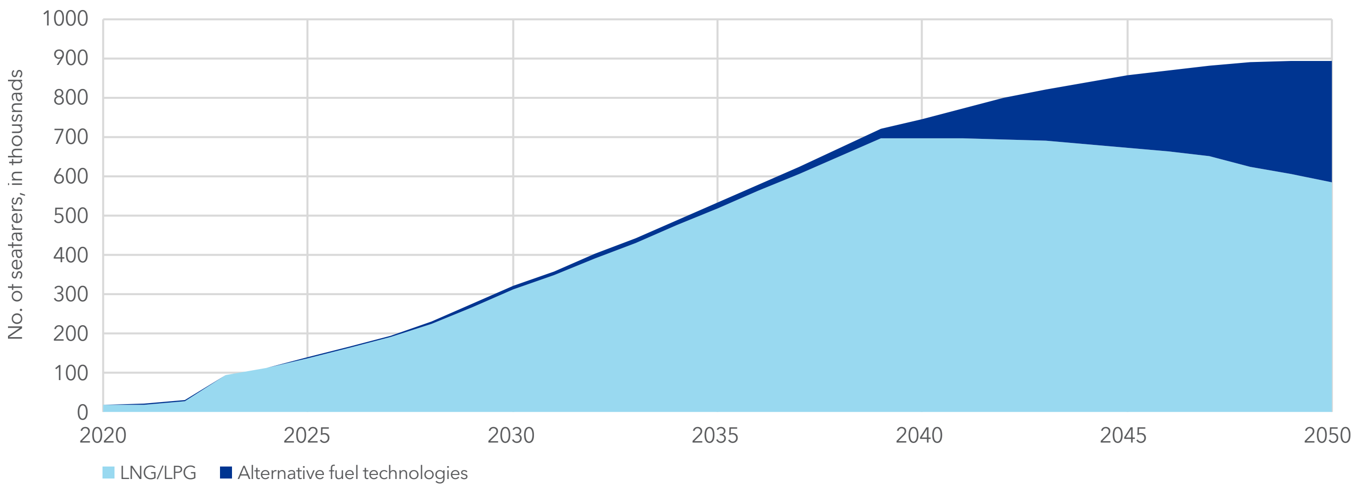


FIGURE 7.8

Estimated number of seafarers on vessels equipped with LNG/LPG and alternative fuel technologies in the DNV modelled 'Decarbonization by 2050 scenario'

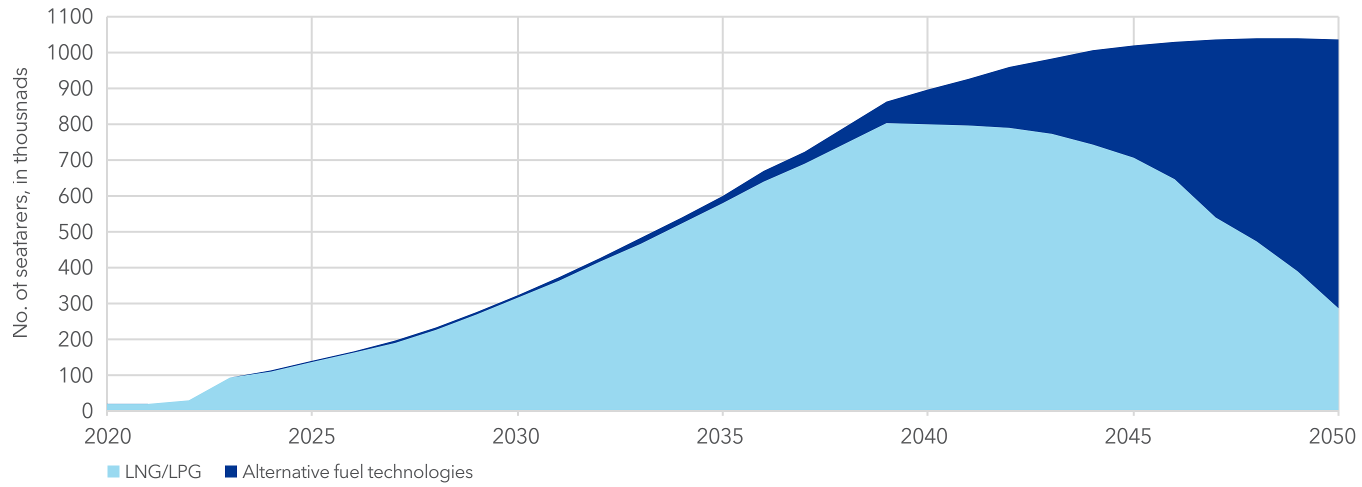
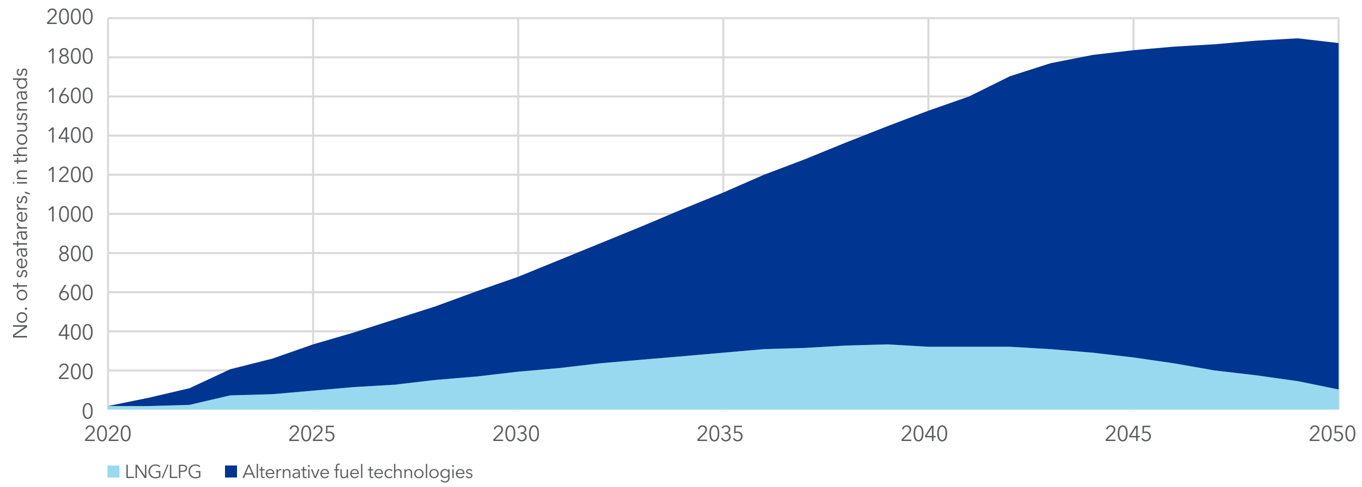


FIGURE 7.9

Estimated number of seafarers on vessels equipped with LNG/LPG and alternative fuel technologies in the LR and UMAS modelled 'Zero Carbon by 2050 scenario'



7.5 Summary – number of seafarers working on ships equipped with alternative fuel technologies

In Figure 7.1 and Figure 7 3, the DNV model anticipates a slow uptake of new alternative fuel technologies in the 'IMO 2018' and 'Decarbonization by 2050' scenarios. In these scenarios, it is assumed that the industry will use drop-in fuels and increasingly use LNG/LPG on ships.

In the 'Zero Carbon by 2050' scenario in Figure 7 5, there is an instant uptake of alternative fuel technologies and use of low to zero carbon fuels from the 2020s onwards.

Figure 7.10 presents a comparison between the three decarbonization scenarios, with a corresponding number of seafarers working on ships equipped with alternative fuel technologies.

It is expected that seafarers will require some kind of relevant training as and when alternative fuel technologies are implemented by Ship Operators.

As can be seen in Figure 7.10, the number of seafarers working on vessels equipped with alternative fuel technologies increases substantially in the more rapid decarbonization trajectories.

In the DNV modelled 'IMO 2018' and 'Decarbonization by 2050' scenarios, Ship Operators, seafarers and training/education centres would see a significant rise in the number of seafarers needing to receive some kind of training due to alternative fuel technologies in the 2040s.

In the LR and UMAS 'Zero Carbon by 2050' scenario, the number of seafarers requiring some kind of training rises steeply in every year to 2050. In this scenario, additional training requirements could put a much higher strain on Ship Operators, seafarers and training/education centres if not properly planned for. However, the alternative fuel technologies might not be available as early as this curve suggests, due to technology maturity issues.

In the DNV modelled 'IMO 2018 scenario', the number of seafarers working on ships equipped with alternative fuel technologies peaks at 310,000 seafarers, whereas in the DNV modelled 'Decarbonization by 2050' scenario and the LR and UMAS modelled 'Zero Carbon by 2050' scenario, the numbers are 750,000 and 1,775,000, respectively. Figure 7.11 provides a comparison between the three decarbonization scenarios, with a corresponding number of seafarers working on ships fuelled by LNG/LPG.

According to Figure 7 11, the number of seafarers expected to work on ships fuelled by LNG/LPG would increase by approximately 100,000 new seafarers every two years until 2038 in the DNV modelled 'IMO 2018' and 'Decarbonization by 2050' scenarios. Seafarers working on vessels fuelled by LNG/LPG will require training according to STCW requirements.

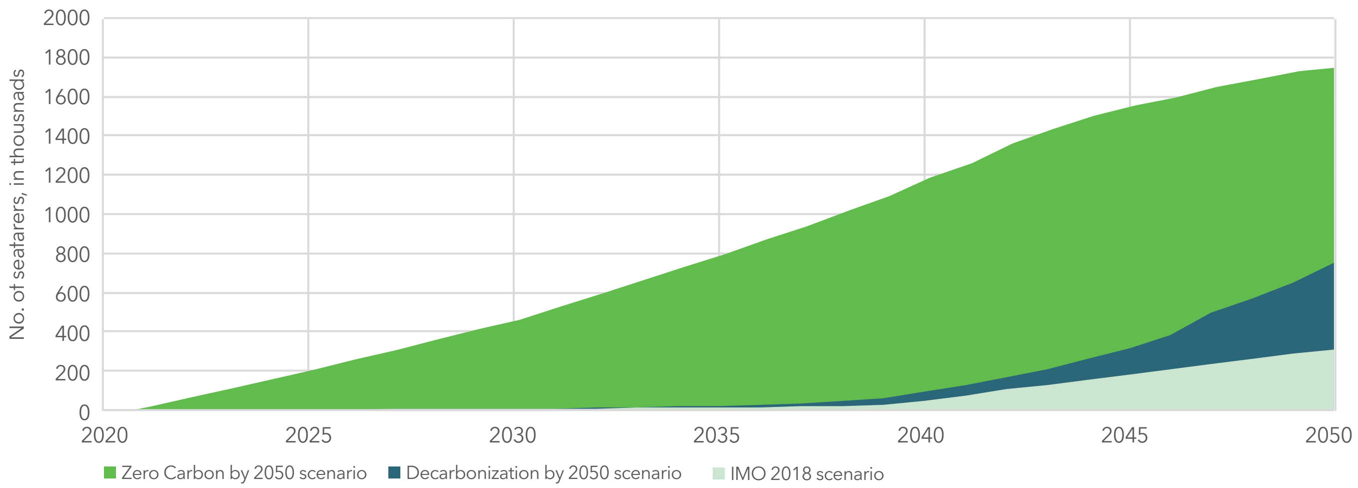
It is also worth pointing out that in the DNV modelled 'Decarbonization by 2050' scenario, the analysis shows that the number of seafarers on LNG/LPG-fuelled ships drops back around 2040. This may imply that seafarers who have been trained to be competent to work on LNG/LPG-fuelled ships, will need to be retrained for other alternative fuel technologies.

In the LR and UMAS modelled 'Zero Carbon by 2050' scenario, the necessary training for seafarers would consist of training in the use of alternative fuel technologies, instead of LNG/LPG training.

Regardless of the scenario, the analysis shows that there will be a need to provide additional training to a vast number of seafarers over the coming years, in order to support shipping's transition. This will be both as STCW training for LNG/LPG and, more importantly, for alternative fuel technologies.

FIGURE 7.10

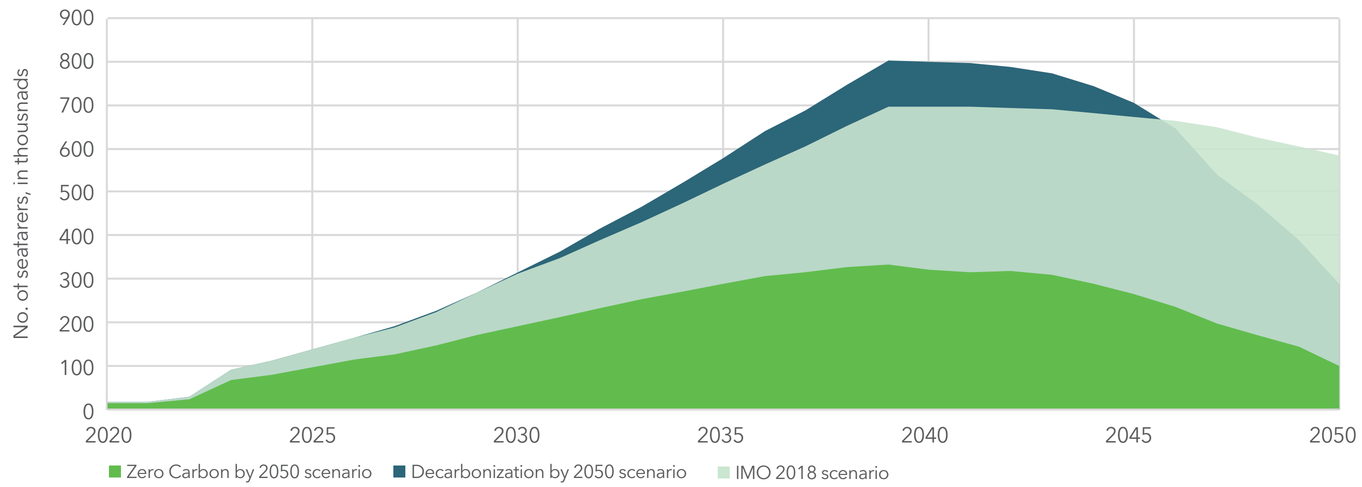
Estimated number of seafarers working on board ships equipped with alternative fuel technologies, all scenarios



CHAPTER 7 Insights into seafarer training and skills needed to support a decarbonized shipping industry

FIGURE 7.11

Estimated number of seafarers working on ships fuelled by LNG/LPG, all scenarios



8 Skills and competencies for future seafarers

8.1 Skills and competencies enabling the implementation of new technologies

The study finds that maritime operations will become more digitalized and automated as the shipping industry implements alternative fuel technologies. This suggests that the industry will need to map the skills and competencies required to implement decarbonization-related technology.

The literature review concludes that personal, organizational and management skills are a prerequisite to exploit the possibilities of future decarbonization-related technology. A study conducted by Menon Economics highlights that both individual and organizational competence will be needed to exploit the possibilities afforded by digital and other technologies.[2]

The EU SkillSea report finds that the competence required by the STCW will not be sufficient for tomorrow's seafarers. Leadership, language and communication skills, as well as soft skills to manage teams and people working remotely, will also be needed. This study also highlights that a new operational paradigm needs to be created to integrate people and digital technology.[3]

The Hamburg School of Business and Administration points out that workers will need to acquire creative and social skills to qualify for post-automation jobs, and that the profound changes caused by the technological transformation will have to be managed through communication and negotiation.[4]

Figure 8.1 shows that personal, organizational and management skills and competencies enable the shipping industry to implement the new technology that accompanies decarbonization, with the complementary skills surrounding them.

Table 8.1 shows a detailed overview of the skills and competences that enable the implementation of new technologies associated with the shipping industry's decarbonization. The table is informed by interviews, workshops and a literature review, and is not intended to be an exhaustive overview.

Definitions

Competence: in a maritime context, 'competence' is a demonstrable attribute including (but not limited to) a person's knowledge, ability to perform specific tasks, decision-making, analytical ability, problem-solving etc. The IMO STCW Convention defines levels of competency and provides specific methods for demonstrating competence leading towards certification.

Skills: specific learned abilities which enable a person to carry out the tasks and duties of a given job (International Labour Organization).

Transferable skills: skills used in one job or career that can also be used in another (Cambridge Dictionary

Training: the process of learning or enhancing the skills needed to do a particular job or activity (Cambridge Dictionary).

Upskilling: the process of learning new skills or of teaching workers new skills (Cambridge Dictionary).

Re-skilling: the process of learning new skills to enable someone to do a different job, or of training people to do a different job (Cambridge Dictionary).

FIGURE 8.1

Skills and competencies required for decarbonization of the shipping industry

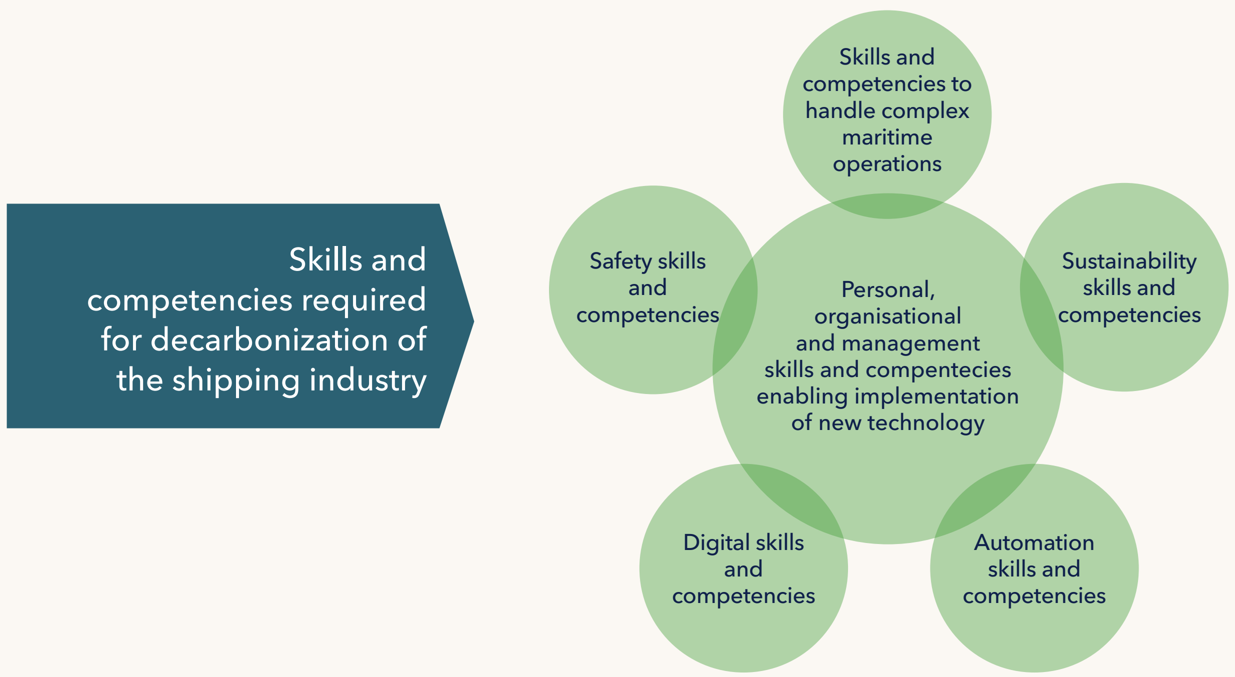
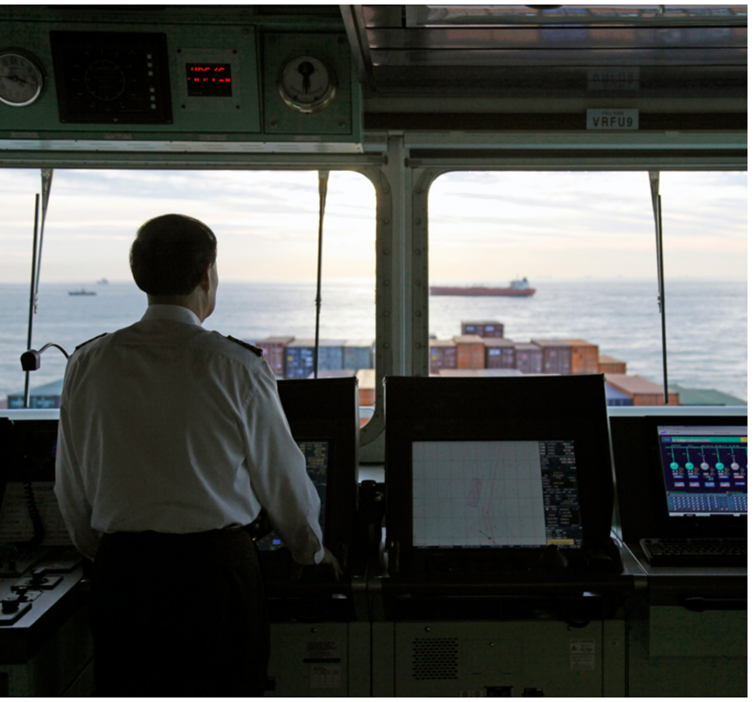


TABLE 8.1

Personal, organizational and management skills and competencies that enable the implementation of new technology in shipping

Personal skills and competencies	
Skills	• Ability to make use of new working methods • Ability to learn new skills as technology changes • Ability to be creative and interact socially with others • Multi-lingual skills for communication in a global operation
Competencies	• Innovation mindset to understand business development and take advantage of digital technology • Analytical thinking (including risk and systems analysis) to interpret and understand the need for change and the measures required
Organizational and management skills and competencies	
Skills	• Ability to communicate and negotiate, to promote required change to colleagues and customers • Ability to market and promote greener products and services • Ability to consult and advise end-users about green solutions and to spread the use of green technologies
Competencies	• Ability to implement change management • Ability to develop and implement management systems • HR and knowledge management • Advanced knowledge in project management to implement new technology • Ability to work strategically, to enable policymakers and business executives to set the right incentives and create conditions to achieve goals • Ability to manage teams and people working remotely and/or in dispersed teams • Ability to coordinate and manage holistic and interdisciplinary approaches incorporating economic, social and ecological objectives



8.2 Seafarer skills and competencies for the decarbonization of shipping

Table 8.2 shows a detailed overview of the skills and competencies needed as a result of the decarbonization of shipping. The table is informed by interviews, workshops and a literature review.

8.2.1 Decarbonization skills known in some parts of industry
The qualitative component of the study, underpinned by the literature review, found that skills already in place in the tanker/gas segment today will be relevant for ships operating with alternative fuel technologies. For example, the interviews pointed out that the skills needed to operate ships using fuels like methanol and ammonia could be similar to the skills required on tanker vessels, as both ammonia and methanol are carried as cargo today. These skills should include the unique risks posed by these fuels and their properties.

The most challenging fuels were said to be those where the industry does not already have extensive experience of transporting them as bulk cargo, such as hydrogen.[5]

The safety mindset required when operating on vessels carrying hazardous cargo, including the related safety challenges, impacts how all parts of the maritime operation are planned and performed, as well as how emergency preparedness is handled.

The interviews and workshops highlighted that Ship Operators not currently involved in tanker/gas shipping could seek to learn from those segments in the years to come. The so-called 'safety mindset' from tanker/gas vessels could be useful to seafarers currently working on other ship types. Against this backdrop, Ship Operators and maritime education providers could consider utilizing seafarers trained according to the STCW methodologies employed for competency in the gas and tanker segments as instructors.

8.2.2 Meeting decarbonization goals, coupled with fast-moving technological developments, including increased automation, requires careful monitoring and reflects a general trend towards a 'higher-skilled' seafarer
In addition to heightened safety skills and a 'safety mindset', the ability to master complex maritime operations and sustainable ship operations were found to be of utmost importance for decarbonized shipping.

In particular, participants in this study highlighted that the industry needs increased digital competencies and skills, as an increased uptake of digital technology and automation on board is expected. It is anticipated that the officers on board will act as 'system managers', utilizing digital and automation systems to perform their daily tasks.

In an earlier case study, DNV found that around 15% of the decarbonization gains required to meet the IMO goal of halving GHG emissions by 2050 will come from operational efficiencies on existing ships. Data-driven measures such as energy efficiency, fuel consumption monitoring, condition monitoring for preventive maintenance, optimized weather routing and vessel performance management can contribute both to reduced emissions and operational economies.[6]

Furthermore, this study highlights that the future workforce will need to be more transferable between jobs at sea and control room jobs ashore, which makes it important to provide seafarers with transferable skills. The experts interviewed also anticipate that there might be more specialization required for the future seafarer. A wide skillset increases mobility for seafarers and limits the additional strain and costs involved in fragmented training.

Feedback from industry experts and findings from the literature review suggest that several onboard jobs will change in profile. Increased IT, digital, technical and organizational competence will be needed in future to meet the demands of decarbonization. This may imply that officer roles on board will increasingly need to be 'higher skilled', and that bridge and engine officers may face higher skill requirements than ratings.

Some interviewees mentioned that countries supplying professional seafarers may need to consider the above demands in their education systems to be able to provide the world's shipping fleet with competent personnel. It was also pointed out that tomorrow's seafarer may require a different academic profile.

CHAPTER 8 Insights into seafarer training and skills needed to support a decarbonized shipping industry

TABLE 8.2

Skills and competencies for the operation of ships using alternative fuel technologies

Safety skills and competencies	
Skills	• Seafarers on vessels operating with conventional fuels will have to adopt the safety mindset of the tanker/gas fleet when working with new fuel types • Ability to implement updated emergency preparedness procedures such as first aid, fire detection and fire fighting
Competencies	• Knowledge of potential hazards of the fuel on board and how these apply to equipment operation and maintenance • Knowledge of gas testing and atmosphere monitoring procedures • Knowledge of fuel-specific chemistry and physics to understand potential safety hazards • Understanding the basic concepts and properties of the different fuel types
Skills and competencies to master complex maritime operations	
Skills	• Ability to perform safe vessel and equipment maintenance with more hazardous fuels on board • Ability to handle the digital and manual systems for bridge, deck, engine, manoeuvring and propulsion that are introduced with the new fuel technology • Ability to master new bunkering methods • Ability to operate complex hybrid and zero-emission machinery • Ability to operate hydraulic components and pneumatic equipment
Competencies	• Knowledge of engine functions and manoeuvring characteristics • Knowledge of how to operate the vessel in an energy efficient manner
Sustainability skills and competencies	
Competencies	• Knowledge of emission monitoring and documentation • Knowledge of environmental economics and the use of performance management systems • Knowledge of logistics and optimization methods to achieve high vessel utilization and advanced routeing • Knowledge of environmental awareness and sustainable development of businesses
Digital skills and competencies	
Skills	• IT and digital skills • Data fluency and ability to interpret and analyse large amounts of data • Ability to operate equipment using digital controls • Ability to solve tasks digitally through operations monitoring and system management • Ability to update, service and repair digital systems
Competencies	• Remote control of operations, logging and analysing data from several sources • Basic digital technology knowledge (IoT, sensors, networks, cyber security, connectivity). Advanced analytics and use of data to optimize the fleet • In-depth technical knowledge to understand complex systems (seafarer as systems manager) • Knowledge of cybersecurity
Automation skills and competencies	
Skills	• Manage automation failure, with onshore support • Detailed knowledge of and proficiency in the use of automated systems. Ability to monitor and correct their function (S/C)
Competencies	• Ability to diagnose defects and rectify via automated systems • Advanced knowledge of electrical systems • Knowledge of programmable logic controllers (PLCs)

9 Safety challenges following the uptake of alternative fuel technologies

Spadeadam Research and Testing

The safety of shipping is generally covered by rules and regulations from the IMO and classification societies. At present, however, there are no IMO regulations in place for alternative fuel technologies, though there are guidelines and rules for some of the technologies available from classification societies. When developing safety regulations, the overarching principle is that the introduction of alternative fuel technologies shall have equal or better safety levels than traditional fuel technologies.

There are a number of safety challenges associated with alternative fuel technologies:
- Flammability
- Explosion risk
- Toxicity

Figure 9.1 presents a high-level overview of the safety challenges related to traditional and alternative fuel technologies. It should be noted that this may vary with different applications and ship types, and the overview is meant to give a rough comparison. As can be seen from the figure, hydrogen, methanol and ammonia come with more serious safety challenges than traditional fuel technologies.

A summary of the safety challenges related to the alternative fuel technologies hydrogen, ammonia and methanol is presented in the following sections.

FIGURE 9.1

Overview of safety challenges for traditional and new fuel technologies[7]

Challenges	HFO/MGO	LNG/LPG	Hydrogen	Methanol	Ammonia
Flammability					
Explosion risk					
Toxicity					

Low risk Medium risk High risk

9.1 Hydrogen

Safety challenges

Hydrogen has historically been shipped in small, packaged quantities and only recently in bulk. Experience of hydrogen as a marine fuel is currently limited. The general understanding of hazards and risks associated with liquefied hydrogen (LH2) is limited. Consequently, no class rules or prescriptive international regulations have yet been developed. Several R&D initiatives are currently ongoing to improve the understanding of LH2 and associated hazards.

For hydrogen, the potential explosion risk related to the low ignition energy and the wide flammability range requires special attention. The very low boiling temperature for hydrogen makes it more challenging to store in its liquefied form.

Hydrogen flames can reach higher temperatures than other gases, but at the same time the flame's radiated heat is normally lower.

A hydrogen leak (and ignition) in an enclosed or semi-enclosed space could cause a catastrophic explosion. Under certain conditions, this scenario might lead to high explosion overpressures.

Although the consequences of a fire are different for LNG and hydrogen, its severity is similar. In addition, hydrogen storage tanks may be at higher pressures. The foreseen rapid increase in hydrogen appliances could lead to an unwanted increase in serious hydrogen explosion incidents if the risk is not addressed properly.

Hydrogen fuel systems can still be made as safe as natural gas systems. However, the adverse effects of hydrogen mean that different, inherently safe designs, and a higher level of safety precautions with preventive and mitigating measures, might be needed to obtain a system whose safety level is equivalent to those of conventional hydrocarbon systems.[8]

9.2 Ammonia

Safety challenges

The key challenges for ammonia include its toxicity, combustion properties, nitrous oxide (N2O) emissions and potential ammonia slip. Due to its toxicity, the introduction of ammonia as a fuel creates new challenges related to safe bunkering, storage, supply and consumption.

Ammonia has alkaline properties and is corrosive. Ammonia will corrode galvanized metals, cast iron, copper, brass or copper alloys. Hence, careful material selection is required. Ammonia is flammable but hard to ignite. Outdoors, ammonia vapours will generally not constitute a fire hazard. Indoors, in confined spaces, the risk of ignition will be higher, especially if oil and other combustible materials are present. Pressure vessels used for storing ammonia may explode when exposed to high heat input.

The main hazards with ammonia are toxicity, explosiveness, corrosiveness, flammability, cryogenic properties and asphyxiating properties.

Anhydrous ammonia is a hydroscopic compound, which means that it seeks water from the nearest source, including the human body. This places the eyes, lungs and skin at greatest risk because of their high moisture content. Caustic burns result when the anhydrous ammonia dissolves into body tissue.

An additional concern is the low boiling point of anhydrous ammonia. The chemical freezes on skin contact at room temperature. It will cause burns similar to, but more severe than, those caused by dry ice.

Most deaths from anhydrous ammonia are caused by severe damage to the throat and lungs from a direct blast to the face. When large amounts are inhaled, the throat swells shut and victims suffocate. Exposure to vapours or liquid can also cause blindness.

Combustion of ammonia may form toxic nitrogen oxides.[9]

9.3 Methanol

Safety challenges

Methanol is a flammable liquid whose vapour is heavier than air. It has a large flammability range (6,7-37%) and high heat of evaporation. Methanol remains flammable in a water solution and has an autoignition temperature of 464°C.

It is toxic and affects vision. Ingestion may cause blindness. It is toxic by inhalation, though a high level is required for irreversible effect. The risk driver for methanol is flammability. It also induces corrosion and can damage seals and certain plastics.

9.4 Alternative fuel technologies' effect on training needs

With the exception of hydrogen, which was until recently only transported in packaged form, most of the alternative fuels are currently carried as bulk marine cargo. The shipping industry is therefore both knowledgeable and experienced with regard to their handling. However, seafarers will need additional training concerning the particular risks associated with using these fuels for propulsion in order to ensure not only their safety but the safety of the environment and local community.

Some Ship Operators have stated that they will be using internal risk management processes defined in their Safety Management System to address all safety aspects in the decarbonization and digitalization transition that the industry is facing. Additionally, it has been pointed out that Ship Operators should continue to implement actions that ensure a sound safety culture in this time of transition. It is time-consuming to build a safety culture and managers and employees must work together to make this happen.

Lastly, it was emphasized in workshops that human factors must be accounted for when addressing fuel hazards and the design of workstations to avoid human error and incidents. This includes efforts to promote seafarers' wellbeing and mental health as an important contribution to safe shipping operations.

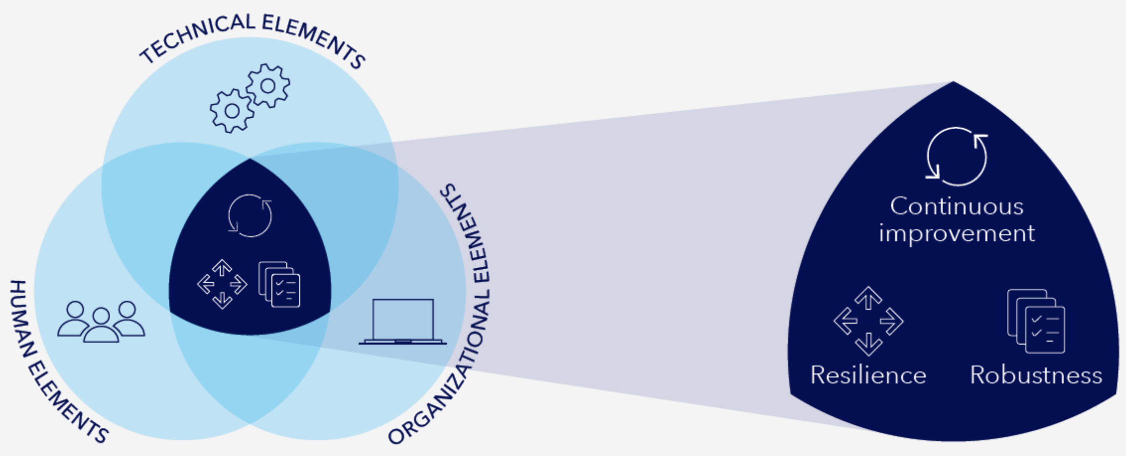
DNV promotes the "HOT" (Human, Organization, Technical) approach when addressing safety. The safety of maritime systems can best be understood in a system perspective that requires constructive interaction between HOT elements which together create robust and resilient systems capable of continuous improvement. DNV believes that this holistic approach to safety is needed to address the safety challenges created by the decarbonization, digitalization and automation of maritime work processes.[10]

The alternative fuel technologies' toxicity, flammability and explosive attributes must be covered in future training programmes for seafarers.

FIGURE 9.2

DNV HOT approach to safety

Interactions and properties of a safe maritime system



10 Challenges in providing seafarer training for the transition

Maritime education

Vocational education for seafarers is based on requirements from the STCW Convention. Education leading up to qualification as officers is delivered by maritime academies. Maritime education and training providers deliver additional training required to serve on particular types of vessels or in positions that require additional skills.

Both maritime academies and maritime education and training providers normally offer training in line with an applicable IMO Model course in order to ensure they comply with the STCW requirement. Such training leading up to a Certificate of Competency (CoC) or Certificate of Proficiency (CoP) needs to be approved by the Flag administration. The CoP is only issued by the flag State upon application from the candidate.

10.1 Training constraints

With respect to providing seafarer training in support of shipping's decarbonization transition, the qualitative analysis identified the following critical barriers and/or training constraints, which need to be urgently addressed. Each of these challenges or constraints is further detailed below.

10.1.1 Slow regulatory development makes investment in seafarer training challenging

During the qualitative process, several experts said that the STCW revision is seen as the key to establishing a common framework for the provision of seafarer training on new hazardous fuels as they enter the market. It was underlined that a basic training framework must be in place for all relevant seafarers. Fragmentation of rules and diverging national and regional standards are not desirable, as such fragmentation would make it harder to have a common standard.

The STCW has laid out training requirements for tankers, both at a basic and advanced level. These regulations could be replicated for other alternative fuel technologies and the already existing framework for training crews on gas carriers and tankers should be utilized to develop appropriate training programmes.

Several experts said that IMO should be responsible for drawing up the training framework to ensure a level playing field for all Ship Operators. The industry would then be responsible for providing the ship-specific and fuel-specific training that is needed in connection with the implementation of new fuel in the fleet.

Furthermore, the qualitative process highlighted that technology development outpaces the development of regulations. This is seen as an obstacle to investing in training activities. There are also concerns about whether enough time will be

FIGURE 10.1

Training constraints

1. Slow regulatory development makes investment in seafarer training challenging
2. A need to invest in training facilities and up to date equipment
3. The availability of competent trainers
4. Shortage of experienced seafarers

given to reskill the workforce before such regulations enter into force. The DNV whitepaper "Closing the safety gap in an era of transformation" points out a similar obstacle, namely that the regulatory frameworks are not keeping up with the pace of technological development.[11]

The investment and operational costs of implementing new technology are high, and the financial model does not reward first movers. The experts point out that this transition is going to last many decades and we must make sure that requirements that are being implemented are valid for the whole industry. Studies from both DNV[12] and Lloyds Register[13] show that the future is unclear when it comes to the decarbonization of shipping. No single fuel will prevail, but rather a mix of fuels. This uncertainty regarding future alternative fuel trajectories is raised by industry experts as a concern. They are awaiting clarity and rapid rule development from international and national governments before investing heavily in training activities related to alternative fuels.

The development of new training courses is expensive, and the maritime experts point out that it is not initiated prior to requirements from regulators or the industry. It is considered important that high priority be given to the STCW revision, to allow time for the industry to develop the necessary training courses. The literature review also substantiates that it takes years to introduce new training programmes and points out that governments can facilitate the development of training through adequate policies and necessary funds.[14]

10.1.2 A need to invest in training facilities and-up-to date equipment
According to the literature, an important aspect of training involves the exposure of seafarers to technologies which mirror real-life scenarios, particularly to enhance safety training.[15] Such simulation technology enables the learning of navigational skills, ships' reactions, and behaviours in a risk-free environment.[16] Indeed, several interviewees cited the importance of seafarers being exposed to the same technology in training as they will find on board the vessels. In this regard, it was highlighted that the practical use of engine, bridge and automation systems should form an essential component of seafarer training.

In addition, industry experts underscored the importance of the availability of simulators and engine/automation replicas at training centres and schools, in order to provide opportunities for hands-on learning experiences. It was also noted that utilizing Virtual Reality/Augmented Reality tools, as well as simulator-based learning and other techniques, can foster the development of digital skills. Several interviewees pointed out that parts of the industry may need to upgrade training facilities with actual replicas of engine rooms, automation systems, simulators and Virtual Reality/ Augmented Reality tools.

It was also highlighted by several participants that more high-tech training facilities would be needed to train seafarers in the decades to come.

However, investing in simulators, virtual reality tools and other such high-tech equipment was referred to as being costly by some participants during the workshops and interviews. This technology would require further investment in training centres and additional support for training infrastructure and capacity.

According to the 2019 Maritime Insights Database, the most commonly cited challenge for training is the existence of financial constraints. Such constraints may make it difficult to ensure that all training centres have access to the high-tech equipment needed.

10.1.3 The availability of competent trainers
The availability of instructors with the required competence was described as a substantial challenge by several interviewees. One interviewee said that "We will be lacking seafarers and the people to train the seafarers". This was further echoed by a workshop participant, who underscored that "It may be a training constraint to find training educators with practical seagoing experience".

The number of available instructors with knowledge and experience from vessels using modern automation systems and running on new fuels is expected to be low and could become a constraint when a large number of seafarers require training. It was also highlighted by several interviewees that there will be a need for highly qualified instructors to meet the increased demands for training in the future.

A lack of qualified maritime instructors is also reflected in the relevant literature and was cited as a common challenge in a survey conducted by the Maritime Insights Database.[17] In addition, it is pointed out by some scholars that a lack of qualified instructors has an impact on the quality of maritime education and training provision.[18] This requires the fostering and professional development of instructors and trainers, and investment in developing the instructors' competence. Moreover, the EU SkillSea study found that demand for specialized education will require training institutions to invest more in developing knowledge units, thereby increasing the organizational complexity.[19]

10.1.4 Shortage of experienced seafarers
The challenges related to the recruitment of seafarers is further discussed in section 11.

10.2 Future training models

This section provides an assessment of future training models for basic seafarer education, fuel and equipment-specific specialized training and ship-specific onboard familiarization.

10.2.1 Basic seafarer education and education systems
Bridge and engine officers
According to the literature review and qualitative interviews, the combined skill requirements relating to decarbonization, digitalization and automation will make it necessary to strengthen basic education for seafarers. This education will need to provide skills in digital technology, automation, chemistry, emerging technologies and management/organizational skills, both for the officers on the bridge and in engine departments.

> The number of available trainers with knowledge and experience from vessels using modern automation systems which run on new fuels is expected to be low and could become a future constraint when a large number of seafarers require training.

Ratings
The data used in this study is not conclusive as to how much the education provided to ratings will need to change in the future to permit them to work on digitalized vessels with alternative fuel technologies. The safety skills needed to work on vessels with alternative fuel technologies will need to be acquired by ratings who move to vessels with more hazardous fuels. This may, however, be solved by IMO model courses and ship-specific familiarization provided by Ship Operators in connection with the implementation of new fuels in their fleets, and not necessarily reflected in ratings' basic education.

General and specialized skills
There were several discussions during the course of the study about whether basic education should involve in-depth specialized skills or more general skills. The discussions tended to favour more generalized skills, with a focus on organizational, digital and safety skills in maritime education institutions (especially for officers), with specialized training to be delivered by training centres and Ship Operators in connection with the implementation of new technology.

This was echoed in a study conducted by Menon. This study points out that Ship Operators will need both generic and specific competence to implement new technologies. As future technologies are unknown and specialized competence can quickly lose its applicability, the study concludes that basic education should cover broad, general competencies. Curricula at training centres can be more tailored to Ship Operators' need to acquire specialized skills when such skills are needed.[20]

Use of modern learning methods in basic education
As previously outlined, interviewees pointed out that seafarers need exposure to emerging technologies in schools to ensure that the training on board can be more efficient.

This study finds that use of simulators, virtual reality tools, e-learning tools and bridge/engine replicas will be an important part of the future training model.

The importance of life-long learning was also emphasized throughout. Indeed, the EU SkillSea report concludes that individual learning paths should be a part of life-long learning for maritime professionals. The report foresees that seafarers will expand their knowledge and acquire transversal skills if the concept of lifelong learning is implemented. Blended learning, using online courses, simulators and collaborative learning is promoted as a future training model.[21]

The Menon study also finds that the future will require a higher degree of continual learning and courses. As the internet provides access to all kinds of information and knowledge, the study argues that future training should focus more on the ability to perform tasks with the use of digital technologies, instead of today's model where students read and remember theory.

A combination of digital and physical meetings at training facilities were also found in the Menon study to be prefered by seafarers. However, seafarers point out that they require systems which promote asynchronized training. This is so they can study at their own pace. The study concludes that seafarers should have access to courses that are close to their practical needs at sea but do not necessarily result in the award of academic credits.[22]

10.2.2 Fuel and equipment-specific specialized training modules

STCW and IMO model courses provided by approved training facilities
The industry experts involved in workshops and interviews pointed out that short module-based courses should be the norm for introducing fuel-specific technology in the shipping fleet. The maritime experts anticipated that fuel and equipment-specific training would be module-based. They also underscored that there would be some generic hazards and skills spanning all fuels and related equipment, as well as some more specific knowledge and skills for particular fuels and equipment for zero-emission shipping.

Participants in interviews and workshops underlined that the STCW revision, as it relates to new alternative fuel technologies, needs to be accelerated. This is to ensure the development of a common framework for the industry to start training, which is seen as a starting point for the fuel transition.

The STCW requirements for alternative fuel technologies should build on existing requirements for STCW IGF Code (LNG/LPG-fuelled ships). These should underpin the development of IMO model courses, which will form a necessary component of future maritime training. These IMO model courses consist of one basic and one advanced course at an approved training facility, plus a minimum of seagoing experience. When these standardized STCW model courses have been made available to the industry, they can be provided by STCW-approved education or training centres.

Ship-specific training and onboard familiarization
The importance of ship-specific onboard familiarization was highlighted in workshops and interviews as a vital part of future training models for decarbonized shipping. This is to help ensure seafarers can handle new alternative fuel technologies safely. Ship Operators currently plan training activities according to their ISM competence process and in line with their respective timelines for implementing alternative fuel technologies. This is often done in cooperation with maritime training centres. Designers and equipment vendors are also often used to assist in developing ship-specific courses.

Many participants underlined that it is as yet too early to provide seafarers with fuel-specific or equipment-specific training. This is due to the current uncertainty surrounding the future alternative fuel mix and the necessary ship-specific equipment to support the implementation of such fuels. Instead, it was argued, this should be provided closer to the implementation date.

These findings are echoed in the Menon study. The Menon study concludes that maritime education and training institutions should be responsible for the general training of seafarers. The study also concludes that specific training on certain technologies should be provided by the industry itself as a just-in-time delivery.

Several maritime experts also highlighted that Ship Operators using vessels with several different types of fuel in their fleets could build up a flexible workforce by moving seafarers around and exposing them to alternative fuel technologies. This would enable the provision of familiarization periods with new fuels and provide critical safety skills.

Maritime experts also underscored that a focus on leadership and the respective leadership teams on board can help to support crew training. Senior staff members are, and will always be, important partners when implementing new systems and routines aboard ship. They should be involved early and given training in the necessary management skills to lead the implementation of new systems and tools through their teams on board.

> Short module-based courses should be the norm for introducing fuel specific technology in the shipping fleet.

11 Inability to attract and retain seafarers pose a significant challenge to the maritime industry`s transition

Both the interviews and the literature review underscored that attracting and retaining seafarers will be a challenge when it comes to implementing new onboard decarbonization-related technologies. This challenge may be further exacerbated in the future as other industries will also be competing for the competencies the future seafarer will require, such as digital skills or a STEM background.

Indeed, a study conducted by Menon anticipates increasing competition to recruit relevant personnel, in particular personnel with digital and technological competence.[23] Against this backdrop, the EU SkillSea study comments that shipping's employment problem is that it is seen as low-tech compared with sectors such as the aviation, automotive and technology industries.[24]

Many interviewees also pointed out that recent global crises – including the Covid-19 pandemic – have resulted in a higher turnover of seafarers globally. The backlog from this turnover may dog the industry for years to come and may put additional pressure on Ship Operators, training centres and seafarers in the short-term during the transition to alternative fuels.

Finding and retaining suitable candidates was considered a challenge by many of those interviewed, with many asserting that the recruitment of seafarers (especially officers) will remain a challenge in the coming years. Many interviewees underscored that the opportunity of pursuing a seafaring career is still relatively unknown to the vast majority of the population in various countries, posing further challenges when it comes to recruitment. Similar challenges are echoed in the relevant literature. According to a study released by ICS and BIMCO (2021), when recruiting STCW certified seafarers, companies report the highest level of difficulty in recruiting Engineering Officers and Electro-Technical Officers, while advising that it is relatively easier to recruit ratings to work both on deck and in the engine room. The report highlights a current shortfall of 26,240 STCW-certified officers, indicating that demand for seafarers in 2021 has outpaced supply.[25] The maritime experts interviewed did not foresee a change in labour-supplying countries. However, it was commented that the countries from which crew are currently drawn may need to update their basic training in the coming years to remain competitive in supplying the fleet with competent seafarers.

Some interviewees and workshop participants raised a concern that future digitalization and automation could lead to a reduction in crew numbers aboard ships.

This trend is reflected by the World Maritime University report, commissioned by the International Transport Workers' Federation (ITF), which highlights that, in the period to 2040, employees in low and medium-skilled jobs in the transport sector face greater prospects of redundancy than their high-skilled peers. Several studies point to a shift in the labour force as new technologies create new types of jobs. While there are indicators that companies in certain countries are willing to retrain workers, other companies plan to hire new staff to fill high-skilled jobs."[26]

However, a report from the Hamburg School of Business Administration, commissioned by the ICS, concludes that there will be no shortage of jobs for seafarers, especially for officers, in the next decade. The size of crews may evolve in response to technological changes on board, but there may be a considerable increase in the number of jobs ashore that require seafaring experience. The training of seafarers is seen as crucial to filling new roles and positions.[27]

CHAPTER 12 Insights into seafarer training and skills needed to support a decarbonized shipping industry

12 References

1 DNV Maritime Forecast to 2050 - Energy Transition outlook 2021

2 Competence needs and competence strategies as a result of technology development in maritime industry. Menon publication 66/2022.

3 EU Skillsea: Future skills and competence needs, deliverable 1.1.3 version 5.0 2022

4 Hamburg School of Business Administration 2018: Seafarers and digital disruption – The effect of autonomous ships on the work at sea, the role of seafarers and the shipping industry.

5 DNV Handbook for hydrogen-fuelled vessels (2021)

6 Maritime impact: DNV supports Grieg Star with digital roadmap for the future 2022

7 Comparison of Alternative Marine Fuels 2019, DNV report 2019-0567 Rev. 3

8 DNV Handbook for hydrogen-fuelled vessels (2021)

9 Green Shipping Program – Ammonia as a marine fuel safety handbook (2021)

10 DNV Whitepaper: Closing the safety gap in an era of transformation 2021

11 DNV Whitepaper: Closing the safety gap in an era of transformation 2021

12 DNV Maritime Forecast to 2050 – Energy Transition Outlook 2021

13 Lloyds Register: Zero-Emission Vessels: Transition Pathways 2022

14 World Maritime University: Transport 2040: Automation, technology, employment – the future of work (2019)

15 Sara Klingenberg and Guido Makransky. Virtual reality enhances safety training in the maritime industry: An organizational training experiment with a non-WEIRD example. 2022. https://doi.org/10.1111/jcal.12670

16 Kim, Te., Sharma, A., Bustgaard, M. *et al*. The continuum of simulator-based maritime training and education. *WMU J Marit Affairs* 20, 135–150 (2021). https://doi.org/10.1007/s13437-021-00242-2

17 Maritime Insights Database (MarTID) survey 2018. http://scholar.wmu.se/martid/

18 Vujičić, S., Hasanspahić, N., Gundić, A. *et al*. Analysis of factors influencing the effectiveness of MET instructors. *WMU J Marit Affairs* (2022). https://doi.org/10.1007/s13437-022-00271-5

19 EU Skillsea: Future skills and competence needs, deliverable 1.1.3 version 5.0 2022

20 ICS/BIMCO seafarer workforce report 2021

21 Competence needs and competence strategies as a result of technology development in maritime industry. Menon publication 66/2022.

22 EU Skillsea: Future skills and competence needs, deliverable 1.1.3 version 5.0 2022

23 Competence needs and competence strategies as a result of technology development in maritime industry. Menon publication 66/2022.

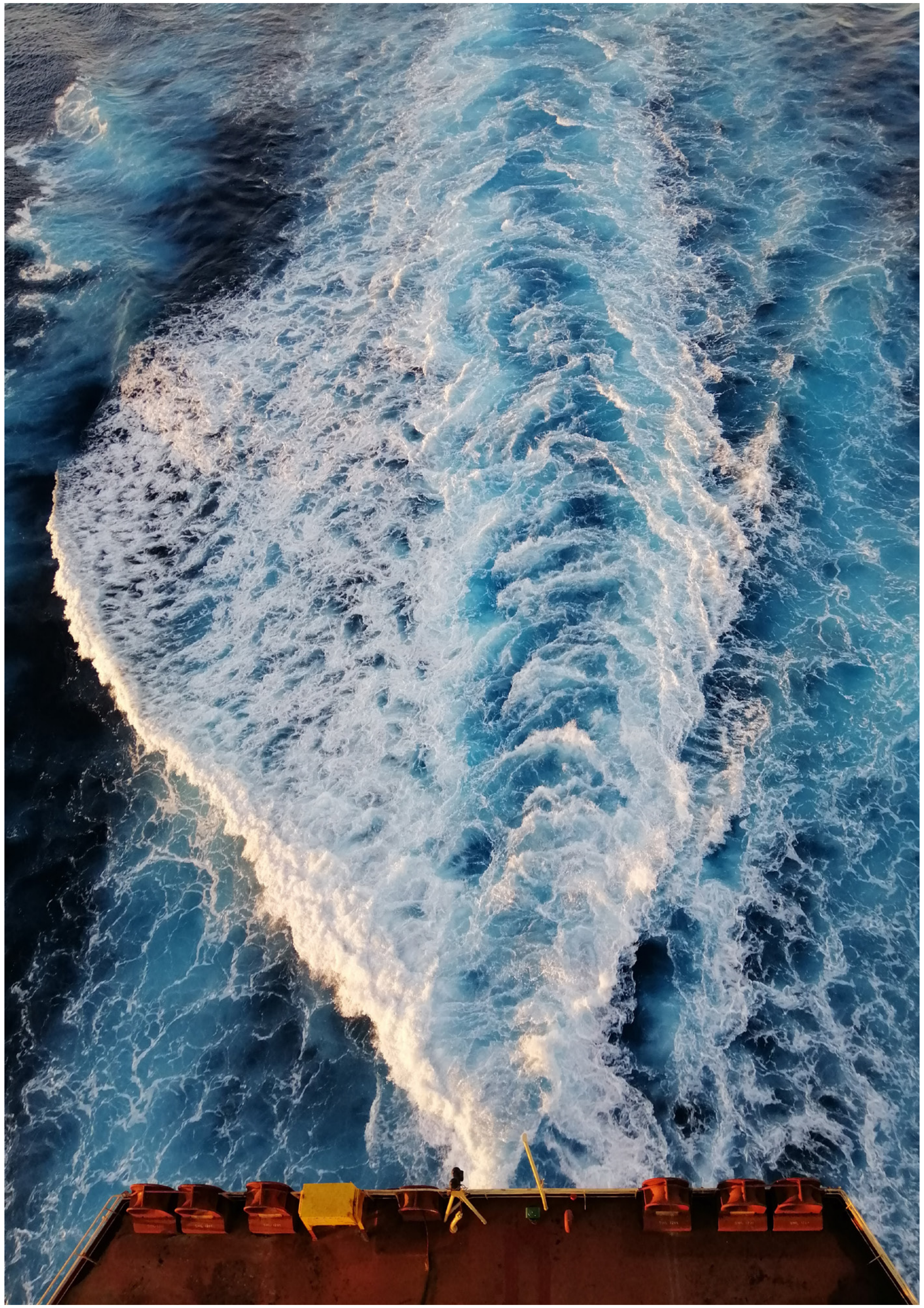
24 EU SkillSea: Future skills and competence needs, deliverable 1.1.3 version 5.0 2022

25 ICS/BIMCO Seafarer Workforce Report 2021

26 World Maritime University: Transport 2040: Automation, technology, employment – the future of work (2019

27 Hamburg School of Business Administration 2018: Seafarers and digital disruption - The effect of autonomous ships on the work at sea, the role of seafarers and the shipping industry.

28 Drewry Ship Operating Costs Annual Review and Forecast 2021/22



CHAPTER 13 Insights into seafarer training and skills needed to support a decarbonized shipping industry

13 Appendices

13.1 Appendix 1: DNV GHG Pathway Model

The DNV GHG Pathway Model has been used to analyse future fleet size and number of seafarers working on board ships with alternative fuel and technologies, as well as LNG/LPG. An overview of the model is shown in Figure 13.1

The DNV GHG Pathway Model comprises the following two core evaluation modules:

1. The fleet development module, in which the future fleet is simulated by adding and removing ships year-by-year. The objective is to provide the fleet supply capacity corresponding to the seaborne trade demand projections used as input. The starting point for the fleet development is the current fleet for the base year 2019, with associated ship activity deriving from actual ship movement data from the AIS tracking data.

2. The abatement uptake module in which the model evaluates available solutions for CO_2 emission reduction on all existing vessels and newbuilds for each year, including alternative fuel technologies, energy-efficiency measures and speed reduction. The ships are fitted with the most cost-effective feasible combinations of measures that fulfil regulatory requirements imposed as input. Possible fuel transitions achieved through drop-in fuels or retrofit of engine and fuel systems are added to the model input.

The regulations underpinning the model assume Tank to Wake emissions. The fuel prices are based on the assumption that they are produced as close to zero well-to-tank as possible – meaning sustainable biofuels (without land use-related emissions), electrofuels from low-carbon electricity and blue fuels from reformed methane with carbon capture and storage (CCS).

The model includes two feedback loops:

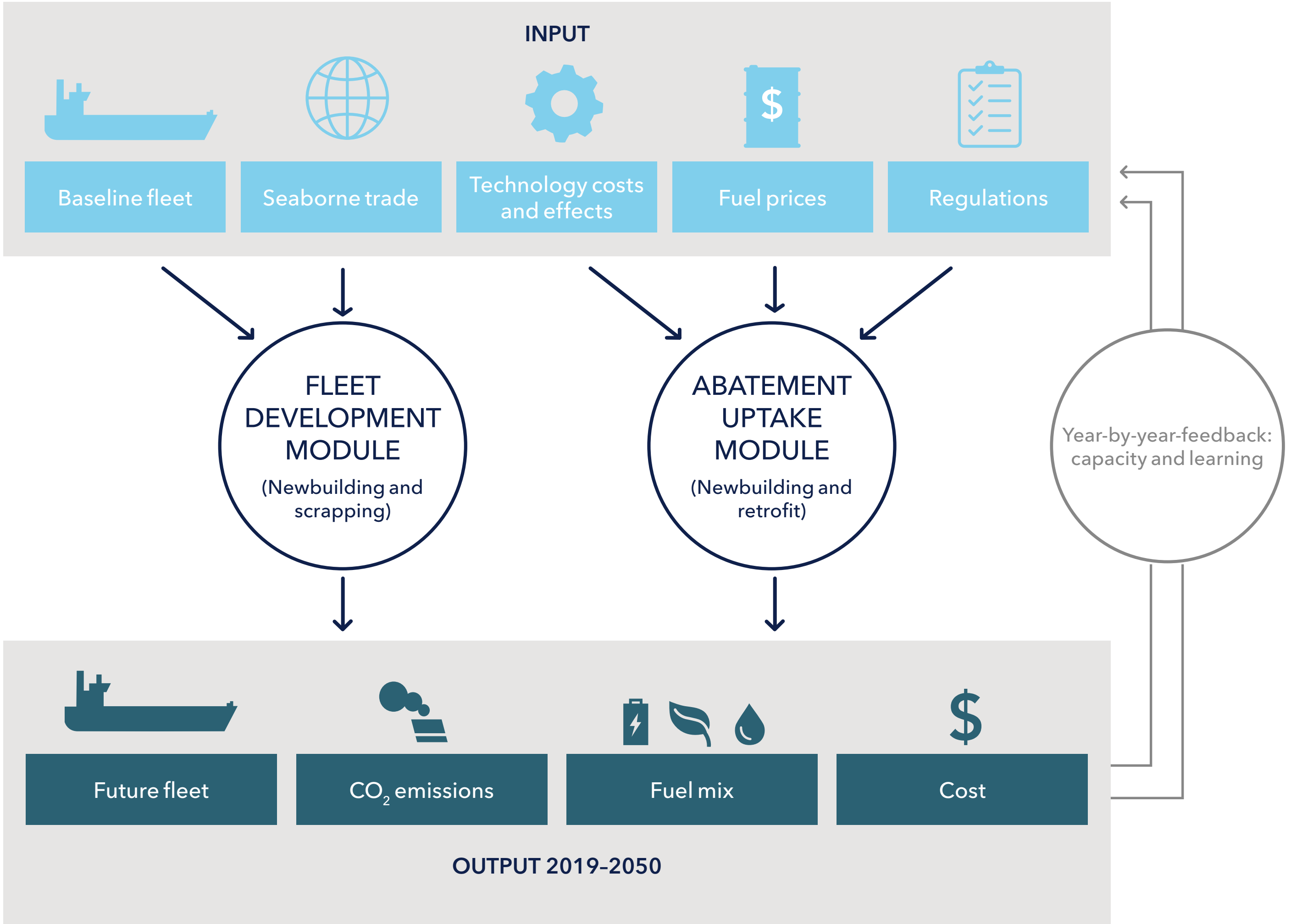
- If speed reductions are adopted by a ship, thereby reducing the trading capacity of the fleet, the fleet development module ensures that additional ships are built to replace the lost capacity.

- In a second feedback loop, uptake of technical measures and fuels results in year-by-year technology learning, which reduces the costs of future installations. The output of the model is vessel specific and provides an overview of energy use, uptake of measures, associated costs and other activity data, such as sailed distance, that can be used to calculate carbon-intensity indicators. At the fleet and segment levels, the output provides projections of the future fleet, fuel mix, CO_2 emissions and abatement cost towards 2050.

More information on the DNV model can be found in the 2021 edition of the DNV Maritime Forecast to 2050, Maritime publications – DNV.

FIGURE 13.1

Overview of the DNV GHG Pathway Model



CHAPTER 13 Insights into seafarer training and skills needed to support a decarbonized shipping industry

13.1.1 Converter options, maturity and compatibility

The allowed engine/fuel cell and fuel-system options, compatible fuels and retrofit options are indicated in Figure 13.2. Drop-in fuels are those that can be used in an engine or fuel cell without any additional retrofit Capex. For each converter option, the model calculates the cheapest fuel combination that will meet the regulatory requirements. Thus, for a dual-fuel methanol engine, the cheapest combinations of bio-methanol, e-methanol, bio-MGO, e-MGO and VLSFO/MGO will be calculated.

We also allow for retrofits from certain engine options to another, as indicated in Figure 13.2. In such cases, this will incur extra Capex for required modifications to the engine and/or to the tanks and fuel system. Allowed retrofit pathways have been determined on the basis of the technical feasibility, with the focus on the implied conversion of fuel-storage systems and engines to each given retrofit fuel. Options that involve a change in the engine type – for example, from an ICE to an electric motor – have been deemed to be technically unfeasible for the general fleet, so have not been allowed in the GHG Pathway Model. Retrofits from one fuel to another have also been disregarded where they would involve significant differences in volumetric energy density; for example, VLSFO/MGO to hydrogen. Finally, retrofits of vessels fuelled by carbon-neutral variants of ammonia, hydrogen and methanol to other fuels have been disallowed altogether.

13.1.2 Energy-efficiency measures

DNV has its own abatement database for different ship types, which has been utilized as input to the Pathway Model. The abatement database covers costs and emission-reduction potential for many technical and operational measures allocated into predefined ship categories. Data on costs and reduction effects for operational and technical measures are based mainly on data from available literature; more than 30 three-phased energy management projects; fuel-consumption data from ship reports; DNV's Technology Outlook activities, and COSSMOS[e] modelling and simulation projects.

FIGURE 13.2

The energy converters, fuel options and transitions allowed in the GHG Pathway Model

FUEL CELLS AND FUEL SYSTEMS / ENGINE						Blue ammonia	Blue hydrogen	
		e-MGO	e-LNG		e-methanol	e-ammonia	e-hydrogen	Electricity from grid
		bio-MGO	bio-LNG		bio-methanol			
ENGINE	HFO	VLSFO/MGO	LNG	LPG				
MF ICE	Retrofit	Drop-in	Retrofit	Retrofit	Retrofit	Retrofit		
MF ICE with scrubber	Drop-in	Drop-in	Retrofit	Retrofit	Retrofit	Retrofit		
DF LNG ICE		Drop-in	Drop-in		Retrofit	Retrofit		
DF LPG ICE		Drop-in		Drop-in	Retrofit	Retrofit		
DF methanol ICE		Drop-in			Drop-in			
DF ammonia ICE		Drop-in				Drop-in		
DF hydrogen ICE		Drop-in					Drop-in	
Hydrogen FC							Drop-in	
Ammonia FC						Drop-in		
Battery EM								Drop-in

Key: Dual fuel (DF); electric motor (EM); fuel cell (FC); internal combustion engine (ICE); liquefied natural gas (LNG); liquefied petroleum gas (LPG); mono fuel (MF)

Drop-in Retrofit

TABLE 13.1

Defining the energy-efficiency packages

EE group	Maturity	Explanation
Baseline EE	–2015	Average energy efficiency of a vessel built before 2015. Includes basic operational measures, as well as standard hull cleaning, propeller polishing, engine auto-tuning and optimization of cargo handling systems
Basic EE	2015–2020	Average energy efficiency of a vessel built between 2015 and 2020. Includes hull form optimization, basic machinery improvements, variable frequency drives, shaft motor/generator, and measures to improve hydrodynamic propulsion, such as devices before the propeller and high-efficiency propellers and rudders.
Enhanced EE	2020–2025	Energy-efficiency measures expected to be mature within five years. Includes first-generation waste heat recovery systems, bow shapes optimized for real sea states, variable engine speed and improved steam-plant operation.
Advanced EE	2025–2030	Energy-efficiency measures expected to be mature within 10 years. Includes, for example, hard sails, solar panels, second-generation waste heat recovery systems, and reduced-ballast design
Cutting-edge EE	2030–	Measures that are expected to mature in more than 10 years are placed in the 'cutting edge' package. Digital twins and onboard wind turbines are included here.

Our model does not evaluate the uptake of each single measure (e.g. waste-heat recovery, air-cavity lubrication). Interactions between the measures are complex to model. Instead, we compile the energy efficiency (EE) measures into internally consistent packages as presented in Table 13.1. The measures included in the different EE packages will depend on the applicability for the ship type in question. This study allocates the EE measures in packages for six main ships segments.

13.1.3 Speed reduction

The model applies five different levels of speed reduction: 0% (sailing at 75–80% of maximum continuous rating, MCR[f]), 10%, 20%, 30% and 50%. The resulting reductions in main-engine power for an individual vessel are estimated based on reported fuel-consumption data from more than 2,000 vessels. Percentage main-power reduction is larger at 10% and 20% speed reduction than at 30% and 50% where the resistance from wind and waves becomes more prominent. Up to 30–35% less fuel is used when speed is reduced by 20%, and 60–67% less when the speed reduction is 50%. Speed reduction comes at a cost. As the transport capacity of the vessel is reduced, its earning capacity also declines. More vessels would have to be built to cover for the lost capacity. In addition, the cargo owner has increased costs due to capital being tied up through longer sailing times. This is reflected in the modelling, where the cost of speed reduction is based on the charter rate of the vessel type and included when considering the most cost-effective measure to apply. The model factors in the applied speed reduction and adds more vessels to make up for the reduced transport capacity.

The fleet sailing in 2019 would already have implemented some of the energy-efficiency and speed-reduction measures. We have assumed that all vessels built before 2015 will have the Baseline EE package while those built from 2015 onward will have the Basic EE package. The difference in efficiency can be observed in the MRV data for 2018 published by the European Commission (European Commission, 2020). In addition, the average speed from the AIS data is used to set an already implemented speed reduction on the baseline fleet in 2019. The model evaluates all combinations of EE packages and speed reductions and selects the combination with the highest net present value.

13.1.4 Logistics

Toward 2050 we expect gradual improvements in the supply chain to increase vessel utilization by about 25% for deep-sea trades excluding bulk (approximately 5% for deep-sea bulk) and some 20% for short-sea trades. We expect average ship sizes to increase by 40% for LNG tankers, 30% for container ships and 10% for bulkers. The sizes of other types of ship will remain as today.

e. DNV GL COSSMOS: Computer platform for modelling, simulation, and optimization of complex ship energy systems.
f. The MCR is the maximum power output from an engine operating continuously within safety limits and conditions increased.

CHAPTER 13 Insights into seafarer training and skills needed to support a decarbonized shipping industry

13.1.5 Regulations

The IMO has come far in developing the first regulations to support its ambitions in the short term. However, uncertainty remains over the pace, form and type of regulatory measures the organization will implement to achieve the desired change towards 2050. To cover this uncertainty, we look at principal ways to incentivize a change (see Table 13.2) – newbuild design requirements and operational emission limits to individual ships, and a carbon price. The design requirements are given as percentage reductions from an EEDI reference line, and the operational requirements as percentage reductions compared with a pre-2013 average ship.

Variations in fuel prices and fleet growth mean different levels of requirements and carbon prices will be needed in each scenario to achieve the desired reduction in GHG emissions. To simplify things, we apply the level needed in the most extreme scenarios – which is the scenarios with high growth and the largest spread between fossil and carbon-neutral fuels – to all scenarios with the same ambition. In all scenarios we assume that the currently adopted EEDI regulations will apply.

13.1.6 Fuel Prices

DNV MF 2020 contains a Marine Fuel Price Mapper, which estimates current and future fuel-prices until 2050. For carbon-neutral fuels, a levelized cost of production and distribution has been used as a proxy for fuel price, an approach based on DNV GL's ExplEnergy[g] tool, which allows analysis of different energy value chains.

The fuel prices are estimated on the assumption that they are produced as close to zero well-to-tank as possible – meaning sustainable biofuels (without land use-related emissions), electrofuels from low-carbon electricity and blue fuels from reformed methane with CCS. The efficiency of the capture rate of CCS and the carbon intensity of electricity are major uncertainties and would need to be at least 90% and less than 40 g/kWh respectively to reduce well-to-wake emissions by 75% relative to fossil fuels today.

The two-step method for calculating carbon-neutral fuel-price trajectories is described below and illustrated in Figure 13.3.

1. Deduction of production costs: Based on a literature review we have mapped the relationship between the cost of fuel production and the price of primary energy sources. The cost of producing biofuels, electrofuels, and 'blue' fuels is assumed to be directly influenced by the price of biomass, renewable electricity and fossil energy respectively. For carbon-based electrofuels, the cost of capturing and utilizing CO_2 (CCU) for fuel production is included. Similarly, the cost of CCS for 'blue' fuel alternatives has also been included. For fuels with immature production processes (e.g. e-MGO), a gradual decrease in future production costs, due to technological developments, is assumed. Where required (e.g. for e-LNG), the cost of additional processes such as liquefaction has been included in the fuel production cost. A variety of information sources (e.g. H21, 2018; Brynolf et al., 2018) have been used as a basis.
2. Calculation of distribution and bunkering costs: Depending on the storage conditions of each fuel product, there will be different costs associated with distribution. For example, distribution of liquefied hydrogen at -253°C will probably incur higher distribution costs than e-MGO which is kept as a liquid in ambient conditions. A review of available literature has been conducted to estimate distribution costs for different fuels (e.g. Delft, 2020; IEA, 2019).

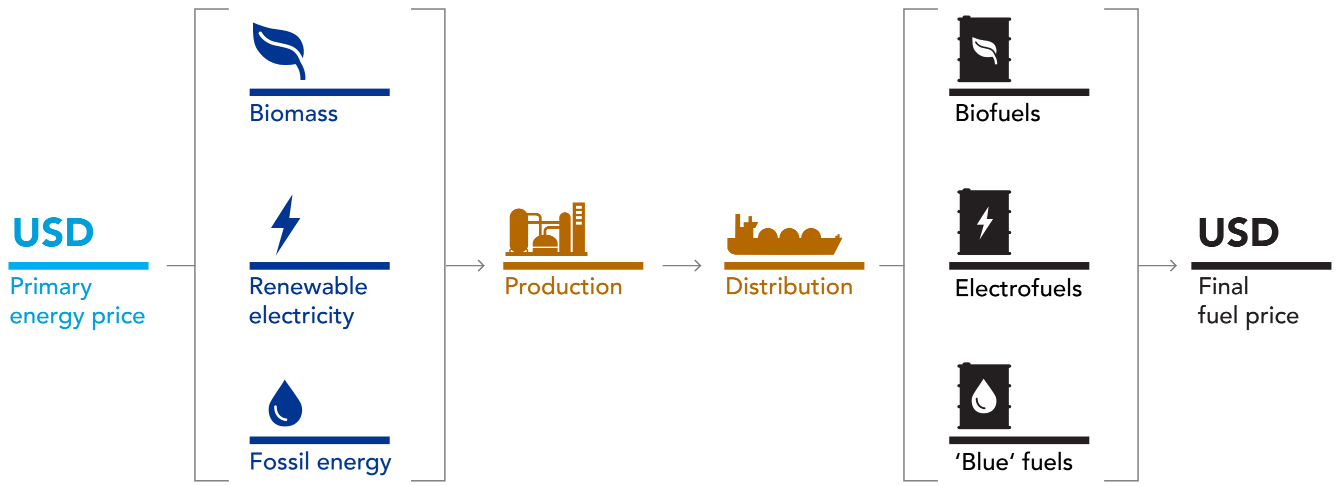
TABLE 13.2

Assumptions regarding regulatory measures and GHG emissions reduction (%)

Ambitions	Regulations	Newbuild requirements	Operational requirements (gradually increasing)
IMO ambitions	Newbuild and operational requirements	Currently adopted EEDI requirements: up to 30% reduction depending on ship type From 2035: 50%-80% reduction depending on ship type From 2040: 90% reduction	2030: 40% reduction 2040: 50% reduction 2050: 60% reduction
Decarbonization by 2050 (95% reduction)	Newbuild and operational requirements	Currently adopted EEDI requirements: up to 30% reduction depending on ship type From 2040: 90% reduction	2030: 40% reduction 2040: 55% reduction 2050: 70% reduction

FIGURE 13.3

Illustration of the method used for calculating future carbon-neutral fuel prices to 2050. For conventional fossil fuels, a different approach has been used



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g. https://www.dnvgl.com/oilgas/contact/explenergy-2019-register-user.html

For the calculation of future bunkering prices for conventional fuels (e.g. LNG and HFO), we have used the historical relationship between bunkering prices[h] and crude oil and natural gas prices. For LNG, a distribution cost has been added to the hub price given in the AFI (Alternative Fuels Insight) platform.

Table 13.3 below shows the assumed price-trajectories of primary energy sources used as input in fuel-price calculations. Due to the long time perspective of the GHG pathway model, recent declines in the natural gas and crude oil prices have not been included in the modelling.

13.1.7 Seaborne trade demand

For the seaborne trade demand, DNV's own updated projection of a 25% growth between 2019 and 2050 has been used (DNV GL, 2020a). This growth is lower than any of the scenarios used in the Third and Fourth IMO GHG Studies. Most of the growth will come before 2030. After that, global seaborne trade will stabilize. Growth in certain segments, especially gas and container trade, will outpace the average rate. However, as the global demand for coal and oil peaks, their trade will also peak, reducing their seaborne trade by more than two thirds and one third, respectively from the peak and till 2050. The projection also takes into account the effect of the Covid-19 pandemic.

FIGURE 13.4

Projected transport work (billion tonne-miles) up to 2050 by main ship categories

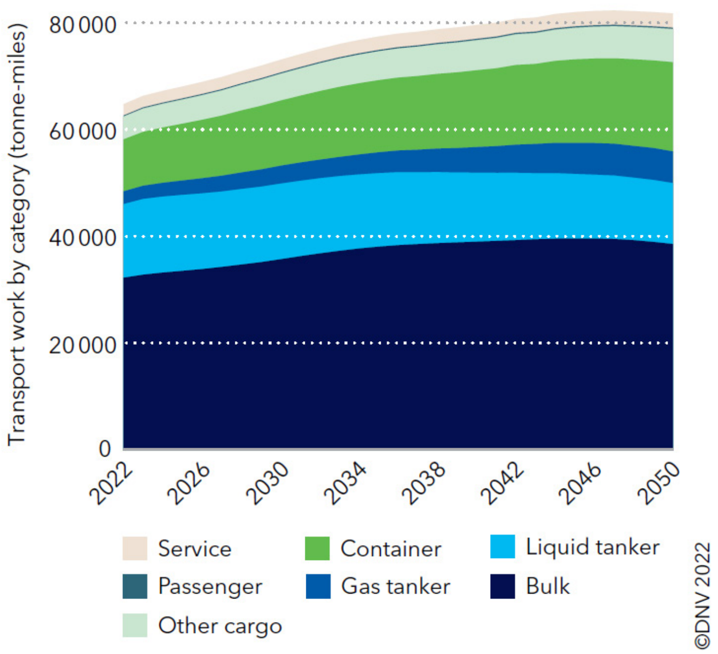

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TABLE 13.3

Assumed primary energy costs by price scenario. Based on current costs and projections for the future cost of primary energy sources (e.g. IEA, 2019, and IRENA, 2019).

Primary Energy Source	2020	2030	2040	2050	Unit
Electricity from renewables[i]	48.2	30.0	25.0	21.0	USD/MWh
Biomass[j]	1.0	1.7	2.0	2.0	No unit
Natural gas[k]	7.7	8.9	9.9	9.9	USD/MMbtu
Crude oil[k]	70.0	89.9	105.2	105.2	USD/barrel

h. Available from afi.dnvgl.com
i. Based on estimated levelized cost of renewable energy production: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/May/IRENA_Renewable-Power-Generations-Costs-in-2018.pdf and https://www.irena.org/publications/2019/Oct/Future-of-wind
j. Average cost of biomass given as a factor relative to cost of biomass in 2020.
k. Based on the fossil-energy price projections from the IEA's Current Policies and Sustainable Development scenarios (World Energy Outlook), with European gas prices.

CHAPTER 13 Insights into seafarer training and skills needed to support a decarbonized shipping industry

13.2 Appendix 2: Lloyd's Register and UMAS pathway model

The model is presented in Lloyd's Register and UMAS' Zero-emission vessels: Transition Pathways as the 'renewables-dominate' pathway.[l]
The inputs used for this paper - Insights into seafarer training and skills needs to support a decarbonized shipping industry - are taken from the LR/UMAS pathway modelling presented in "ZEV transition pathways". This work, undertaken in 2019 represents the fuel and upstream energy mix associated with a transition in primary energy use by shipping that starts in 2020 (100% fossil fuel use for primary energy) and transitions with a constant rate of substitution of energy use in order to reach zero primary energy fossil fuel use in 2050. This scenario assumes that e-fuels, also known as green hydrogen and hydrogen-derived fuels like ammonia and methanol, become dominant over biofuels.

Key assumptions and model parameters, marine fuel and energy source evolution.
The energy mix in the "ZEV transition pathways" study are derived from an energy system model run to find a whole-economy solution that does not exceed the 1.5 C threshold[m]. Achieving a 1.5-aligned decarbonisation for the whole economy requires large amounts of renewable electricity. International shipping is assumed to leverage this wider-scale transition to renewable electricity and derive the majority of its primary energy used from renewable electricity by 2050.

The wider energy system backdrop of rapidly growing renewable electricity production (from 50EJ to 200EJ) is expected to also be associated with a reducing price of renewable electricity. The resulting fuel mix and emissions of the scenario is not contingent on a given price, but it is expected that in locations where conditions for producing renewable energy are favourable (e.g. parts of Latin America and the Middle East), the price approaches 19$/MWh and production of electro-fuels/e-fuels based on green hydrogen is increasingly located in low cost of production countries. The scaling of renewable electricity in geographies suited to low cost production in combination with initiation of volume production of e-fuels in the 2020's is expected to have a positive feedback effect further lowering cost of production. The analysis of this scenario therefore expects that in combination costs of key components (such as electrolysers) reduce to around $500/kW in 2030 and further to $250, which in combination with electricity price forecast data contribute to a cost of production for green hydrogen falling to around $400/t of HFOe (e.g. the price of green hydrogen per unit of energy, falls by 2050 to similar levels to that of HFO today). Comparatively smaller contributions are made to the primary energy mix from bio energy and fossil fuels (used in combination with carbon capture and sequestration (CCS) to produce low GHG hydrogen-derived fuels). The assumptions in the "ZEV transition pathways" renewable dominate scenario, are broadly consistent with more recent modelling also undertaken by UMAS, with UCL and E4tech, in "International Maritime Decarbonisation Transitions".[n] The modelling considered a broad range of candidate fuels and machinery solutions and made the following assumptions.

Energy efficiency technologies, including wind assistance
Technological and operational improvements that lower energy use through efficiency are expected to be further taken up during the 2020's. Their use is driven both by existing regulations, as well as market forces (fuel savings), which strengthen as the sector moves to use more expensive zero emission fuels. Significant further fuel savings from speed reduction do not materialise except through optimisation of logistics e.g. reducing time at anchor through more precise coordination of arrivals and berth utilisation. Overall, the consequence of energy efficiency improvements is for modest impact on absolute GHG emissions, leaving the large majority of GHG reduction needing to be driven from a switch to low and zero emission fuels.

LNG – It is assumed in the modelling that whilst take-up of LNG as a marine fuel occurs in the 2020's, the high GHG emissions mean that the associated technology and infrastructure has a limited role and increasingly has to use bio-LNG/e-methane and hydrogen/methane blends which are less competitive than the emerging low and zero GHG emission fuels. In a decarbonising wider energy system, high demand for bio gas and e-methane for substitution for

l. Lloyd's Register and UMAS (2019) Zero-emission vessels: Transition Pathways. Available online: https://www.lr.org/en/insights/global-marine-trends-2030/zero-emission-vessels-transition-pathways/
m. Huppmann D. at .al (2018), IAMC 1.5°C Scenario Explorer and Data hosted by IIASA. Integrated Assessment Modeling Consortium & International Institute for Applied Systems Analysis, 2018
n. The work in "International Maritime Decarbonisation" is derived from an extensive analysis both of IPCC evidence on 1.5 C, wider energy system transition, and shipping transitions. It is underpinned by evaluations of whether the fuel production and shipbuilding/retrofitting scenarios produced are feasible. In combination, this evidence presents arguments as to why even the numbers used from "ZEV transition pathways" on the scale of the energy transition that shipping is likely to experience if aligning to IPCC science on 1.5C, is conservative. This work is available here: IMarEST submission to ISWG 13, 2022

CHAPTER 13 Insights into seafarer training and skills needed to support a decarbonized shipping industry

on-land use of natural gas means that more competitive use of these fuels, which does not incur the cost of liquefaction and reduces the transport and supply chain costs, makes their use in shipping less attractive. The use of methane on land for hydrogen production, with capture and sequestration of CO_2 byproduct enables some continued role for gas for a duration that depends on how quickly the move to green hydrogen production from renewable energy takes.

Batteries – Batteries are used on smaller ships with short range. However, the pathway foresees little role for them in ocean-going shipping as they have limited potential for substituting liquid fuel use in ocean going shipping. This finding is based on projections of further cost reduction in batteries, however that even with these cost reductions taken into account, they would not be competitive relative to a hydrogen-derived fuel.

E-fuels – Of the e-fuels, the modelling estimates that hydrogen (green or blue) is the lowest cost per unit of energy to produce. This is because hydrogen is the most fundamental liquid/gaseous energy molecule produced from renewable energy and a feedstock for other fuels. Blue hydrogen produced from natural gas with CCS, is assumed to be lower cost in the 2020's, but growth in production is dominated by green hydrogen which has greater cost-reduction potential and lower well-to-wake GHG emissions. E-ammonia and e-methanol (produced using low and zero GHG hydrogen and CO_2 captured from the atmosphere) are also considered in the analysis and based on costs and competitive are expected to become the dominant e-fuels. The production process differences are expected to result in e-methanol being more expensive than e-ammonia (30-50% more expensive per unit of energy) however with lower costs associated with onboard storage and use than ammonia. Liquid hydrogen's use as a fuel is explored and has the potential to be competitive relative to ammonia and hydrogen if there are large cost reductions associated with storage, but without evidence of those cost reductions, this outcome is considered unlikely. E-gas oil (also known as e-MDO), is considered but dismissed as it is forecast to be even more expensive than e-methanol and therefore uncompetitive. E-fuel use with both internal combustion and fuel cell solutions is considered. Under scenarios with large cost-reductions for fuel cells (including for use with hydrogen, ammonia or methanol), they can become competitive relative to internal combustion engines.

Biofuels – bio variants of existing and future fuel molecules are considered (bio-gas oil, bio methanol and bio methane). In the scenario used in the "ZEV transition pathways" their production is assumed to grow steadily between 2020 and 2050, but by 2050 they only contribute approximately 25% of the total energy demand for international shipping. The majority of energy used in international shipping is renewable energy. In a global economy on a 1.5-pathway, there is the added demand for both aforrestation and biomass use with CCS on land (to produce negative emissions), both of which further reduce sustainable supply for use in shipping. Taking the competition for biomass into account, [o]the scenario's assumption of 25% of bioenergy relative to total energy used in international shipping in 2050 therefore appears high. This means that the estimate for the sector's demand for e-fuels is conservative and even higher levels and rate of growth may be needed.

Key assumptions and model parameters, policy and stakeholder actions

- ZEV transition pathways is agnostic as to the specifics of the policy used to drive a transition away from fossil fuel use. However, the assumed scenario is expected to require clear policy. This includes further policy measures particularly to incentivise an early shift to long-run scalable fuels such as e-fuels, and to further increase the energy efficiency of both the existing and future fleets.
- The scenario produced is associated with a gradual reduction in fossil fuel use to a lower and ultimately zero GHG emissions on a well-to-wake basis. This can be driven by command and control policy (such as a mandate or fuel standard). But equally, it can also be driven by carbon pricing, acing in isolation or in combination with mandates/fuel standards.
- The modelled outcome is expected to come about not only by regulation, but also through collaboration across the value chain (ports, financiers as well as owners), and through an expected increase in civil society pressure. *"Employee focus groups and surveys could be implemented for roles going from high-carbon solutions to low-carbon solutions, asking them why we need to make this change and where we go from here."*

o. Energy Transitions Commission (ETC) (2021) Bioresources within a Net Zero Emissions Economy. Available online: https://www.energy-transitions.org/publications/bioresources-within-a-net-zero-economy/

TABLE 13.5

Estimated number of crewmembers per ship type

Type of vessel	Estimated number of crew members
Bulk carrier	23
Chemical tanker	27
Container	24
Cruise	35
Ferry-pax	15
Ferry-ropax	25
General cargo	23
Liquefied gas tanker	24
Miscellaneous fishing	14
Miscellaneous other	14
Offshore	14
Oil tanker	27
Other liquids tanker tankers	24
Refrigerated bulk	22
Ro-ro	23
Service other	14
Service tug	5
Vehicle	23
Yacht	9

13.3 Appendix 3: Method to estimate number of seafarers

The first step was to estimate the typical number of crew-members, including engine room, bridge and deck staff[p], needed to run a ship within each of the 19 ship categories used in the DNV GHG Pathway model. Two main sources for information were used: Drewry Ship Operating Costs Annual Review and Forecast 2021/22[27] and ICS BIMCO Seafarer Workforce Report 2021. Both reports use information received from ships and other sources in order to give typical crew sizes on board a number of different ships. In case estimates were only found in one source, DNV expert estimates have been included. The estimated number of crewmembers is presented in Table 13.5.

The next step was to estimate the split between engine room, deck and bridge. As this split is not included in the sources used, a simplified division was made between engine room and deck/bridge crew. The analysis showed a 50/50 split between these two groups. Although there is some variance in the split, it was deemed reasonable by DNV experts.

The DNV GHG Pathway model predicts how many vessels will need to use a different fuel in order to meet certain emission targets for each year from today until 2050. The number of crewmembers was then used to find the total number of seafarers in need of training by multiplying the number of ships with the estimated number of crew members.

The number of crewmembers on board ships has gradually decreased due to automation and other factors. It can be argued that this trend will continue, given the ongoing digitalization and perhaps a shift to more remote-controlled and/or autonomous ships. In the calculations presented in this report, we have assumed that the number of crew-members needed to run each ship type will not change over the period.

TABLE 13.4

Seaborne trade demand growth assumptions

	Average annual change			
Assumptions	**2022-2030**	**2031-2040**	**2041-2050**	**Total change 2022-2050**
Bulk	1.4%	0.9%	-0.1%	**22.3%**
Liquid tank	0.5%	-0.9%	-1.3%	**-15.9%**
Gas tanker	4.4%	3.6%	2.2%	**160.2%**
Container	2.9%	1.7%	1.5%	**77.2%**
Other carge	2.2%	1.2%	1.0%	**50.5%**
Passenger and Service	1.7%	0.8%	0.3%	**31.2%**
Total growth	**1.6%**	**0.9%**	**0.3%**	**29.5%**

p. Catering staff and passenger service personnel on cruise ships are left out of the estimate.

13.4 Appendix 4: Individual views expressed by a range of stakeholders, including seafarers and shipowners

“Many companies are already taking initiatives to reskill their seafarers with regard to modern technologies, using new training methodologies including AR/VR.”

“The unions are here to help, please use our expertise and our contacts. It is easy to get seafarers together, get groups of members together, conduct surveys.”

“Important to recognize that it is not only about training. The people who will work with it must embrace it. A good safety culture is important, and this takes time.”

“New technology allows for new ways of training people no matter where they are located. The training standards should not be compromised based on where you are located.”

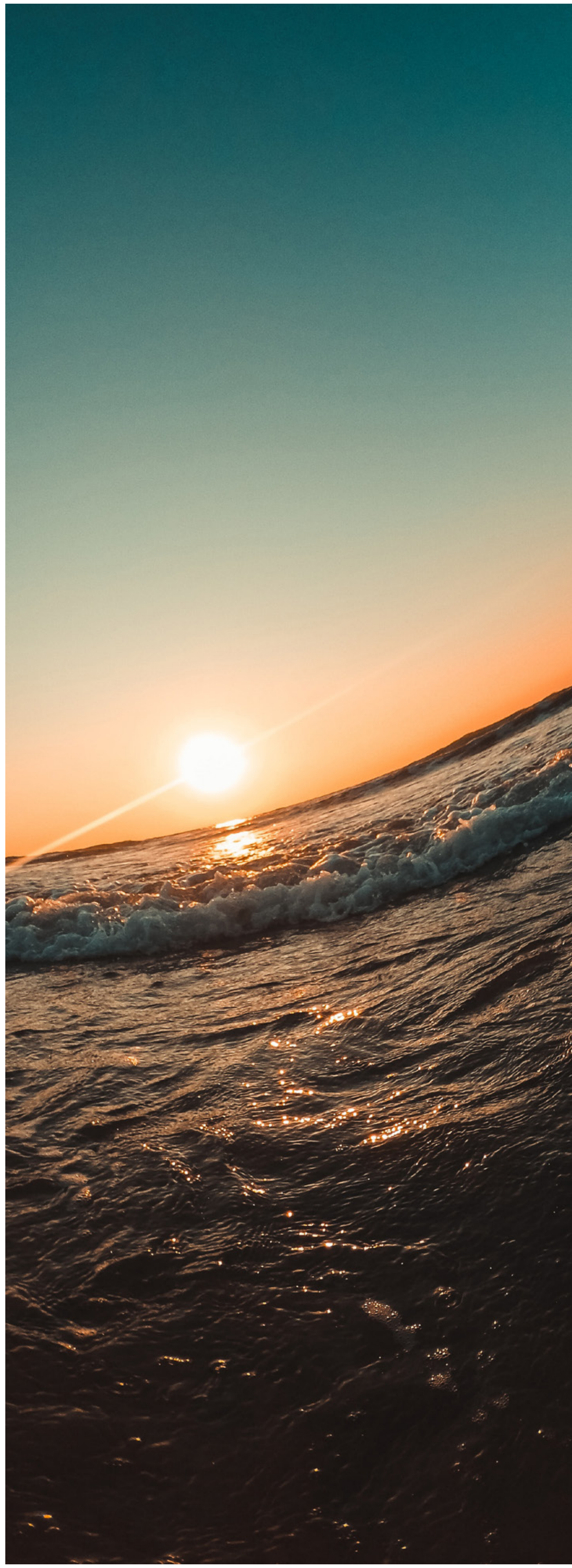
“We should support capacity building measures worldwide already now, even though we do not know which fuel type will prevail in the future. Training standards can be fine-tuned when the value chains of new fuel types will be clearer.”

“We should identify the different training centres world-wide and prepare a train-the trainer programme for alternative fuel technologies.”

“The next generation of seafarers is often trained by existing seagoing crewmembers. Are we moving towards a future where people have less seagoing time and take jobs on land with higher salaries?”

"Employee focus groups and surveys could be implemented for roles going from high-carbon solutions to low-carbon solutions, asking them why we need to make this change and where we go from here."

“The STCW revision does not happen quickly. How do we balance the need for a global standard with the need for fast action?”



ABOUT DNV

DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and in-depth expertise, DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions.

Whether assessing a new ship design, optimizing the performance of a wind farm, analysing sensor data from a gas pipeline or certifying a food company's supply chain, DNV enables its customers and their stakeholders to make critical decisions with confidence.

Driven by its purpose, to safeguard life, property and the environment, DNV helps tackle the challenges and global transformations facing its customers and the world today, and is a trusted voice for many of the world's most successful and forward-thinking companies.

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