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Fossil fuel carrying ships and the risk of stranded assets

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Executive summary

The transition toward a low or zero-carbon global economy, particularly in electricity generation, transportation, and industrial sectors entails substituting fossil fuels with renewable electricity or other low or zero-carbon alternatives. The decline in demand for fossil fuels can therefore create demand-side risks for the ships used to transport those fuels.

Aims and objectives

This report focuses on the risk of stranded assets for stakeholders of the shipping industry involved in the shipping of fossil fuels as a cargo and aims to understand the following:

1. Who builds, finances, owns, flags, and operates fossil fuel carrying ships (fossil fuel carriers)?
2. What is the current value and age structure of the fleet of fossil fuel carriers?
3. What type and number of fossil fuel carriers will retire naturally until 2050?
4. What will be the over-capacity of fossil fuel carriers in a 1.5°C scenario until 2050?
5. What will be the volume of stranded assets in the form of book loss and lost profits[1] under different shipbuilding scenarios: no new ships ordered as of 2024 versus continued newbuilding until 2030?
6. What is the gap between existing and necessary ship recycling capacities, also considering the Hong Kong Convention[2]?
7. What segments of the fossil fuel carrying fleet can be repurposed for carrying other forms of energy or other commodities?

Key findings

- The ownership and the operation of the fossil fuel carrying fleet is fragmented across many actors. For oil tankers and bulk carriers, the fleet is made up of many small actors, and owner and operators of oil tankers are highly specialized in that segment. Comparatively, the LNG and LPG segments are somewhat less but still fragmented and specialised in those two segments. This means that if the risk of stranded assets materialises, a large number of operators and owners will be impacted, some more than others.
- Flag states are found to flag all the different types of fossil fuel carrying ships as well as other ship types, so have less exposure to stranded asset risks. One exception to this relative diversification is Bermuda where nearly half of its flagged ships are LNG tankers. Similarly, shipyards demonstrate considerable diversity in terms of their capability to build across the different shipping segments, with only a few exclusively focused on constructing fossil fuel carriers. Generally, this diversification reduces the sensitivity of shipbuilders and flag states to demand-side stranded asset risks.
- In addition to the stranded asset risks for liquefied gas (LNG and LPG) tankers, oil tankers are also projected to be in oversupply and therefore at risk of being stranded, with a peak of oversupply around 2030 if the demand for oil and gas aligns with a 1.5°C scenario. Coal carriers are found to be much less at risk of being stranded, as they can more readily switch to transporting other commodities; it is expected that demand for bulk cargo increases, and this can more than compensate for the fall in coal transportation demand.

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[1] This report used two monetary estimates of stranded assets: first, book loss, i.e. a ship's capital value which would be lost if it were decommissioned early or unexploited before its projected economic lifetime; and second, lost profits, i.e. the reduction in financial income that may result from a low-carbon transition.

[2] The Hong Kong Convention is an international treaty by the IMO, aiming to ensure safe and environmentally friendly ship recycling. It sets standards for recycling facilities, focusing on worker safety and environmental protection. Despite adoption in 2009, it hasn't come into force, awaiting ratification by enough countries. Upon enforcement, it will regulate ship recycling globally, managing hazardous materials and promoting sustainability in the maritime sector.

Oil tankers can, in principle, be repurposed to carry a different cargo, and have some potential to mitigate their stranding risks. However, this potential may be limited by technological and economic challenges as well as trading restrictions (cargo size and port restrictions). The shipping assets that transport fossil fuels represent a large capital cost and investment.

- The total estimated value of the existing and ordered fossil fuel carrier fleet is at around USD 875 billion in 2023, where bulk carriers account for approximately USD 336 billion, followed by oil tankers at USD 286 billion, LNG tankers at USD 186 billion, and LPG tankers at USD 67 billion.
- One consequence of an oversupply for ships that remain in service, is that profits[3] may sustain at much lower levels than the levels expected when the investment decision was initially made. For example, over the period of 2024-2050, the report finds that USD 214 billion of expected profits would not materialize if demand aligned with a 1.5 °C trajectory, even if no new ships are ordered during this period, see Figure 1. This estimate does not include the potential profits if those ships are retrofitted to move new cargoes and should therefore be understood as maximum profits at risk. This represents around 32% of the expected profits over the period from the existing and ordered fleets. This amount increases to USD 286 billion in the scenario where newbuilding continues to 2030, or 37% of the estimated expected profits.
- Another consequence of an oversupply, if ships are retired earlier than their expected lifespan, is that part of the fleet could be left stranded. The report estimates that the book loss could peak at USD 90 to 108 billion by 2030 if no new ships are ordered (25 to 30% of the oil and gas tankers' fleet value in 2030), increasing to USD 121 to 147 billion with further ordering (27 to 33% of the oil and gas tankers' fleet value in 2030), see Figure 1.
- The estimated demand that may fail to materialize corresponds to approximately 1.3 to 1.5 billion tonnes of cumulative CO_2-equivalent shipping emissions by 2050 if no new ships are commissioned and rising to 2 billion tonnes if new builds continue. This equates to roughly 1.2 to 1.9 times the 2018 annual shipping emissions and comprises 11 to 15% of the remaining carbon budget for shipping aligned with a 1.5°C trajectory. This also indicates that under expectations of IMO regulation to control shipping GHG emissions, the fossil fuel carrying fleet can expect rising costs (to comply with GHG regulation) at the same time as declining profits and declining valuations.
- The materialisation of demand-side stranded assets risks significantly increase the demand for shipbreaking. If stringent regulation regarding shipbreaking practice is implemented and enforced, the materialisation of stranded assets might put some additional pressure on the shipbreaking market. In a tighter shipbreaking market, higher prices may lead to a potential decrease in scrapping value to shipowners, therefore further increasing the total value at risk of stranding. At the time of writing, the capacity which is potentially compliant with the Hong Kong Convention is not known. Also, it remains to be seen whether the requirements of the Hong Kong convention would create such an effect. On the one hand, the lack of enforcement mechanisms and the continued practice of beaching might mean that the supply for shipbreaking continues to be elastic in the future. On the other, a strengthening of the Convention's requirements, or the difficulties of yards to obtain a Statement of Compliance proving that they are compliant with the Convention, could create such an effect.

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[3] The profits calculated in the report correspond to the profits after fuel expense and ships operating costs. Those are reported by Clarksons SIN which is based on the BDO OpCost survey, and includes crew wages, other crew, lubricants, stores, spares, repairs & maintenance, H&M insurance, P&I insurance, management fees and dry docking. This does not consider several operating expenses typically reported in financial statements, for example capital depreciation.

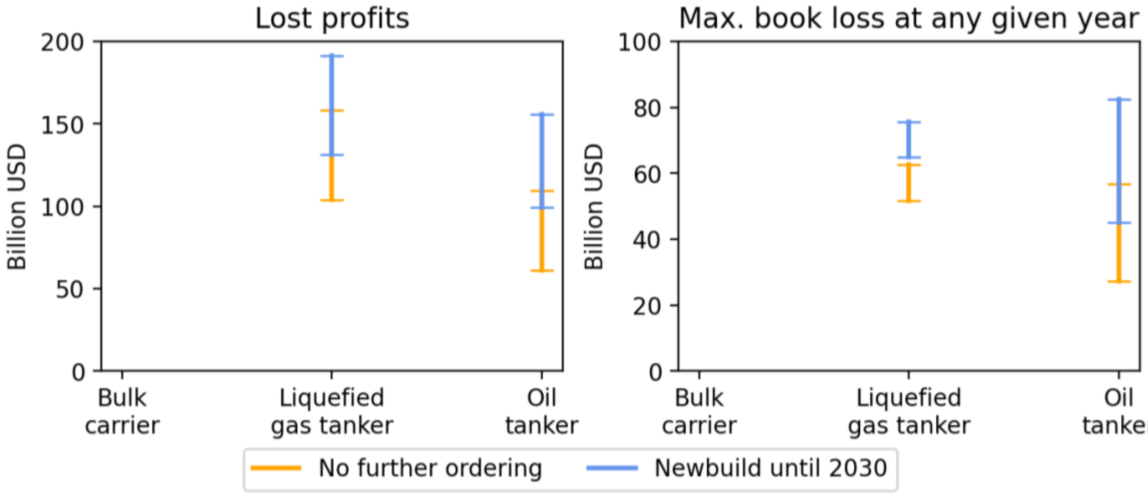

Figure 1: Cumulative demand-side risk until 2050. Demand aligns from 2023 onwards.

a. *Book loss corresponds to the maximum value of the unused fleet due to the lack of demand at any point in time over the 2024-2050 period. This is likely to be an overestimate, as some of those ships would be used at other points in time.*

Implications

The findings suggest that a potentially large share of the fossil fuel carrying fleet, particularly oil and gas tankers, is at risk of being stranded, should the world economy align with a 1.5 °C trajectory and fossil fuel demand falls significantly. Shipowners and financiers could manage or account for those risks by avoiding investment in segments with uncertain future transport demand, investing in optionality for repurposing to other cargoes, and by factoring this risk into expected returns.

Repurposing fossil fuel carriers to other commodities could be seen as one of the more sustainable ways to mitigate some of these demand-side risks, which potentially also avoids additional emissions due to scrapping and newbuilding. Various factors, however, determine whether and to what extent these carriers can be repurposed. Coal carriers, for instance, sit on one end of this spectrum, in that they can readily carry other dry commodities, and also switch back and forth between them. LNG tankers, however, sit at the other end of the spectrum, as they are highly specialised and significantly more difficult to convert to carry non-fossil gases or even other liquids. Oil and LPG tankers fall somewhere in between. The former could be considered much more readily convertible to carrying liquid chemicals such as methanol or bio-based products, offering them a relatively certain opportunity to continue operations. They may, however, face obstacles regarding their suitability for the batch sizes to be transported, and their compatibility at ports or facilities that the chemical industry currently uses; most oil tankers today are significantly larger than the typical sizes at which chemicals like methanol are moved or traded. Whilst oil tankers may have multiple liquid cargo options, LPG tankers may not have many other options other than ammonia and their value and profits will therefore be highly sensitive to the growth in the seaborne trade of ammonia. All of these changes incur a cost that can vary from small to very large and eventually prohibitive, depending on specific circumstances and market conditions. It would therefore be prudent to consider an estimate of these costs relative to the alternatives in any calculation of risk and expected returns.

Method

This report uses a range of methods to answer the research questions. The mapping of the fleet and actors is conducted using Clarksons World Fleet Register (WFR). Estimates of future capacity, oversupply and scrapping activity are based on a model using Clarksons WFR and the Fourth IMO GHG Study demand scenarios aligned with a 1.5°C trajectory. Finally, the assessment of the possibility to repurpose fossil fuel carriers is based on interviews with industry practitioners.

RQ	**Method**
1	Literature review and data collection from Clarksons WFR
2	Data collection from Clarksons WFR and modelling of ships second-hand value based on regression of the ships' newbuild value and the average scrapping age from Clarksons WFR (methods detailed in Fricaudet et al, 2024)
3	Modelling of fleet evolution, overcapacity and risk of stranded assets based on the output from RQ2 and the demand scenarios from the Fourth IMO GHG Study (methods detailed in Fricaudet et al, 2024)
4	
5	
6	Modelling of the demand for ship breaking detailed in the report
7	Interviews with industry practitioners

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Disclaimer

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About UCL Energy Institute

The UCL Energy Institute hosts a world-leading research group focused on the decarbonisation of the shipping sector. The shipping research group undertakes research to support the above using models of the shipping system, shipping big data, and social science analysis of the policy and commercial structure of the shipping system. The research group's multi-disciplinary work is underpinned by state-of-the-art data supported by rigorous models and research practices, which makes it have a cutting edge on three key areas; using big data to understand drivers of shipping emissions, using models to explore shipping's transition to a zero emissions future and providing interpretation to key decision makers in the policy and industry stakeholder space.

About Kühne Climate Centre

The Kühne Climate Center is part of the Kühne Foundation, a family-owned operative foundation that primarily implements its own projects and programs. The Center develops and implements logistics-oriented solutions that reduce emissions, remove CO_2, and strengthen climate resilience to drive the transition to a just, low-carbon society. It has three established workstreams: Applied Projects and Expertise; Building Skills for Green and Resilient Development, and Foresight and Analysis under the theme 'Transport and Logistics for the Low-Carbon Society of 2050'. In this area, the Center strives to lay out the structural changes in the economy to which transport and logistics will need to adapt, the capacities the sector has to develop, and the opportunities it can seize to enable sustainable development at the global and local scale.

Contents

1 Introduction

In its updated net zero scenario 2050, the International Energy Agency (IEA) estimates that by 2050, demand for coal falls by 90% to 500 million tonnes, for oil by 75% to 24 million barrels per day, and for natural gas by 78% to 900 billion cubic meters (IEA, 2023). The shift toward a low or zero-carbon global economy, particularly in electricity generation, transportation, and various other sectors and applications, entails substituting fossil fuels with renewable electricity or other low or zero-carbon alternatives. While long-term global trade is predominantly driven by GDP, it is also influenced by the energy strategies adopted in the aforementioned sectors (Sharmina et al., 2017; Walsh et al., 2019). The decline in demand for and trade of fossil fuels would lead to a reduced demand for transporting coal, oil, and fossil gas — what Smith et al. (2015) defines as "demand-side risk". Additionally, it could potentially precipitate the obsolescence and devaluation of specific shipping segments. While the decrease in demand for the transportation of fossil fuels may be somewhat substituted by a demand for transporting alternative fuels like bioenergy, hydrogen-derived fuels or eventually CO_2, it is improbable that these alternatives will entirely compensate for the overall decline in energy transportation (Jones et al., 2022).

With the decline of fossil fuel trade, the shipping industry will need to restructure its investments to avoid stranded assets and to seize new market opportunities. Ships are capital-intensive, long-lived assets with lifetimes of 20 to 50 years. Currently, more than a third of the global fleet is used to transport fossil fuels[4]. Investments in new bulk carriers and oil tankers continues, and investments in LNG tankers are surging(Clarksons Research, 2022). The financial resources currently locked up in fossil fuel carriers could be re-channelled into activities in support of green industries to align with a 1.5°C temperature increase target. Some vessels may be repurposed, others will be retired, which further raises the question of their safe and sustainable recycling, with ship recycling capacities currently concentrated in Asia: --Bangladesh and Pakistan recycle 72%, India 18% of ships (UNCTAD, 2022), largely under unsafe conditions for workers and the environment (Abdullah et al., 2023; Ahmad, 2022). After 16 years, The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships aiming to improve these conditions will enter into force in June 2025(IMO, n.d.)

This report focuses on the risk of stranded assets for stakeholders of the shipping industry, which ship fossil fuels as a commodity. We further focus on the concept of "stranded capital" (Daumas, 2023; van der Ploeg & Rezai, 2020), i.e., assets that are projected to lose value or require costly conversion; and the expected profits from these assets, which would not materialise if the world economy decarbonises (lost profits) (Daumas, 2023; van der Ploeg & Rezai, 2020).

1.1 Aim and research questions

The purpose of this research is to analyse the current structure the fossil fuel shipping fleet and to model the transformations it will go through towards a 1.5°C-aligned scenario. This report is the first-of-its-kind analysis with the objective to raise financiers' and shipping industry's actor awareness for the need to assess and restructure their fleets, and to re-channel investments towards assets compatible with and needed in a 1.5°C-aligned scenario up to 2050. It is written in parallel with the article Fricaudet et al (2024) and uses the results from this paper to answer the research questions.

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[4] 36%, calculated using the deadweight of the existing and ordered fleet of liquefied gas tankers and oil tankers, plus a further 17% of the deadweight of the existing and ordered fleet of bulk carriers from Clarksons WFR (Clarksons Research, 2022). 17% is the share of the coal trade in bulk trade (in tonne-miles) from Clarksons Shipping Intelligence Network (SIN)(Clarksons Research, 2023).

The following research questions (RQ) are being addressed in this report:

1. Who builds, finances, owns, flags, and operates fossil fuel carriers?
2. What is the current value and age structure of the fleet?
3. What type and number of vessels will retire naturally?
4. What will be the overcapacity of fossil fuel carriers in a 1.5 °C scenario until 2050?
5. What will be the volume of stranded assets under different shipbuilding scenarios (no new ships ordered, and continued newbuilding until 2030)?
6. What is the gap between existing and needed ship recycling capacities, also considering the Hong Kong Convention?
7. What type of vessels can be repurposed for carrying other forms of energy or other commodities?

1.2 Overview of the research methods

A wide range of research methods were used to answer the research questions and are summarised in Table 1. The main stakeholders who are economically involved with fossil fuel carriers (RQ1) were identified based on the Clarksons WFR and existing evidence from the literature. The structure and age of the fleet (RQ2) were described using the data in the Clarksons WFR. Its current and future value (RQ2) was estimated using the results of a regression of newbuild ship prices and average age at scrapping (details in Fricaudet et al, 2024). Future evolution of the fleet, potential for stranded assets and early scrapping (RQ3 to 5) were estimated using a model of the fleet and is based on the estimates of future demand for transporting fossil fuels estimated in the Fourth IMO GHG Study. This methodology is described in detail in Fricaudet et al. (2024). The model used to answer RQ6 builds on the outputs from RQ3 to 5 and is described in the report. Finally, the potential for repurposing fossil fuel carriers to other commodities is assessed based on interviews with industry practitioners.

Table 1: Summary of research methods

RQ	Method
1	Literature review and data collection from Clarksons WFR
2	Data collection from Clarksons WFR and modelling of ships second-hand value based on regression of the ships' newbuild value and the average scrapping age from Clarksons WFR (methods detailed in Fricaudet et al, 2024)
3	Modelling of fleet evolution, overcapacity and risk of stranded assets based on the output from RQ2 and the demand scenarios from the Fourth IMO GHG Study (Faber et al., 2020)(Faber et al., 2020) (methods detailed in Fricaudet et al, 2024)
4	
5	
6	Modelling of the demand for ship breaking detailed in the report, using the findings from (Solakivi et al., 2021)
7	Interviews with industry practitioners

1.3 Overview of the report

The report is structure as follows: the next section describes the current fleet of fossil fuel carriers, and its future evolution up to 2050. The following describes the main stakeholders of fossil fuel carriers, namely the owners, operators, builders, flag states and financiers and answers RQ1. Section 4 presents the results of the modelling exercise and the estimates of stranded assets up to 2050. It answers RQ3, 4 and 5. Section 5 describes the potential for repurposing those ships to alternative cargoes and answers RQ7. Finally, section 6 discusses the estimated early scrapping with the existing ship recycling capacity and answers RQ6.

2 Characterisation of the fossil fuel carrier fleet

Fricaudet et al. (2024) estimates the total value of the existing and ordered fleet to be around USD 875 billion as of 2023. Bulk carriers account for approximately USD 336 billion, followed by oil tankers at USD 286 billion, LNG tankers at USD 186 billion, and LPG tankers at USD 67 billion (see Figure 2). It is anticipated that these vessels would generate, under business-as-usual conditions, profits of USD 1.2 trillion out to 2050, with bulk carriers contributing USD 490 billion (if the share of coal in bulk remains constant in the future, that would mean 83 billion for coal shipping only), oil tankers USD 234 billion, and liquefied gas tankers USD 446 billion.

The current and ordered capacity of fossil fuel carriers is predominantly comprised of bulk carriers and oil tankers, whereas LNG and LPG tankers constitute a smaller proportion in terms of both vessels and deadweight (see Figure 2 and Table 2). Nevertheless, due to the higher costs associated with LNG and LPG tankers, they account for a disproportionately larger share of the value of the fleet. Furthermore, the current orderbook for bulk carriers, and particularly for oil tankers, is relatively constrained, accounting for only 9% and 7% of the current fleet deadweight, respectively. However, the orderbook for LNG and LPG tankers is extensive, comprising 55% and 28%, respectively. Consequently, new or upcoming ships (from the 2021-2030 generation) constitute over half of the value of their respective fleets (see Figure 2 and Table 2).

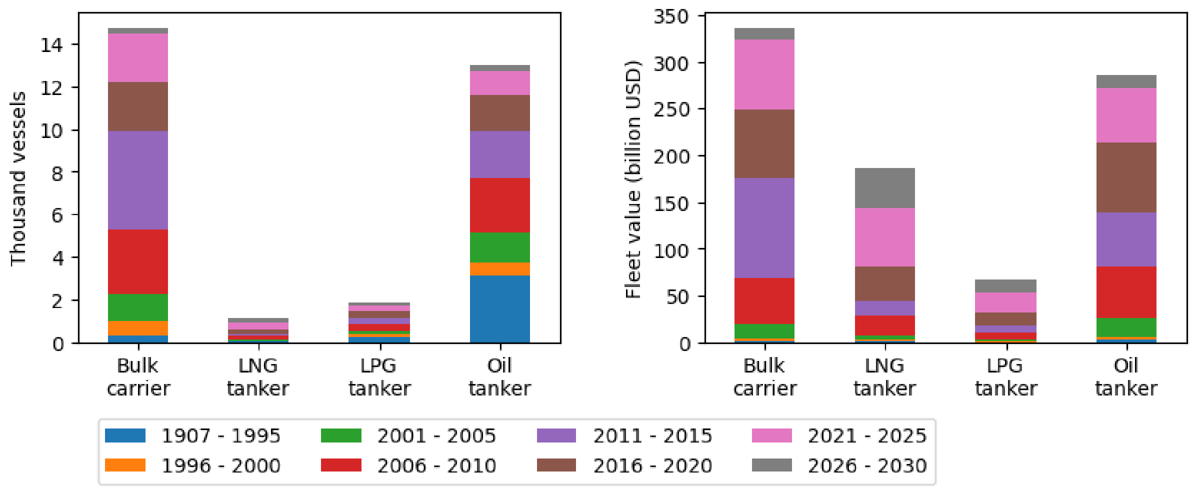


Figure 2: Fleet value by segment and build generation in 2023, under the scenario “No further ordering”. From Fricaudet et. al (2024)

Table 2: Descriptive statistics on the fleet of fossil fuel carriers, by shipping segment

Shipping segment	Number of existing ships	Number of ordered ships	Existing deadweight	Ordered deadweight	Average age	Average scrap age	Average newbuild value (USD million)	Average scrap value (USD million)
Oil tanker	12,385	581	664,460,178	47,962,014	19.9	29.7	43.2	3.5
LPG tanker	1,628	210	33,159,048	9,290,259	14.1	33.2	46	1.4
Bulk carrier	13,555	1,191	1,002,469,771	90,942,161	11.5	28.8	32.9	4.6
LNG tanker	752	356	60,775,869	33,246,700	7.2	37.8	194.6	5.3

a. *Calculated based on Clarksons WFR*

b. *Ships are noted “ordered” if their build year is equal or greater than 2024.*

c. *The average age and average scrapping age come from Fricaudet et al (2024)*

d. *The average prices are calculated using the regression coefficients reported in Fricaudet et al (2024) applied on the fleet reported in Clarksons at the time of writing.*

Table 3: Average age, average scrapping age, average newbuild value and scrap value of the current and existing fossil fuel carriers, by shipping segment and size bin

Shipping segment	Size bin	Min. size	Max. size	Unit	Number of ships	Av. age	Av. scrap age	Av. newbuild value (USD m)	Av. scrap value (USD m)
Oil tanker	1	0	4,999	dwt	5,220	28.9	36.0	26.8	0.1
	2	5,000	9,999	dwt	1,235	17.4	31.2	29.3	0.4
	3	10,000	19,999	dwt	327	15.7	35.4	32.5	0.9
	4	20,000	59,999	dwt	2,391	12.5	25.3	44.0	2.9
	5	60,000	79,999	dwt	476	14.0	21.5	51.3	4.5

Shipping segment	Size bin	Min. size	Max. size	Unit	Number of ships	Av. age	Av. scrap age	Av. newbuild value (USD m)	Av. scrap value (USD m)
	6	80,000	119,999	dwt	1,274	11.3	21.6	59.4	6.9
	7	120,000	199,999	dwt	747	10.8	22.6	71.1	9.7
	8	200,000	max	dwt	931	11.6	22.5	106.5	19.1
LPG tanker	1	0	49,999	cbm	1,284	16.8	32.8	16.5	0.6
	2	50,000	99,999	cbm	543	8.1	34.0	113.8	3.4
	3	100,000	199,999	cbm	11	-2.5	38.5	132.3	3.8
Bulk carrier	2	10,000	34,999	dwt	3,152	15.1	33.1	17.4	1.5
	3	35,000	59,999	dwt	4,230	12.5	28.9	26.3	3.0
	4	60,000	99,999	dwt	5,254	9.0	28.2	34.5	4.7
	5	100,000	199,999	dwt	1,300	12.2	21.8	58.2	10.6
	6	200,000	max	dwt	810	7.4	26.5	76.9	15.1
LNG tanker	1	0	49,999	cbm	83	8.0	32.8	20.4	0.6
	2	50,000	99,999	cbm	11	9.9	34.0	85.1	2.5
	3	100,000	199,999	cbm	949	6.8	38.5	206.8	5.6
	4	200,000	max	cbm	65	10.6	35.1	257.1	7.3

a. *The average age and average scrapping age are from Fricaudet et al (2024)*

b. *The average prices are calculated using the regression coefficients reported in Fricaudet et al (2024) applied on the fleet reported in Clarksons at the time of writing.*

3 Main stakeholders of fossil fuel carriers

This section looks at the stakeholders who own, operate, finance, flag and build fossil fuel carriers. If the risk of stranded assets were to materialize, these entities would bear the brunt of the losses: owners and their financiers would incur write-downs in asset value, while builders, operators, and flag states would likely experience lost profits.

Appendix A contains the top 10 actors (owners, operators, flag states and shipyards) for each shipping segment of fossil fuel carrier. Each table provides, for each segment, the share of the world fleet (expressed in number of ships) the top ten owners, operators, flag states and shipyards); and second to which extent they are specialised in this shipping segment, expressed as the share of their own fleet which is made of ships of this shipping segment. The results offer several insights.

The ownership and the operation of all segments is fragmented, particularly oil tankers and bulk carriers, and the top shipowners and operators are often specialised in one segment (see Table 8 and Figure 3). More generally, it appears that many operators and owners exhibit a high degree of specialization in fossil fuel carriers, as illustrated in Figure 4. This specialization makes them more vulnerable to demand-side risks. 43% to 71% of owners and operators in the different segments (43% to 65% for tankers segment only) manage fleets that are composed by over 90% of one specific carrier segment (see Figure 4).

On the contrary, in each segment, the top 10 flag states cover the majority of the ships, and they are less specialised in one segment – with the notable exception of Bermuda, with nearly half of its flagged ships being LNG tankers. When considering only ship types that look less likely to more easily switch to different demand e.g. oil tankers and LNG tankers/carriers, national flags/registries tend to be diversified across ship types and so should not experience a fundamental risk to business related to these sectors (see Table 4). National flags with higher levels of exposure to risk (e.g. large share of oil/LNG tanker and large total number of ships registered) include Marshall Islands (29% of total fleet) and Singapore (25% of total fleet). Similarly, the construction of fossil fuel carriers is fairly concentrated with fewer actors. The leading 10 shipyards are responsible for over 60% of the current and ordered capacity (measured in deadweight, but not in the number of vessels) for oil, LNG, and LPG tankers. In contrast, the construction of bulk carriers exhibits a somewhat more dispersed pattern (see Table 8 and Figure 3). Similarly to flag states, shipyards demonstrate considerable diversity across shipping segments, with only a few exclusively focused on constructing fossil fuel carriers (see Table 8 and Figure 4). This diversification mitigates the sensitivity of shipbuilders and flag states to demand-related risks.

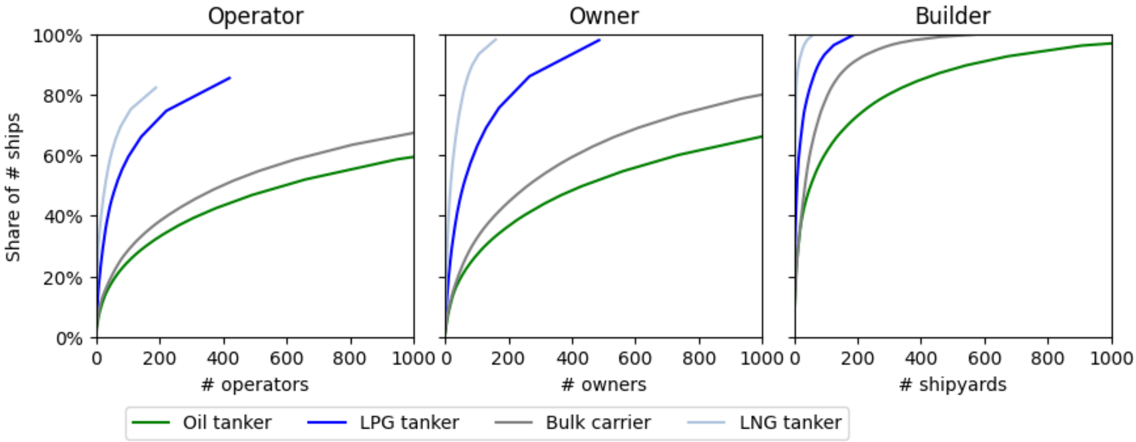


Figure 3: Concentration of fossil fuel carriers by operators, owners and builders. From Fricaudet et al (2024)

a. The plotted lines correspond to the cumulative number of ships owned/operated by/built by actors.

b. The actors are ordered by their share of the fleet, with the largest actors plotted first. Read as such: the top 200 operators operate 30% of oil tankers.

c. The share of operators does not reach 100% some ships are not registered under an operator in the Clarksons WFR.

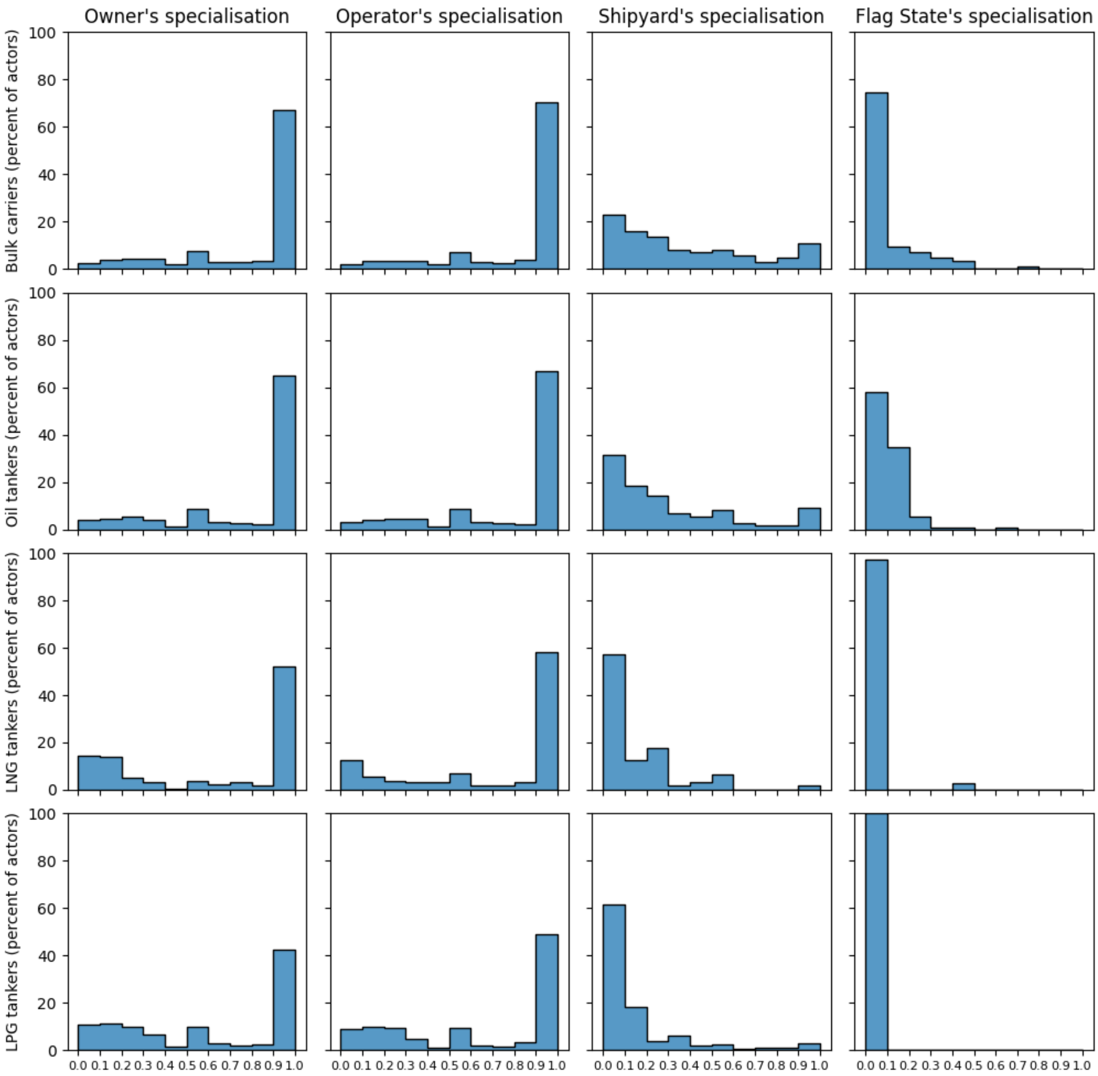


Figure 4: Distribution of actors, by degree of specialisation in fossil fuel carriers. From Fricaudet et al (2024) and Clarksons WFR

a. *Only the actors who operate/own/have built at least one fossil fuel carrier are represented.*
b. *All numbers plotted are expressed in number of ships.*
c. *The x-axis represents the share of operated, owned and built ships which are fossil fuel carriers. The y-axis represents the share of operators/owners/shipyards which falls in this bandwidth. Read as follows: for 64% of the owners of oil tankers, above 90% of their fleet (in number of ships) is an oil tanker.*

Table 4: Specialisation of Flag States in tankers (oil, LNG and LPG tankers)

Flag State	Specialisation in tankers	# tanker vessels
China P.R.	19%	1,775
Panama	16%	1,326
Unknown	18%	1,273
Marshall Is.	29%	1,265
Liberia	23%	1,202
Indonesia	7%	829
Japan	16%	821
Singapore	25%	807
Hong Kong	18%	459

Malta	24%	445
Russia	13%	389
Greece	28%	338
Thailand	37%	324
Bahamas	22%	286
South Korea	12%	270
Philippines	10%	225
Malaysia	10%	186
Bangladesh	30%	182
India	9%	177
Vietnam	8%	158
Turkey	12%	148
Gabon	71%	142
Nigeria	14%	134
Danish Int'l	20%	117
Norwegian Int'l	15%	103
Italy	8%	103
Sierra Leone	17%	102

The specific financiers underwriting fossil fuel carriers are not clearly identified in the literature, nor their beneficial owners, which is the person or company who ultimately owns and control the registered owners. However, there is substantial literature and information available regarding the primary financiers of shipping in general. Traditionally, shipping banks have served as the primary source of financing in the shipping industry (Alexandridis et al., 2018) (see Figure 5 and Figure 6), and historically, the ability of shipping companies to secure financing with favourable terms, especially low interest rates, has been crucial for their longevity (Stopford, 2009). However, due to unfavourable market conditions and stricter BASEL III capital requirements implemented by the Basel Committee on Banking Supervision after the 2007-2008 Global Financial Crisis, banks have limited their exposure to the shipping industry (Gong et al., 2013). Nevertheless, lending continues to be the primary external source of financing for shipping (Del Gaudio, 2018; Drobetz et al., 2013).

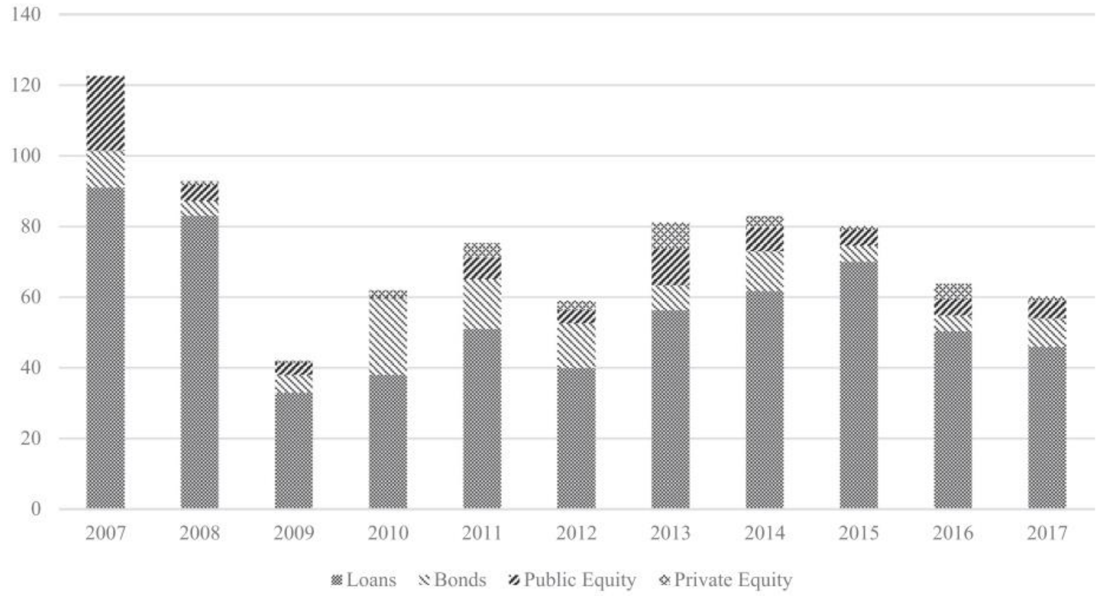
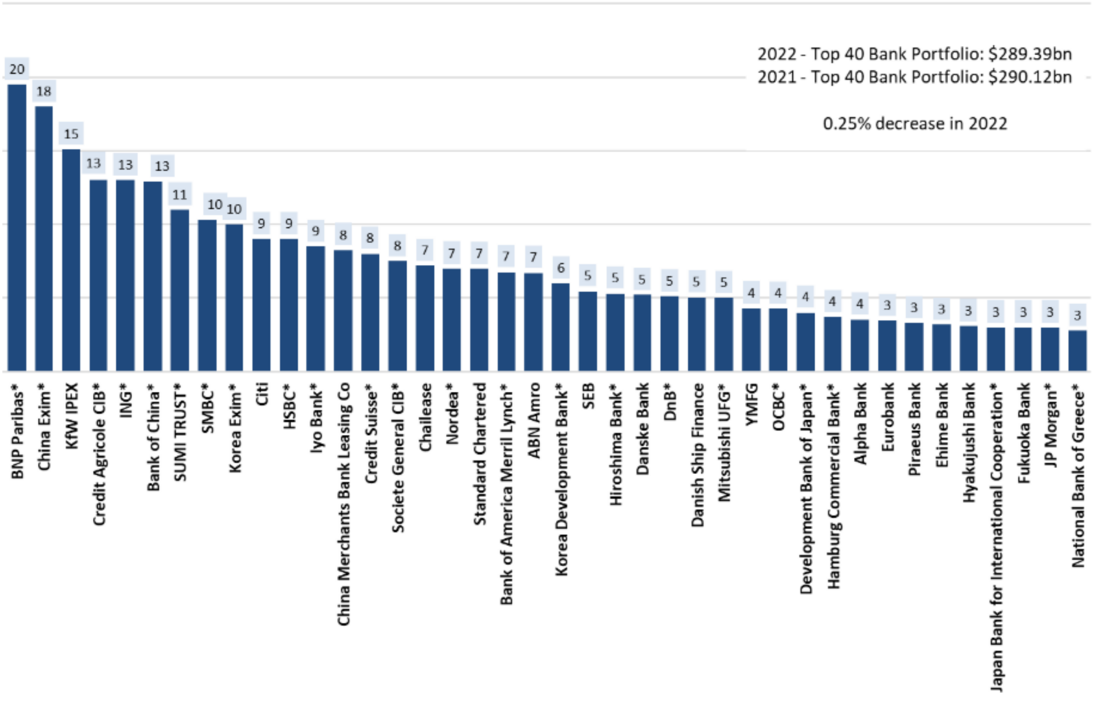


Figure 5: Sources of finance in the shipping industry (USD billion). From Alexandridris et al. (2018)



*Market estimate

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Figure 6: Top 40 banks in ship finance (USD billion). From (Petropoulos, 2023)

4 Scale of stranded assets risks

This section estimates the risks of stranded assets – book loss and lost profits[5] – if demand for transporting fossil fuels falls as projected in line with a 1.5°C trajectory, and if the fossil fuel carrying fleet is unable to repurpose to alternative cargoes.

4.1 Scenarios of shipping supply

The future composition of fossil fuel carrier fleets will be influenced by both the retirement of existing vessels and the construction of new ones in the forthcoming years. To capture these dynamics, we employ a modelling approach that accounts for each vessel currently in operation or on order, which is fully described in Fricaudet et al (2024). We project the operational lifespan of each vessel based on its type and size, considering eventual scrapping. Additionally, we incorporate newbuilds into the fleet under two scenarios:

- **No further ordering**: In this scenario, no additional fossil fuel carriers are constructed beyond those already ordered as of the data collection date (January 2024).

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[5] The profits calculated in the report correspond to the profits after fuel expense and ships operating costs. Those are reported by Clarksons SIN which is based on the BDO OpCost survey, and includes crew wages, other crew, lubricants, stores, spares, repairs & maintenance, H&M insurance, P&I insurance, management fees and dry docking. This does not consider several operating expenses typically reported in financial statements, for example capital depreciation.

- **Newbuild until 2030**: Under this scenario, new vessel construction continues until 2030, with the average fleet growth matching the average fleet growth of the previous decade.

Furthermore, we provide estimates of the current fleet's value at any given time, its committed supply (measured in tonnes miles) over its remaining lifespan, and the associated profits linked to this committed supply. Additional details can be found in Fricaudet et al (2024).

Given the orderbook for bulk, LNG and LPG tankers, over the next few years, the natural retirement of older vessels is expected to be offset by the introduction of new ships currently on order, maintaining a stable supply of shipping services on those segments (measured in tonne miles), fleet capacity (in thousand vessels), and fleet value (in USD). In fact, due to significant existing orders for bulk carriers, LPG tankers, and particularly LNG tankers, these fleets are projected to expand until shortly before 2028 (refer to Figure 7). Moreover, given the relatively recent ordering activity and the long operational lifespans of LNG and LPG tankers (as detailed in Table 2), their supply and capacity is not anticipated to decrease until after 2040.

In contrast, the fleet value of oil tankers remains steady, but the annual availability of transportation services begins to decline as early as 2024 (see Figure 4). This decrease is relatively swift due to the short average remaining lifespan of oil tankers (see Table 2).

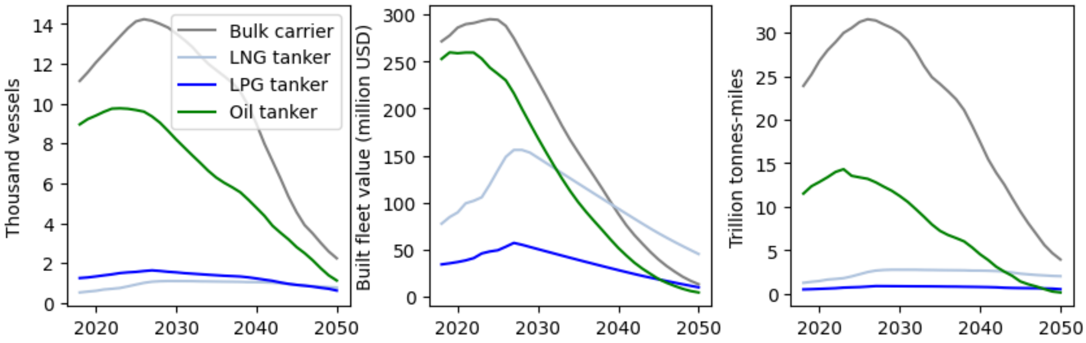

Figure 7: Fleet natural evolution, if only currently ordered ships are built. From Fricaudet et. al (2024)

4.2 Scenarios of shipping demand

The future demand for shipping fossil fuels has been derived from the Fourth IMO GHG Study (Faber et al., 2020), which in turn relied on forecasts from the Institute for Applied Systems Analysis (IIASA) database as input for consumption of the traded commodities. Within the Fourth IMO GHG Study, various models were employed to project shipping demand, which are summarised in Table 5. For shipping demand related to energy commodities such as coal, fossil gas, and oil, this report uses the shipping demand associated with the Representative Concentration Pathway (RCP) RCP1.9, which aligns with a carbon budget of 1.5ºC. Two scenarios are presented: one estimated through the logistic model (RCP19L), and another projection based on the International Institute for Applied System Analysis projections (RCP19*). Regarding shipping demand for non-energy commodities, this paper incorporates each Shared Socioeconomic Pathway (SSP) compatible with RCP19, namely SSP1, SSP2, and SSP5. In the Fourth IMO GHG Study, these were estimated using both a logistic model (L) and a gravitational model (G).

Table 5: Description of demand scenarios. From (Faber et al., 2020)

Non-coal dry bulk, containers, other unitized cargo and chemicals (relation between transport work and relevant drivers: Logistics, denoted by _L; Gravitation model, denoted by _G)	**Coal dry bulk, oil tankers and gas tankers**
Long-term socio-economic scenarios	**Long-term energy scenarios**
SSP1 (Sustainability – Taking the Green Road)	RCP1.9 (1.5° C) in combination with SSP, SSP2 and SSP5)
SSP2 (Middle of the Road)	RCP2.6 (2°C, very low GHG emissions) in combination with SSP1, SSP2, SSP4 and SSP5
SSP3 (Regional Rivalry – A Rocky Road)	RCP3.4 (extensive carbon removal) in combination with SSP1, SSP2, SSP4 and SSP5
SSP4 (Inequality – A Road Divided)	RCP4.5 (2.4°C, medium-low mitigation or very low baseline) in combination with SSP1, SSP2, SSP4 and SSP5
SSP5 (Fossil-fuelled Development – Taking the Highway)	RCP6.0 (2.8°C medium baseline, high mitigation) in combination with SSP1, SSP2, SSP4 and SSP5

Given the considerable uncertainty surrounding future shipping demand, we assess stranded assets across all these scenarios (RCP1.9 combined with SSP1, 2 and 5, and logistic and gravitational model) and present a range of outcomes accordingly. Since the Fourth IMO GHG Study does not distinguish between LNG and LPG trade, these two segments have been combined under the category "liquefied gas tankers."

As outlined in Fricaudet et al. (2024), the demand estimates presented in the Fourth IMO GHG Study were computed in 2018. Consequently, shipping demand begins to align with a temperature trajectory from 2019 onward. For liquefied gas and oil tankers, the projected shipping demand corresponding to a 1.5°C target until 2023 is notably lower than the actually observed demand until 2023 (Fricaudet et al, 2024). This also echoes the conclusions of the 6th IPCC Report of 2023, which indicates that the global decarbonization efforts are insufficient to achieve the Paris Agreement's goals (Rogelj et al., 2022). Due to the continued reliance on fossil fuels in the early 2020s, the transition has experienced a delay; consequently, staying withing the remaining carbon budget necessitates a more pronounced reduction in fossil fuel use to meet climate targets. Furthermore, the war in Ukraine has shifted part of the LNG transport from pipeline to ship, resulting in even greater shipping demand (OECD, 2023). Consequently, using the scenarios from the Fourth IMO GHG Study for the 2018-2050 period leads to a gap between observed reality and the scenario, and an overestimation of stranded assets during the initial years of our projections and an underestimation in the later years.

For this report, we therefore refit the estimates of future demand from the Fourth IMO GHG Study so that the shipping demand from 2018 to 2023 equals the observed shipping demand (from Clarksons SIN) while keeping the expected cumulative transport work over the 2018 to 2050 period constant. To do so, we further assume that the refitted shipping demand is a function from 2023 to 2050 minored by 0 and that the 2050 demand is equal to the 2050 demand projected in the Fourth IMO GHG Study The refitted shipping demand is thus still equal to the cumulative demand in the initial Fourth IMO GHG Study aligned with a 1.5°C trajectory. One can fit an infinite number of curves given those two assumptions, so the refitted curves are only one option among others. The annual results might somewhat vary depending on the choice of curve. However, if one assumes that the shipping demand in 2050 is equal to one projected in the Fourth IMO GHG Study, maintaining a cumulative shipping demand constant requires a fast fall in demand up to 2030. The later the alignment to a 1.5°C trajectory starts, the steeper the decrease must be to compensate for the non-aligned shipping demand which happened before. In a sensitivity analysis, we fit this linear function from 2025 onward rather than 2023. This sensitivity analysis provides insights on what the stranded assets would be, should the decarbonisation of the world economy be further delayed. The resulting curves are plotted in Figure 8.

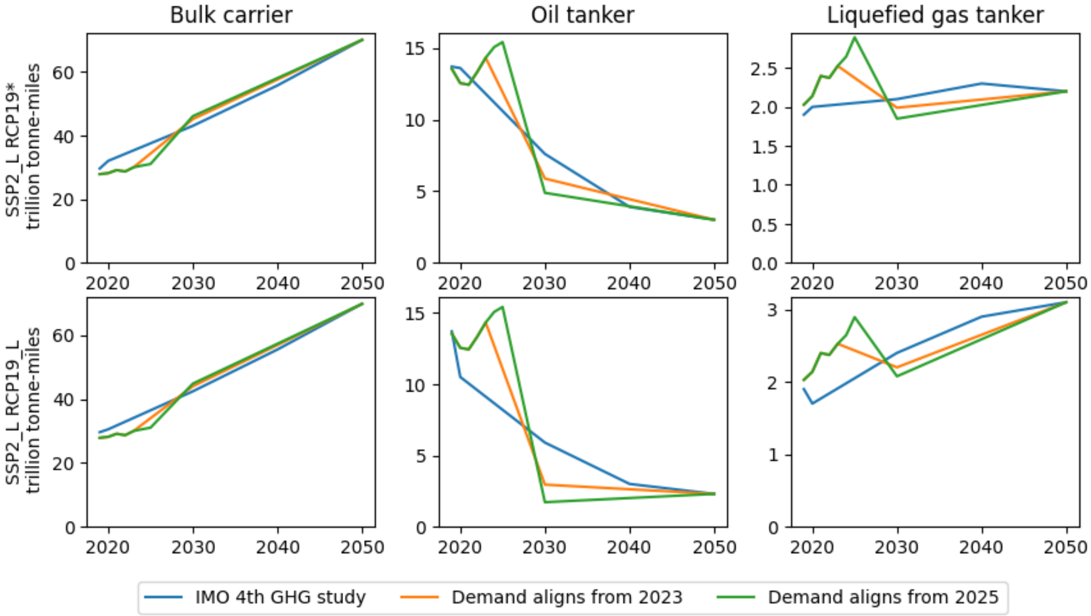

Figure 8: Shipping demand aligned with a 1.5°C temperature increase and up to 2050

a. *Only the SSP2 scenarios are plotted.*

4.3 Modelled amount of stranded assets

We find that oil and liquefied gas tankers are in oversupply until the early to mid 2040s. Both the demand for transporting oil products and the committed supply of oil tankers in the “no further ordering” scenario decrease constantly after 2024. Because the drop in demand is faster than the natural retirement of the fleet, the committed supply to transporting oil is above the projected demand until the 2040s (Figure 9). As the committed supply falls relatively fast during this period - many ships can be expected to retire naturally due to the old age of the fleet - the gap between supply and the rapidly declining demand in a 1.5 °C scenario is therefore reduced. However, if further oil tankers are ordered, the committed supply does not fall before 2032 and the oversupply of oil tankers is much larger (Figure 9, “newbuild until 2030” scenario).

On the contrary, and as showed in Fricaudet et al (2024), long remaining lifespans and large orderbook means that the committed supply of liquefied gas tankers increases until 2029, even in the “no further ordering scenario”. As a result, the committed supply of liquefied gas tankers is much larger than the demand aligned with a 1.5°C trajectory, and even more so in the “newbuild until 2030” scenario (Figure 9).

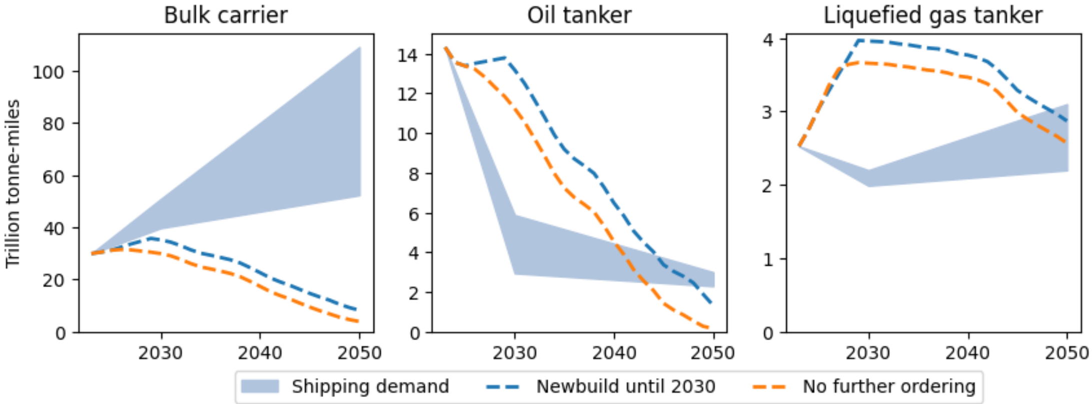

Figure 9: Shipping demand (starts aligning from 2023 onward) and committed supply

This oversupply suggests that both oil tankers and liquefied gas tankers are at risk, as the shipping activity and the associated profits that were expected at the point of their investment decision are unlikely to materialise with the transitions towards a low or zero-carbon economy. The modelling does not include the potential for vessels to retrofit (which is discussed qualitatively in section 5), so those estimated amount of stranded assets should be taken as a maximum value at risk. In particular, as the demand for oil transportation falls dramatically up to 2030, a large share of the expected profits are lost in 2030 (48 to 74%), see Figure 10, top row. This corresponds to USD 7.1 to 10.9 billion of annual lost profits at the peak in the “no further newbuild” scenario, a range which increases to 9.6 to 13.4 billion in the “newbuild until 2030” scenario (55 to 78%) see Figure 10. Refer to Fricaudet et al (2024) for a description of the methods. Similarly, up to 40 to 46% of the annual activity and profits of liquefied gas tankers are in oversupply over the period, which corresponds to lost profits of USD 7.3 to 8.3 billion in the “no further ordering” scenario (see Figure 10). Further ordering until 2030 increases the annual profits at risk to USD 8.8 to 9.8 billion (44 to 50%) (see Figure 10).

The potential responses to the oversupply of oil and liquefied gas tankers can, in reality, be various; here, we assume that either a significant portion of the ships remains unused (book loss) or that all ships are being utilized but at substantially reduced rates. In the first case (see Fricaudet et al (2024) for a description of the methods) and in the “no further ordering” scenario, this corresponds to USD 27.4 to 56.8 billion of oil tankers fleet left idled in 2030 (16 to 34% of the fleet in terms of value), and 45 to 82.4 billion (19 to 36%) in the “newbuild until 2030” scenario Similarly, 26 to 32% of the liquefied gas tankers’ fleet value are left idled around 2030, corresponding to USD 51.7 to 62.7 billion (Figure 11). This increases to USD 65 to 75.6 billion (30 to 36%) in the “newbuild until 2030” scenario.

Our findings regarding the bulk carrier segment indicate that the shift away from coal transportation does not pose a significant threat to bulk carrier values and profits. This is because the anticipated growth in the transportation of other dry cargo types is expected to more than offset the decline in coal transportation (refer to Figure 9). Consequently, bulk carriers do not appear to be at risk of oversupply in the forthcoming decades. Moreover, additional investments will be necessary to meet the projected future demand, particularly as the committed supply falls below the committed demand by the mid 2020s in the "No further ordering" scenario, and a few years later in the "newbuild until 2030" scenario (see Figure 9).

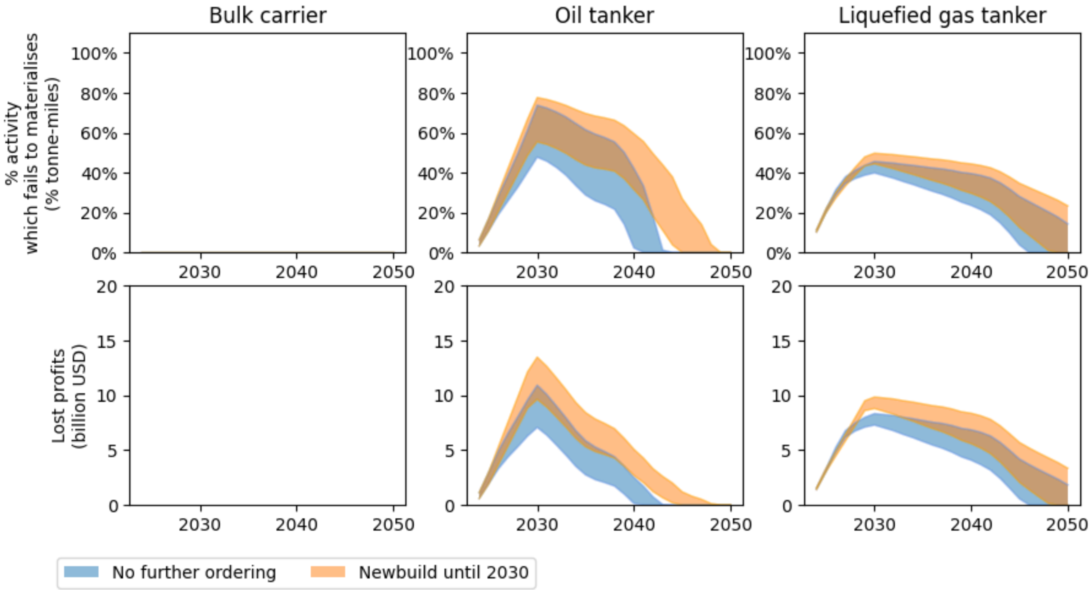

Figure 10: Demand-side risk and lost profits (demand starts aligning from 2023 onward)

a. *The areas represent the range of estimates in various shipping demand scenarios.*

b. *Bulk carriers are plotted for completeness, but not asset stranding takes place.*

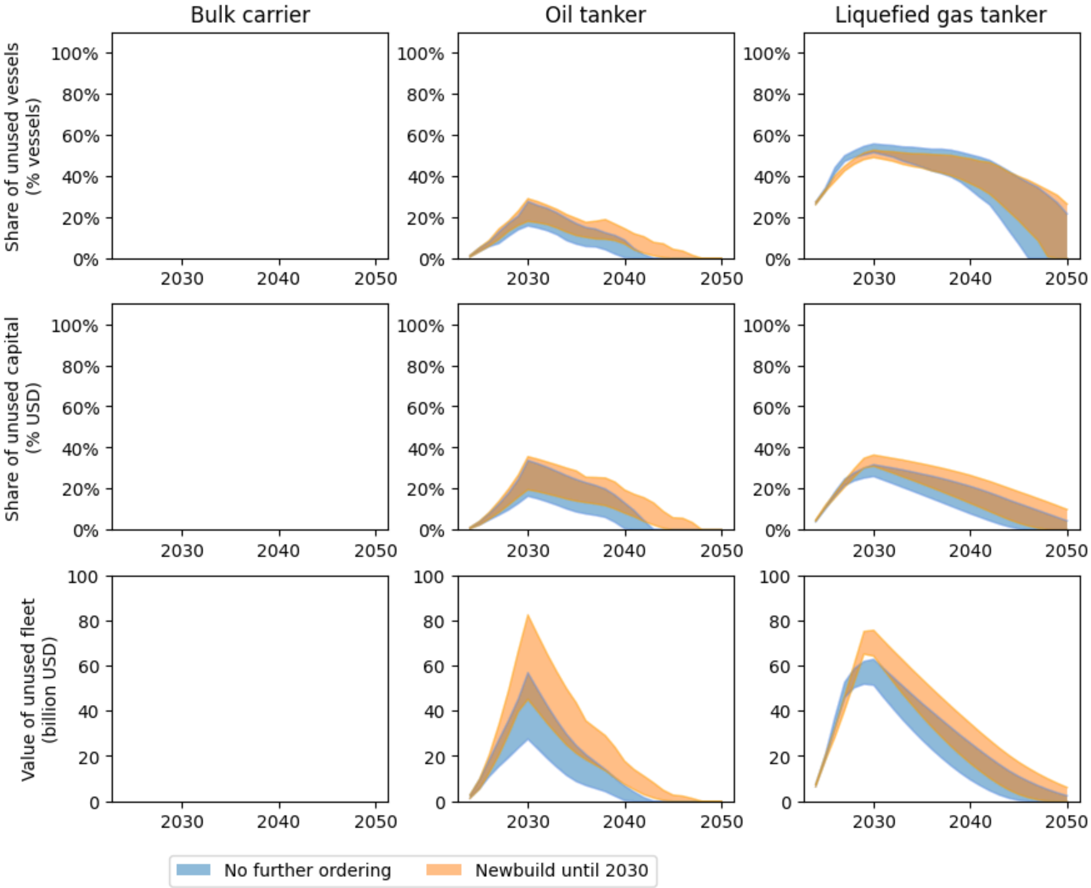

Figure 11: Demand-side risk and book loss (demand starts aligning from 2023 onward)

a. *The value of the unused fleet can be considered a worst-case proxy for book loss. It is a cumulative value rather than an annual flow.*

Over the period of 2024-2050, we find that, USD 214 billion of profits would not materialize if the demand for shipping fossil fuels aligned with a 1.5 °C trajectory, even if no new ships are ordered (USD 59 to 107 billion for oil tankers and USD 104 to 158 billion for liquefied gas tankers). This represents around 32% of the expected profits over the period from the existing and ordered fleet. This amount increases to close to USD 286 billion in the "newbuild until 2030 scenario", or 37% of the expected profits (USD 97 to 153 billion for oil tankers, and USD 131 to 191 billion for liquefied gas tankers). The absolute amount is somewhat lower than the estimates from Fricaudet et al (2024), which used the original demand from the Fourth IMO GHG Study which starts aligning from 2019 onward but the share of profits lost is similar.

At its peak in 2030 and in the "no further ordering" scenario, the fleet of a value of USD 90 to 108 billion would be left idled. Although those ships might not get scrapped right away in our scenario but might be used before and after, this range gives the scale of the maximum book loss. The fact that the book loss estimate is lower than the estimate of lost profits suggests that shipowners might be better off scrapping early their vessels, rather than keeping them for a long time at a loss. If further ships are ordered until 2030, the amount of book loss increases to USD 121 to 147 billion. Those estimates are similar to those when using the Fourth IMO GHG Study demand (Fricaudet et al (2024)).

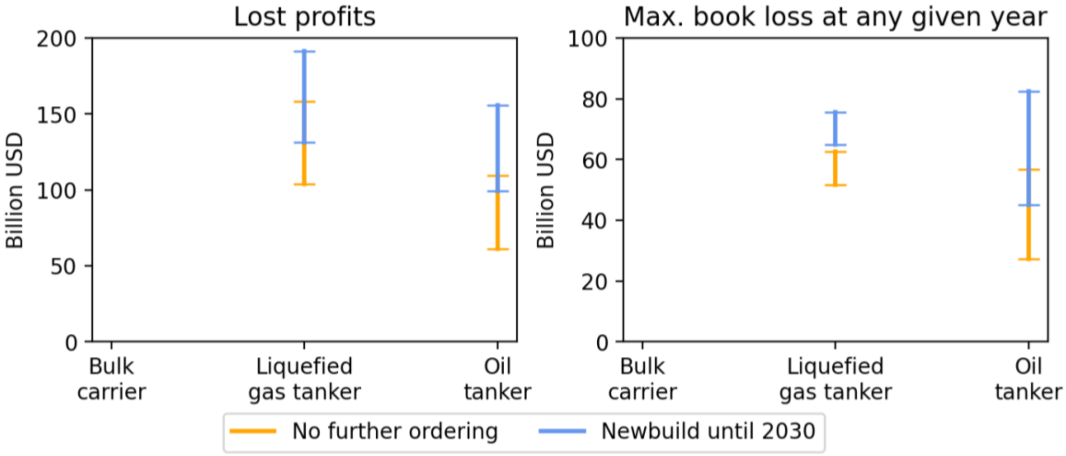

Figure 12: Cumulative demand-side risk until 2050. Demand aligns from 2023 onwards.[6]

b. *Book loss corresponds to the maximum value of the unused fleet due to the lack of demand at any point in time over the 2024-2050 period. This is likely to be an overestimate, as some of those ships would be used at other points in time.*

5 Potential for repurposing fossil fuel carriers

In cases where repurposing fossil fuel carriers to alternative cargoes is technologically and economically possible, and where there is enough transport demand for those cargoes, then part of the stranded assets identified above may be avoided. This section takes an initial look at the potential for repurposing fossil fuel carriers to identify

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[6] The profits calculated in the report correspond to the profits after fuel expense and ships operating costs. Those are reported by Clarksons SIN which is based on the BDO OpCost survey, and includes crew wages, other crew, lubricants, stores, spares, repairs & maintenance, H&M insurance, P&I insurance, management fees and dry docking. This does not consider several operating expenses typically reported in financial statements, for example capital depreciation.

key options and barriers, but there remains a need to carry out more detailed analysis. The results of this section were based on interviews with various stakeholders responsible for the design and operation of the vessels, including vessel superintendents, chief engineers, and commercial operations teams working on oil, gas, and dry bulk vessels. Interviews were also done with naval architects who have designed oil and gas carriers. This was combined with literature from the International Bulk Chemical Code (IBC), the International Convention for the Safety of Life at Sea (SOLAS), MARPOL Annex II, and The International Code for The Construction and Equipment of Ships Carrying Liquefied Gases In Bulk (IGC).

5.1 Oil tankers

Crude oil or heavy fuel oil tankers may have limited and potentially expensive conversion options. These vessels are typically found within the largest size categories of oil tankers as listed above, with an Aframax (80,000 dwt to 120,000) or Panamax-class (50,000 to 80,000 dwt) vessel usually being the smallest to carry these heavier base oils before either use or further refining.

Conversion of these vessels to carry chemicals and products, which would include, for instance, methanol and biofuels, seems most promising and likely. What type of chemicals or products such a vessel would like to carry sets the requirements or changes needed on the vessel. These requirements are defined in part in the International Bulk Chemical Code (IBC), the International Convention for the Safety of Life at Sea (SOLAS), and MARPOL Annex II. Most chemicals and hazardous liquid cargoes can be grouped into 1 of 3 IMO Types, with Type 1 generally requiring the strictest conditions and Type 3 the least. Methanol, for example, falls under IMO Type 3. Type 1 and 2 cargoes may be inherently difficult to switch to, especially for the largest of oil tankers, as there are maximum volumes specified for those cargoes that could be stored in any individual tank (1250m^3 and 3000m^3, respectively). Such a restriction is not in place for Type 3 cargoes. For all 3 types, an oil tanker would typically need to install an (nitrogen) inert gas system and potentially change the inner coating of the tanks to zinc, epoxy, or stainless steel. For Type 1 and 2 cargoes, the vessel will need to ensure the distances between each tank and both the hull and bottom of the vessel meets minimum distance requirements for safety. These minimum distances would be very difficult to change, should an oil tanker not meet them already.

An oil tanker owner would also need to consider whether the vessel can berth at ports able to load or receive such chemicals, with most currently being served by smaller sized tankers than those used for crude or fuel oils. Ship-to-ship transfers to smaller tankers may be one way to mitigate this risk but adds to the cost of utilising such large tankers on trades that have yet to reach the scale at which crude oil moves today.

5.2 Liquified gas tankers

The liquefied gas tanker fleet is largely made up of liquefied petroleum (LPG) and liquefied natural gas (LNG) carriers, who share quite a few similarities especially in terms of technology onboard but also have significant differences. Other gas carriers include those used for ammonia and a few dedicated CO_2 carriers.

LPG tankers carry by-products of crude oil extraction like propane and butylene and come in three forms: fully pressurised, semi-pressurised (or semi-refrigerated), and fully refrigerated. The level of pressurisation and refrigeration generally determines the amount of LPG that can be carried, where increasing the amount of refrigeration reduces the need for high pressures and increases carrying capacity. Fully pressurised LPG carriers operate at about 17 bar of pressure, but individual tanks are typically then limited to 3500m^3. At the other end of the scale, fully refrigerated LPG carriers operate at a minimum of –50°C and around 0.3 bar, allowing them to carry up to—or potentially more than—85,000m^3.

LPG carriers may be obvious candidates to carry ammonia as a cargo, given similarities in ammonia's properties and requirements for storage. Ammonia is a liquid at atmospheric pressure and temperature below -33°C, and at, for example, 20°C, it is a liquid at about 7.5 bar of pressure. However, the vessel's tank coating and systems to contain ammonia need to follow the requirements set in the IGC and the IBC. If ammonia were to be used as a fuel as well as being a cargo, other evolving regulatory requirements need to be adhered to—such as those described in (Bureau Veritas, 2022; DNV, 2023). Further, the quality and composition of the ammonia carried poses potential problems, including the amount of water and oxygen or exposure to thereof, such that additional monitoring and mitigating procedures may need to be put in place. Personnel onboard and at loading and discharging facilities will also need a greater level of training and access to risk mitigation measures, given ammonia's high toxicity.

Unlike LPG carriers, LNG carriers need to use extremely low temperatures (around -162°C), and sometimes pressures above atmospheric pressure, to liquefy and store natural gas. LNG therefore needs insulated tanks that can withstand those temperatures and special piping and equipment to manage the LNG. Like LPG carriers, this means the LNG fleet differs in the level of refrigeration and pressurisation and the cargo sizes they can carry. In part, this makes LNG carriers a much more difficult problem for conversion to carry an alternative like ammonia (and potentially other commodities like CO_2), with major changes needed, including on the tanks and equipment on deck. LNG-specific equipment would also become redundant if carrying ammonia, and hence the economics of the investment could potentially put the converted LNG to ammonia carrier at a disadvantage to either a converted LPG carrier or a dedicated ammonia carrier. LNG tankers may, however, have an opportunity to more readily carry something like liquefied bio-methane (LBM), but the scale of parcels and availability of LBM at present would imply that those vessels would likely create an oversupply in the transportation market for LBM.

Liquefied CO_2 could be another cargo that some LPG or LNG carriers could adapt to. This will likely be limited to vessels that have tanks that are both pressurised and refrigerated (typically called Type-C tanks). This is because CO_2 becomes a solid (and turns into dry ice) at or below -56°C and around 5 bar, whilst at the other end it reaches a supercritical state above 31°C and around 73 bar. Hence, to keep CO_2 liquefied and to prevent dry ice formation—as this would damage, for example, the tanks, valves, and piping—carriers would need to manage relatively low temperatures and medium to high pressures. Like with ammonia, the purity of CO_2 will also have an influence in its stability and the pressure and temperatures required. Further, CO_2 toxicity is a function of the level and duration of exposure, but remains much safer in comparison to ammonia. A summary of other considerations for gas carriers to move to CO_2 can be found in (Society of International Gas Tanker & Terminal Operators, 2024).

Even if technical compatibility and provisions can be made, commercial risk is present for both LPG carriers moving to either ammonia or CO_2 and LNG carriers moving to LBM or CO_2. This is because seaborne movements of ammonia and CO_2 remain small in comparison to those of fossil-based gasses, and the ability of major ports to safely receive and manage these commodities at scale remains nascent.

5.3 Bulk carriers

Dry bulk carriers can be separated largely on their size and whether they move major or minor bulks. Major bulks today include ores (like iron), coal, and grains, whilst minor bulks cover things like cement and scrap metal. Bulk carriers can vary in size from 10,000 dwt to 400,000 or more, with coal and iron ore carriers typically falling into the largest of size classes of dry bulk carriers.

Coal carriers would be considered most at risk in the dry bulk fleet, but they can relatively readily switch to carrying certain other dry commodities. Iron ore is a common substitution for coal carriers, generally when coal transportation demand falls relative to that for iron ore (all else equal). Switching to food grade or more hazardous cargoes, which would include certain minerals, will require other modifications and considerations. This could include the carriers mitigating the potential for corrosion, catering for the fragility of the cargo, and meeting temperature control requirements—all of which may be considered more difficult of a transition for a coal carrier than switching from coal to iron ore.

Commercial and trading risks exit for coal carriers switching to iron ore, too, as this may flood and create an oversupply in the iron ore markets. There may also be differences in port and terminal compatibility between some coal and iron ore ports, which may require some adaptation. A mitigating factor for coal carriers would be the expected rise in the trade of minerals, especially those necessary for, say, battery production and solar panels, which could over time supplant the fall in coal movements.

5.4 Summary

The results of the analysis and industry stakeholder interviews is summarized below, where the risk levels are split between elements relating to operational (safety, trading), structural (retrofitting requirements and complexity), costs (return potential), and market optionality (if the market for alternative cargoes does not evolve or is not strong enough to replace lost demand from the transportation of fossil-fuels).

In general, based on current knowledge and expectations, coal carriers seem least at risk from a decline in fossil-fuel transportation, with greater optionality to move iron ores and other minerals that are expected to grow in demand. Crude carriers follow in terms of risk profile, followed by LPG, and finally LNG being considered the most specialised and most at risk. Most of these vessels will require some form of retrofitting, but the attractiveness of retrofitting typically declines with age and the state of the markets the vessel would enter and would be expected to experience for the remainder of its life. Hence, for some vessels, a transition to alternative cargoes may not be economical, and they may already be at a point of no return.

Table 6: Assessment of the challenges for repurposing fossil fuel carriers

	Toxicity and safeguarding	Structural changes	Trading, cargo size, and port restrictions	Costs and return on investment	Cargo optionality
Crude and heavy fuel oil tankers to chemical and product carriers (including methanol or bio-products)	**Low-medium** Especially for methanol. Potentially higher for other, more hazardous chemicals.	**Medium** Deal-breaker if distances between tanks and outer surfaces too small, as structural changes could be prohibitively costly.	**Medium-High** Current markets would find large oil tankers difficult to include in chemical and bio-based fuel trades—as these are traded in much smaller parcels than what a crude or fuel oil carrier would carry—unless ship to ship transfers or different berths or ports could be used.	**Medium** Ideally, changes ought to be made at first dry dock—which is the first time the ship is taken out of the water for repairs and modifications, generally 5 years after launch and every 5 years thereafter—maximizing the period over which the additional investment could be recouped.	**Medium** Other chemicals and bio-based liquids needing transport, though returns in such a market may be limited if those markets are flooded with excess crude tonnage.
LPG tankers to ammonia carriers	**Medium** Higher safety and safeguarding requirements for ammonia than for LPG, with leakages most likely at loading or discharging at the manifolds. Carriers will need stricter monitoring and leakage management, as well as training for the crew, at ports, and for any vessel or other structure that may need to approach the LPG/ammonia tanker.	**Low** Reliquification systems may be necessary to prevent boil-off, especially if carrying ammonia.	**Medium** Dependent on how the ammonia trade grows over time and whether it moves into ammonia being used as more than just a fertilizer or as an input into other manufacturing processes. More ports and receiving facilities would then also need to adapt to these vessels. LPG sizes may be more closely aligned to current ammonia	**Low-Medium** Whilst retrofit costs could be small, returns will depend on how the ammonia shipping market scales and the relative returns from carrying LPG versus ammonia.	**Medium-High** Fewer alternative cargoes, if ammonia transport demand remains low. Liquefied CO_2 as a cargo requires a certain form of LPG carrier (semi-refrigerated or semi-pressurised), which limits the scope for carrying CO_2 using the current fleet.

	Toxicity and safeguarding	Structural changes	Trading, cargo size, and port restrictions	Costs and return on investment	Cargo optionality
			movements than LNG sizes.		
LNG tankers to ammonia carriers	**Medium** Same as for LPG to ammonia.	**Medium-High** The membrane in the tanks and equipment on deck may need to be changed. Reverting to carry LNG may also then no longer be possible without a recertification.	**Medium-High** Like LPG tankers, dependent on the evolution of the ammonia trade and ports adapting to larger vessels and parcel sizes.	**Medium-High** Excess equipment on an LNG made redundant, changes to the membrane or tanks, and new equipment may put a converted LNG carrier at a significant economic disadvantage to either a converted LPG tanker or a dedicated ammonia carrier.	**Medium-High** Same as LPG carriers moving to ammonia, fewer alternatives to rely on other than LBM. Same constraints for this fleet to switch to CO_2as with the LPG fleet.
Coal carriers to other dry commodities (like iron ore or other minerals)	**Low** None, unless carrying any dry products that can be toxic or needs special handling capability (food grade items, or even some minerals).	**Low** None, unless carrying any dry products that can be toxic or needs special handling capability (food grade items, or even some minerals).	**Low-Medium** Potentially a risk of compatibility for certain alternative dry commodities.	**Low-Medium** Some costs may be required to adjust equipment, especially for loading and unloading.	**Low** None, as they could switch to commodities that are not energy carriers.

6 Hong Kong Convention and recycling capacities

The world ship-breaking capacity is estimated to lie between 15 and 70 million light displacement tonnage[7] (LDT) per year (Solakivi et al., 2021). This wide range suggests that there is a large uncertainty on the real capacity of shipbreaking. Furthermore, much of this shipbreaking capacity concerns dangerous and unsustainable shipbreaking practices, in particular the use of beaching (Barua et al., 2018; Matz-Lück, 2010), which consists in sailing the ships to shallow tidal waters and then breaking on the beach. In contrast, dry docking of "wet method" (the ship is dismantled with the use of floating installations) are more sustainable and less dangerous, but they are much more expensive (Engels, 2013).

Several initiatives have attempted to regulate shipbreaking to ensure the safety of the workers and reducing the negative environmental impacts. The Basel Convention prohibits the transfer of hazardous waste from OECD to non-OECD nations and could be extended to ships intended for dismantling (Matz-Lück, 2010). However, practical implementation faces challenges as ships are typically not directly sold for shipbreaking by their owners but through intermediaries, which, in a global marketplace, leads to untransparent trades and inconsistent enforcement (Alcaidea et al., 2016).

The Hong Kong Convention aims to establish minimum standards for worker safety and pollution prevention in shipyards. It was adopted in 2009 by the IMO and will enter into force in 2025, more than a decade after its adoption. The entry-into-force date was set two years after the fulfilment of the following criteria:

- At least 15 States had ratified the convention.
- At least 40% of the world's merchant shipping, measured by gross tonnage, had ratified the convention.
- The combined ship recycling capacity of the mentioned States equalled at least 3% of the gross tonnage of their combined merchant shipping.

Those requirements were fulfilled in 2023 after the ratification by Bangladesh and Liberia. The Convention requires ships to carry an inventory of hazardous materials embedded in the structure and equipment and prohibits or restricts the use of listed hazardous materials in shipyards, ship repair yards, and vessels (IMO, n.d.). Ship recycling facilities are further mandated to furnish a Ship Recycling Plan detailing the approach for dismantling each ship (IMO, n.d.) and should be authorized by the competent authority. However, its implementation is weakened by a lack of robust enforcement mechanisms and specific prohibitions, such as beaching (Argüello Moncayo, 2016; Matz-Lück, 2010). At the time of writing, it is unclear what the capacity of Hong-Kong Convention-authorised yards could be, and therefore whether the Convention will put pressure on the availability of shipbreaking capacity or not.

The European Union's requirements, as outlined in the 2013 EU Ship Recycling Regulation, are more ambitious, but also more limited in reach, as their only concern EU ships. It imposes a list of authorised ship recycling facilities, whose capacity is

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[7] The weight of the ship excluding cargo, fuel, water, ballast, stores, passengers, crew, but with water in boilers to steaming level

estimated to be 2.8 million LDT, much lower than the total shipbreaking capacity (Solakivi et al., 2021). It is unclear at the time of writing what the shipbreaking capacity aligned with the Hong Kong convention would be.

To estimate the sustainability of the additional scrapping, this report estimates shipbreaking demand until 2045 by adding the estimated shipbreaking demand in the absence of demand-side risk (as calculated in (Solakivi et al., 2021)) and the additional scrapping, if demand-side risk materialises. We compare this estimate to the EU-certified capacity, to the current global capacity, and to the maximum theoretical shipbreaking capacity provided by (Solakivi et al., 2021). The ships' deadweight was first transformed into LDT values, using the dwt to LDT coefficients from (Solakivi et al., 2021). At the peak of overcapacity, in 2030, we find that the overcapacity, if scrapped, would create demand for ship scrapping of 40 to 65 million LDT, which is well above the EU-compliant capacity and dangerously close to the maximum shipbreaking capacity (and that is ignoring the natural scrapping of the fleet). However, it is unlikely that all scrapping would happen on the same year, but it is uncertain at which year ships would actually get scrapped. We model two scrapping scenarios:

- An ordered scenario, where the maximum amount of stranded capacity over the period is spread equally from 2024 until peak underutilisation year. For example, peak in oil tankers unused capacity happens in 2030, and is spread over 2024-2030.
- An unordered scenario, where all unused ships each year are scrapped (and removed from the future fleet). The cumulative scrapping in this scenario is not only more concentrated in time but also higher, as some unused ships which get scrapped in this scenario, are used after in an ordered scenario (in a sense, sudden scrapping might lead to undercapacity).

The results are plotted on Figure 13 and Figure 14. The early scrapping of ships significantly adds to the shipbreaking demand likely to incur due to the natural depreciation of the fleet, especially if newbuilding continues until 2030 and/or if ships are scrapped in a disorderly scenario. The results are qualitatively close to those of (Solakivi et al., 2021) in the absence of demand-side risk: although the present global capacity is insufficient to satisfy future demands, regions with limited infrastructure and requirements for equipment and safety, such as Bangladesh and India, along with ample labour availability in ship-breaking sites, are likely capable of meeting rising demands. However, the EU-certified capacity is clearly below the demolition volumes in any scenario, even if no demand-side stranded assets take place.

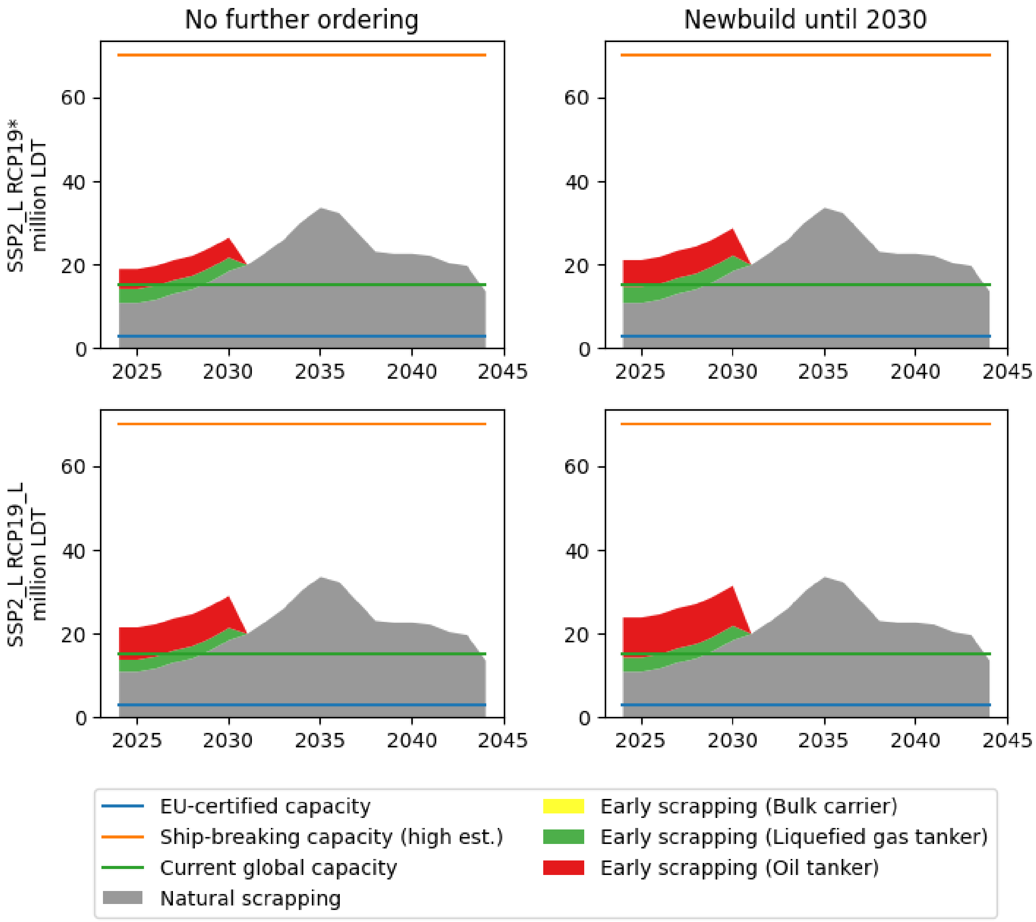

Figure 13: Estimated demand for ship breaking in the ordered scrapping scenario. Natural scrapping and capacity estimates are taken from (Solakivi et al., 2021)

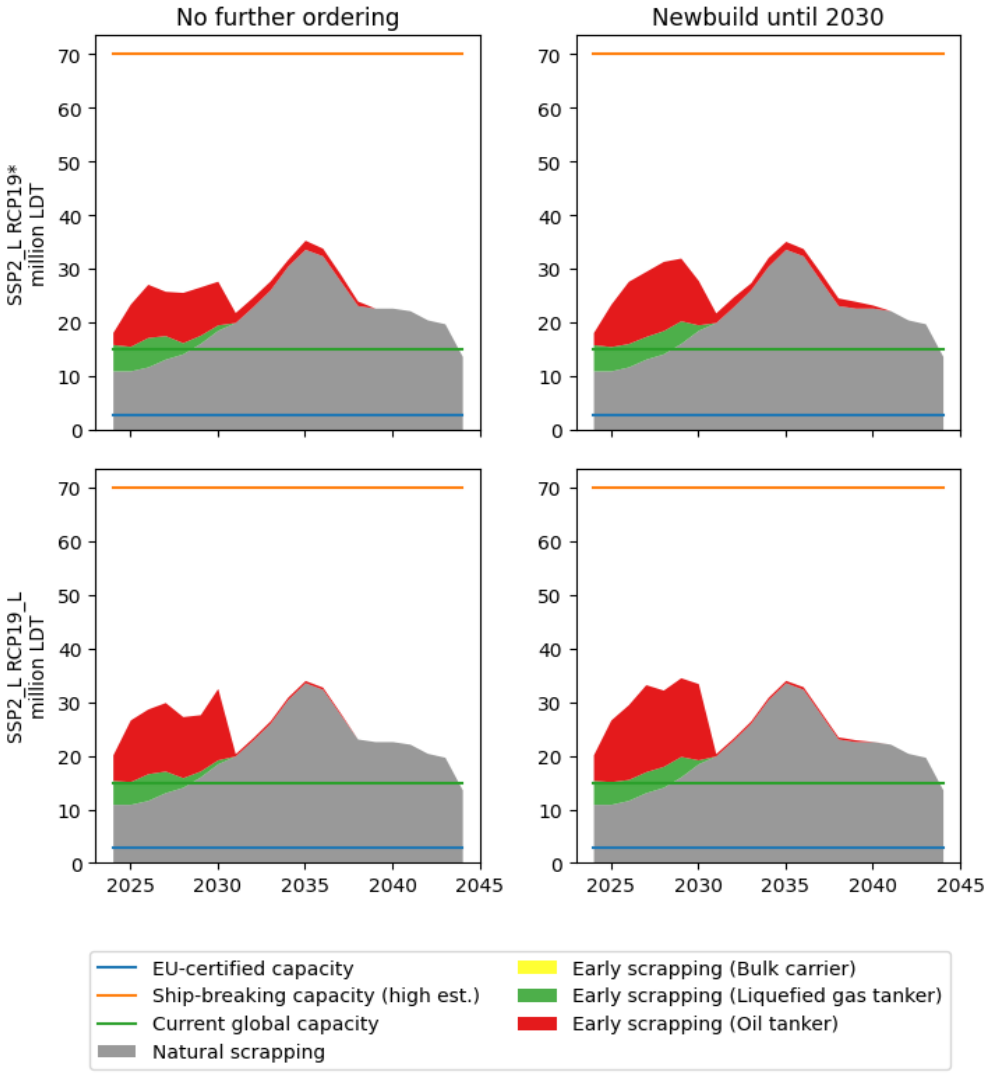

Figure 14: Estimated demand for ship breaking in the disorderly scrapping scenario. Natural scrapping and capacity estimates are taken from (Solakivi et al., 2021)

Paradoxically maybe, an increase in the safety and environmental regulation for shipbreaking might therefore incentivize the repurposing of ships and therefore reduce the number of ships effectively stranded. An ambitious increase in shipbreaking regulation would likely lead to a fall in scrapping value: (Barua et al., 2018) show that the current scrapping value, up to USD 260/LDT is based on the fact that the majority of the fleet is scrapped by beaching. On the other hand, most environmentally friendly and safe methods, e.g. dry dock, alongside or landing methods, are only able to pay shipowners USD 37/LDT. In the scenario where there is an Increased demand for sustainable capacity with limited supply, for example in the event of the strengthening of regulation of shipbreaking (e.g. the Hong Kong Convention), this would further fall due to market competition. In that context, scrapping a ship could become less attractive relative to the residual value of the ship after repurposing cost, provided of course such repurposing was technically feasible, as discussed in Section 5.

Overall, the materialisation of demand-side stranded assets risks significantly increase the demand for shipbreaking, which might create tensions on the shipbreaking market if the supply of shipbreaking limited due to the implementation of stringent regulation of shipbreaking. It is therefore important that sufficient sustainable shipbreaking capacity is anticipated and available when significant stranding takes place. At the time of writing, it is unclear whether the requirements of the Hong Kong convention would create such effect, as the lack of enforcement mechanism and the fact that the use of beaching continues to be allowed means that the supply for shipbreaking might continue to be elastic in the future. Such a scenario would happen the regulation is strengthened and/or if few yards are able to obtain a statement of compliance with the Hong-Kong Convention, putting pressure on the supply of shipbreaking.

7 Conclusions

This section first summarizes the findings of this report, grouped under each research question set in Section 1.1. It then discusses the implications of those findings to investors, and finally the limitations.

7.1 Summary of results

7.1.1 Who builds, finances, owns, flags, and operates fossil fuel carriers?

The results of this report highlight the fragmented ownership and operation of fossil fuel carriers, especially in oil tankers and bulk carriers. Furthermore, between 43% and 71% of owners and operators, depending on the segment, manage fleets predominantly composed of vessels belonging to one segment. On the contrary, ships are flagged and built by few flag states and shipyards respectively, and those appear to be diverse in the types of vessels they flag and build. While specific financiers for fossil fuel carriers are unclear, shipping banks play a key role in financing ships. However, market shifts and stricter regulations have led to reduced bank exposure to this sector, though bank lending remains the primary external financing source.

7.1.2 What is the current value and age structure of the fleet?

The total value of existing and ordered fossil fuel carrier fleet is around USD 875 billion in 2023. Bulk carriers lead at USD 336 billion, followed by oil tankers at USD 286 billion, with LNG and LPG tankers at USD 186 billion and USD 67 billion, respectively. Profit projections until 2050 ignoring demand-side risks reach USD 1.2 trillion, with bulk carriers contributing USD 490 billion (if the share of coal in bulk remains constant in the future, that would mean 83 billion for coal shipping only), oil tankers USD 234 billion, and liquefied gas tankers USD 446 billion. The orderbook for LNG and LPG tankers is extensive, with over half their fleet value represented by new or upcoming ships from the 2021-2030 generation.

7.1.3 What type and number of vessels will retire naturally?

In the coming years, the natural retirement of older vessels will be balanced by the arrival of new ships, maintaining stable capacity to transport fossil fuels and value of the fleet. Bulk carriers, LPG tankers, and especially LNG tankers are expected to grow until around the late 2020s. The LNG and LPG fleet, with recent large orderings compared to historical average and longer operational lifespans, are not projected to decrease significantly until after 2040. However, our model shows that if oil tankers are scrapped at their historical average scrap time and if no new vessels are ordered, the capacity of the oil tanker fleet begins declining as early as 2024, primarily due to their shorter remaining lifespan.

7.1.4 What will be the over-capacity of fossil fuel carriers in a 1.5 °C scenario until 2050?

Oil and liquefied gas tankers may face continuous oversupply if the demand aligns with a 1.5°C trajectory and ships cannot be repurposed to other cargoes. For oil tankers, despite declining demand and committed supply post-2024, the fleet's natural depletion is expected to lag, keeping supply above demand until the 2040s. Ordering further tankers delays the supply decrease until the 2030s, exacerbating oversupply. LNG tankers, with long lifespans and substantial orders, see committed supply growth until 2029 even if no further ships are ordered, surpassing the 1.5°C-aligned demand.

7.1.5 What will be the volume of stranded assets in such scenarios?

The oversupply of oil and liquefied gas tankers poses risks, with potential lost profits of around USD 215 billion by 2050 in the 1.5°C trajectory scenario and in the absence of repurposing, representing 32% of expected profits, if no further ships are built. This rises to USD 286 billion if newbuilding continues until 2030. The results further suggest that early scrapping might mitigate losses. In the "no further ordering" scenario, the value of the idle ships could peak at USD 90 to 108 billion by 2030 (25 to 30% of the tankers’ fleet value), increasing to USD 121 to 147 billion with further ordering (27 to 33%).

7.1.6 What type of vessels can be repurposed for carrying other forms of energy or other commodities?

If technological and economic feasibility align with transport demand, repurposing fossil fuel carriers could mitigate stranded asset risks. Conversion of oil tankers to carry chemicals and products, like methanol and biofuels, seems one of the most viable options. However, they would require the scale at which those products are traded today to adapt to the typically significantly larger sizes in which oil has been carried until now. LPG tankers could switch to ammonia but the carriers themselves as well as vessels, ports, and people that interact with the carrier would need to adhere to stricter safety protocols than with LPG. LNG tankers face potentially significant hurdles, especially if they intend to carry ammonia, including costly tank membrane and equipment modifications. Commercial risks persist across the fossil-fuel carrying fleet, due to uncertainty on demand for alternative commodities, trading capacities and market adaptation, port infrastructure compatibility, and the capability of receiving facilities for the new commodities. Unlike fossil-fuel liquid and gas carriers, coal carriers may inherently be more adaptable to carry other dry cargoes, and therefore face lower risk. In all cases, however, converted tonnage would be cannibalising on an existing and parallel market or set of markets, with potentially negative impact on profits in those markets should the converted tonnage increase transport supply all else equal. A prudent evaluation of the potential for converting fossil-fuel carriers therefore needs to consider all of these elements carefully.

7.1.7 What is the gap between existing and needed ship recycling capacities, also considering the Hong Kong Convention?

Modelling scrapping scenarios reveals that the materialisation of demand-side risks would result in a significantly higher demand, within the theoretical upper bound of global capacity but well above the capacity aligned with EU requirements. It is not clear at the time of writing what the capacity of shipbreaking aligned with the Hong Kong convention is and so how those estimates of additional scrapping compare with the Hong Kong convention-compliant capacity.

7.1.8 Overall summary

Table 7 summarises together the results of this report for each segment. Overall, the owners and operators of LNG tankers appear most at risk of demand side stranded asset risks, given that they are highly specialised in this segment, that they face high amount of lost profits and the potential for repurposing is low and uncertain. Oil and LPG tankers owners and operators also face significant risk, although to a lesser extent due to the relatively easier ability to repurpose their vessels. Bulk carrier operators and owners, because of the low amount of lost profits and ability to repurpose to carry other dry cargo, face little risk. Flag states and shipyards, because of their low degree of specialisation in any of those segments also face lower risks.

Table 7: Summary of the results

	Bulk carriers	Oil tankers	LNG tankers	LPG tankers
Specialisation of operators*	71%	56%	59%	49%
Specialisation of owners*	67%	65%	52%	43%
Specialisation of flag states*	0%	0%	0%	0%
Specialisation of builders*	11%	9%	2%	3%
Lost profits** (USD billion)	0	59-107	104-158	
Book loss** (USD billion)	0	27-57	52-63	
Challenges for repurposing	Low	Medium	High	Medium

** Share of actors where >90% of their ships are of one segment*
*** In the “no further ordering” scenario*

7.2 Implications

The current investments in fossil fuel carriers suggest that investors have a strong focus on immediate returns, and they may overlook future evolutions that limit the profitability of these investments, consistent with prior research by Fricaudet et al. (2023). Shipowners and financiers can do this and manage these risks by tempering investment in segments with uncertain future transport demand, investing in additional optionality, or by factoring this risk into expected returns—albeit potentially at the expense of short-term competitiveness.

Repurposing fossil fuel carriers to carrying other commodities could be seen as one of the more sustainable ways to mitigate some of these demand-side risks, which potentially also avoids additional emissions due to scrapping and newbuilding. Various factors, however, influence whether and to what extent these carriers could be repurposed. Coal carriers, for instance, sit on one end of this spectrum, in that they can be relatively easily adapted to carry other dry commodities. LNG tankers, however, sit at the other end, as they are highly specialised and significantly more difficult to convert to carry non-fossil gasses or even other liquids. Crude oil and LPG tankers fall somewhere in between. The former could be considered much more readily convertible to carrying chemicals such as methanol or even bio-based products, offering them a relatively positive opportunity to continue operations. One of the hurdles, however, would be their compatibility at ports or facilities that the products and chemical industry currently uses, because most crude oil tankers today are significantly larger than the typical sizes at which chemicals like methanol are moved or traded. Whilst crude carriers may have multiple liquid cargo options, LPG tankers may not have many other than ammonia and will therefore be highly sensitive to the growth in the seaborne trade of ammonia. All of these changes incur a cost that can vary from very small to very large and prohibitive, and it would therefore be prudent to consider an estimate of these costs relative to the alternatives in any calculation of risk and expected returns.

Limitations in recycling capacity, as highlighted in our findings, could paradoxically enhance the appeal of retrofitting over scrapping to investors. This scenario might arise if stricter environmental and safety regulations for shipbreaking lead to a reduction in scrapping costs that shipowners could potentially recoup.

To mitigate these risks, shipowners and financiers can adopt proactive measures such as investing in vessels designed for potential repurpose. Additionally, when valuing ships in the present, they should factor in the anticipated costs of future retrofitting and potential returns in the market or segment they would expect the vessel to operate if converted. This approach can enhance the resilience of their investments in the face of evolving market dynamics and regulatory landscapes.

While the reduction in shipping demand for fossil fuels poses a risk to investors, it also contributes to sectoral decarbonization. The estimated stranded demand in this study corresponds to approximately 1.3 to 1.5 billion tonnes of CO_2-equivalent emissions by 2050 if no new ships are commissioned, rising to 2 billion tonnes if new builds continue[8]. This equates to roughly 1.2 to 1.9 times the 2018 annual shipping emissions and comprises 11 to 15% of the remaining carbon budget for shipping aligned with a 1.5°C trajectory. This also indicates that under expectations of IMO regulation to control shipping GHG emissions, the fossil fuel carrying fleet can expect rising costs (to comply with GHG regulation) at the same time as declining profits and declining valuations.

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[8] Using the carbon intensity, Energy Efficiency Operating Indicator, from the Fourth IMO GHG Study (Faber et al., 2020), and assuming a ratio well-to-wake to tank-to-wake of 1.21 (Comer & Carvalho, 2023)

7.3 Limitations and further research

There are several ways in which the findings and methods in this study could be enhanced. First, trade scenarios were based on 2018 estimates from the Fourth IMO GHG Study, which are now outdated as the consumption (Rogelj et al., 2018) and consequent transportation of fossil fuels did not align with a 1.5°C trajectory. To address this limitation, trade from 2019 to 2023 was corrected to use actual, historical trade over this period. Future trade until 2050, however, was adjusted to remain aligned with a 1.5°C trajectory. This adjustment brings many uncertainties:

- one could fit an infinite number of curves for this adjustment, of which only one was selected for practical reasons. A sensitivity analysis, reported in the appendix, controls for the uncertainty of choosing one curve over another.
- this estimate does not include a bottom-up modelling of energy goods consumption and their impact on trade, because such modelling is not available at the date of writing. The fitted curves should therefore be considered a proxy for 1.5°C-aligned trade rather than a strict estimate.
- Limitations of the initial input data from the Fourth IMO GHG Study remain. In particular, this does not include the recent evolutions in trade, the consequences of the conflicts in Ukraine and Gaza onto global trade such as the increase in sea distance, mode shift from pipeline to ship, or reduction in gas consumption due to higher prices.

Second, this initial assessment of stranded assets is based on averages taken for each type and size-class of vessel, making the findings indicative. Enhancing precision may entail refining these estimates by incorporating more granular data at the individual ship level. Distinguishing between various types of liquefied gas tankers, such as LNG and LPG tankers, could provide deeper insights, given significant differences in everything from how they are designed to their cost structures. Alternatively, conducting a case study on a specific ship model of the risk of stranded asset and economic potential of repurposing, as it has already been done for ship propulsion (Jeong et al., 2023), could offer valuable insights. Furthermore, the possibility of ships to retrofit for alternative cargoes was qualitatively assessed, but the cost of repurposing was not quantified. As the quantitative estimates of stranded assets and scrapped capacity ignore these possibilities, the estimates should therefore be considered as the maximum value at risk. This opens avenues for further research.

Last, this analysis only covered one factor of demand-side risks and focused on three segments: bulk carriers, liquefied gas tankers, and oil tankers. Other factors linked to a low-carbon transition could exacerbate future demand uncertainties. For instance, a global shift away from fossil fuels may reduce offshore activities associated with fossil extraction, while increased regionalization of trade may decrease shipping distances and activity (Walsh et al., 2019; Walsh & Mander, 2017). Conversely, current demand estimates often overlook the potential uptake of alternative commodities like biofuels, CO_2, and hydrogen-derived fuels, which could partially offset the decline in fossil fuel transport demand. Further research is required to explore the future trade dynamics of these commodities and assess the economic feasibility of retrofitting existing ships to accommodate these functions.

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9 Appendix A: List of top 10 actors in each segment

Table 8: Top 10 owners, builders, operators and flag states of bulk carriers, oil, LNG and LPG tankers

a. *Calculated based on Clarksons WFR, data collected on 9/02/2024*
b. *The number of vessels include both existing and ordered fleet.*

9.1.1.1 Top 10 Flag States of Oil tankers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	China P.R.	1,668	13%	18%
2	Marshall Is.	1,033	8%	24%
3	Panama	992	8%	12%
4	Liberia	975	8%	19%
5	Indonesia	730	6%	6%
6	Japan	669	5%	13%
7	Singapore	597	5%	18%
8	Hong Kong	391	3%	16%
9	Russia	385	3%	13%
10	Malta	315	2%	17%

9.1.1.2 Top 10 Owners of Oil tankers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	COSCO Shipping Energy Transportation Co Ltd (CSET)	134	1%	98%
2	Scorpio Tankers Inc	106	1%	100%
3	Sovcomflot	100	1%	84%
4	Sinokor Merchant Marine Co Ltd	100	1%	52%
5	Dynacom Tankers Management Ltd	96	1%	99%
6	Frontline plc	91	1%	100%
7	Hafnia Limited	85	1%	79%
8	TORM A/S	81	1%	94%
9	International Seaways Inc	77	1%	100%

10	Tsakos Energy Navigation (TEN) Ltd	63	0%	95%

9.1.1.3 Top 10 Operators of Oil tankers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	Hafnia Limited	157	1%	79%
2	COSCO Shipping Energy Transportation Co Ltd (CSET)	124	1%	98%
3	Scorpio Tankers Inc	113	1%	100%
4	Maersk Tankers A/S	90	1%	70%
5	Frontline plc	88	1%	100%
6	Penfield Marine LLC	82	1%	100%
7	TORM A/S	82	1%	94%
8	Sovcomflot	78	1%	94%
9	Norden Tanker Pools	70	1%	100%
10	Navig8 Asia Pte. Ltd.	64	0%	86%

9.1.1.4 Top 10 Shipyards of Oil tankers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	Hyundai Mipo	699	5%	49%
2	Hyundai HI (Ulsan)	408	3%	25%
3	Samsung HI	358	3%	31%
4	STX SB (Jinhae)	321	2%	59%
5	Daewoo (DSME)	307	2%	31%
6	Hyundai Samho HI	286	2%	35%
7	New Times SB	196	2%	49%
8	Dalian Shipbuilding	177	1%	47%
9	Hakata Zosen	161	1%	51%
10	GSI Liwan	152	1%	63%

9.1.1.5 Top 10 Flag States of LPG tankers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	Panama	276	15%	3%
2	Liberia	191	10%	4%
3	Singapore	157	9%	5%
4	Japan	127	7%	2%
5	China P.R.	101	5%	1%
6	Marshall Is.	100	5%	2%
7	Indonesia	91	5%	1%
8	Thailand	79	4%	9%
9	Malta	57	3%	3%
10	South Korea	36	2%	2%

9.1.1.6 Top 10 Owners of LPG tankers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	Navigator Holdings Ltd (Navigator Gas)	51	3%	100%
2	BW Epic Kosan Ltd	43	2%	100%
3	StealthGas Inc	32	2%	100%

4	Eastern Pacific Shipping Pte Ltd	31	2%	13%
5	Solvang ASA	29	2%	100%
6	Tianjin Southwest Maritime	27	1%	69%
7	Siam Lucky Marine Co. Ltd.	27	1%	96%
8	Petredec Ltd	26	1%	100%
9	Pilatus Marine Co.	24	1%	100%
10	Pacific Gas Pte Ltd	24	1%	100%

9.1.1.7 Top 10 Operators of LPG tankers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	BW Epic Kosan Ltd	59	3%	102%
2	BW LPG Limited	38	2%	100%
3	Navigator Holdings Ltd (Navigator Gas)	37	2%	100%
4	Geogas Maritime SAS	33	2%	97%
5	StealthGas Inc	33	2%	100%
6	GasChem Services G.m.b.H. & Co K.G.	33	2%	100%
7	Unigas International (B.V. United Gas Carriers)	26	1%	100%
8	Siam Lucky Marine Co. Ltd.	25	1%	96%
9	Dorian LPG	23	1%	100%
10	Tianjin Southwest Maritime	22	1%	71%

9.1.1.8 Top 10 Shipyards of LPG tankers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	Hyundai HI (Ulsan)	246	13%	15%
2	Hyundai Mipo	133	7%	9%
3	Jiangnan SY Group	113	6%	42%
4	Shitanoe Zosen	91	5%	34%
5	Kawasaki HI Sakaide	67	4%	39%
6	MHI Nagasaki	65	4%	28%
7	Hyundai Samho HI	57	3%	7%
8	Miura Zosensho	54	3%	10%
9	Murakami Hide	48	3%	14%
10	Sasaki Zosen	44	2%	15%

9.1.1.9 Top 10 Flag States of Bulk carriers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	Panama	2,754	19%	33%
2	Liberia	2,072	14%	40%
3	Marshall Is.	2,021	14%	47%
4	China P.R.	1,948	13%	21%
5	Hong Kong	1,011	7%	40%
6	Singapore	617	4%	19%
7	Malta	467	3%	25%

8	Bahamas	343	2%	27%
9	Cyprus	247	2%	25%
10	Indonesia	198	1%	2%

9.1.1.10 Top 10 Owners of Bulk carriers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	COSCO Shipping Bulk Co Ltd	204	1%	100%
2	Wisdom Marine Group	139	1%	91%
3	China Development Bank Financial Leasing Co Ltd	132	1%	66%
4	Star Bulk Carriers Corp	117	1%	100%
5	Pacific Basin Shipping (HK) Ltd	116	1%	99%
6	Nisshin Shipping Co Ltd	106	1%	76%
7	Oldendorff Carriers GmbH & Co KG (Egon Oldendorff)	101	1%	94%
8	Golden Ocean Group Ltd (GOGL)	87	1%	100%
9	Pan Ocean Co Ltd	78	1%	65%
10	Nippon Yusen Kaisha (NYK Line)	73	0%	26%

9.1.1.11 Top 10 Operators of Bulk carriers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	Oldendorff Carriers GmbH & Co KG (Egon Oldendorff)	246	2%	98%
2	COSCO Shipping Bulk Co Ltd	226	2%	99%
3	SwissMarine Services SA	118	1%	100%
4	Pacific Basin Shipping (HK) Ltd	115	1%	103%
5	Wisdom Marine Group	108	1%	92%
6	Vale SA	108	1%	89%
7	Star Bulk Carriers Corp	99	1%	99%
8	G2 Ocean	93	1%	96%
9	Golden Ocean Group Ltd (GOGL)	86	1%	101%
10	Fednav Ltd	78	1%	99%

9.1.1.12 Top 10 Shipyards of Bulk carriers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	Oshima Shipbuilding	908	6%	97%
2	Tsuneishi Cebu	389	3%	96%
3	Tsuneishi Zosen	364	2%	82%
4	Imabari SB Marugame	315	2%	71%
5	Chengxi Shipyard	303	2%	81%

6	Tsuneishi Zhoushan	278	2%	82%
7	Imabari SB (Imabari)	275	2%	63%
8	Shanghai Waigaoqiao	272	2%	58%
9	Namura Shipbuilding	246	2%	81%
10	Mitsui SB (Tamano)	241	2%	83%

9.1.1.13 Top 10 Flag States of LNG tankers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	Marshall Is.	132	12%	3%
2	Bahamas	85	8%	7%
3	Malta	73	7%	4%
4	Panama	58	5%	1%
5	Bermuda	54	5%	49%
6	Singapore	53	5%	2%
7	Greece	46	4%	4%
8	Liberia	36	3%	1%
9	Hong Kong	34	3%	1%
10	Japan	25	2%	0%

9.1.1.14 Top 10 Owners of LNG tankers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	Mitsui OSK Lines Ltd	59	5%	21%
2	Nippon Yusen Kaisha (NYK Line)	50	5%	18%
3	Knutsen OAS Shipping AS	44	4%	94%
4	Maran Gas Maritime Inc	44	4%	100%
5	Nakilat	40	4%	91%
6	Seapeak LLC	40	4%	77%
7	QatarEnergy	32	3%	97%
8	Malaysia International Shipping Corp (MISC)	31	3%	61%
9	GasLog Ltd	30	3%	100%
10	BW LNG AS	29	3%	97%

9.1.1.15 Top 10 Operators of LNG tankers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	QatarEnergy	84	8%	85%
2	Nakilat	61	6%	100%
3	STASCO (Shell International Trading & Shipping Co Ltd)	49	4%	39%
4	Petroliam Nasional Berhad (Petronas)	41	4%	80%
5	Korea Gas Corp (KOGAS)	30	3%	100%
6	Shell Tankers (Singapore) Pte. Ltd.	26	2%	40%
7	Yamal Trade Pte Ltd	25	2%	100%
8	ExxonMobil Corporation	19	2%	20%
9	Maran Gas Maritime Inc	15	1%	100%
10	BP Shipping Ltd	14	1%	33%

9.1.1.16 Top 10 Shipyards of LNG tankers

Rank	Name	Vessels	Share of fleet (# ships)	Specialisation (# ships)
1	Samsung HI	246	22%	21%
2	Hyundai HI (Ulsan)	182	16%	11%
3	Daewoo (DSME)	177	16%	18%
4	Hyundai Samho HI	92	8%	11%
5	Hudong Zhonghua	76	7%	21%
6	Hanwha Ocean	67	6%	53%
7	MHI Nagasaki	49	4%	21%
8	Kawasaki HI Sakaide	35	3%	20%
9	Dalian Shipbuilding	14	1%	4%
10	Mitsui SB (Chiba)	14	1%	7%

10 Appendix B: Sensitivity analysis

In this section, we present the results of stranded assets if the demand for fossil fuel carriers continues increasing as predicted in Clarksons SIN until 2025, before aligning with a 1.5°C scenario. The methods used for refitting the curve is the same as described in Section 4.2. The cumulative amount of lost profits is very similar to the central scenario (alignment from 2023 onwards) (see Figure 12). However, as those lost profits happen in fewer years, the peak in unused capital is somewhat larger than in the central scenario (see Figure 10 and Figure 11). This results in somewhat higher level of scrapping (see Figure 13 and Figure 14), but the interpretation of the results remains similar.

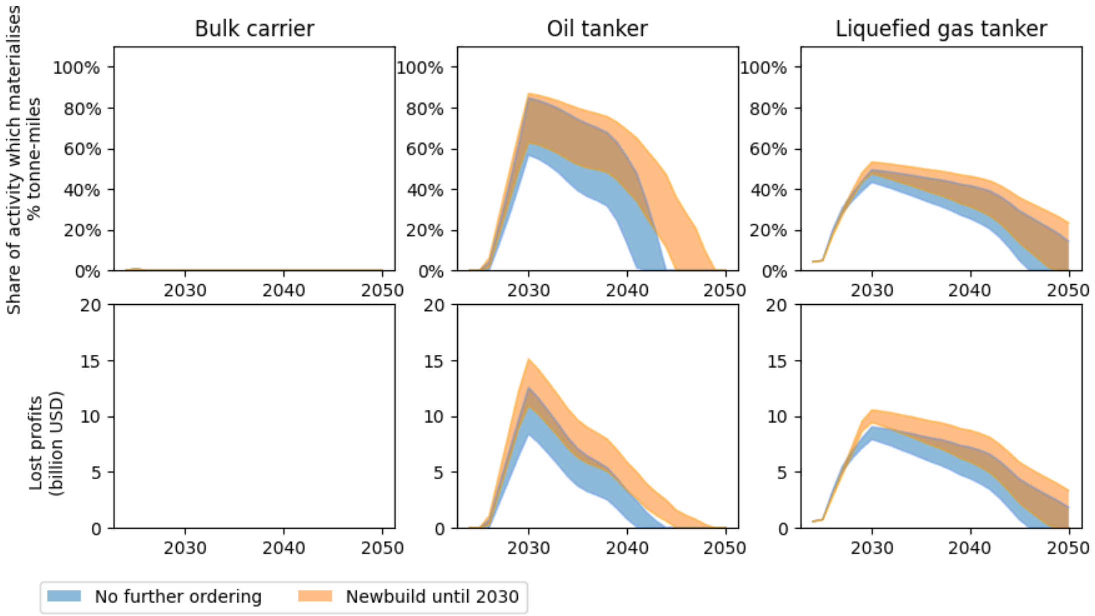

Figure 15: Demand-side risk and lost profits (demand starts aligning from 2023 onward)

a. *The areas represent the range of estimates in various shipping demand scenarios.*

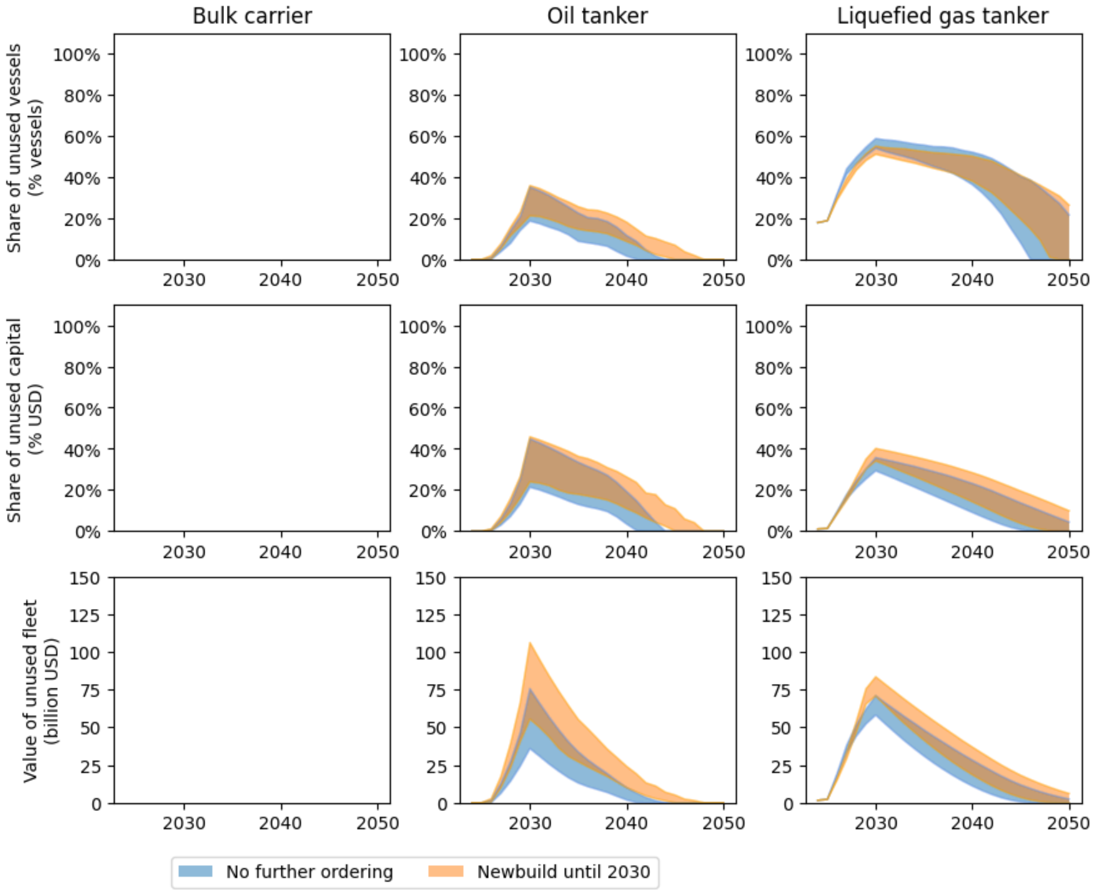

Figure 16: Demand-side risk and book loss (demand starts aligning from 2025 onward)

a. *The value of the unused fleet can be considered a worst-case proxy for book loss. It is a cumulative value rather than an annual flow.*

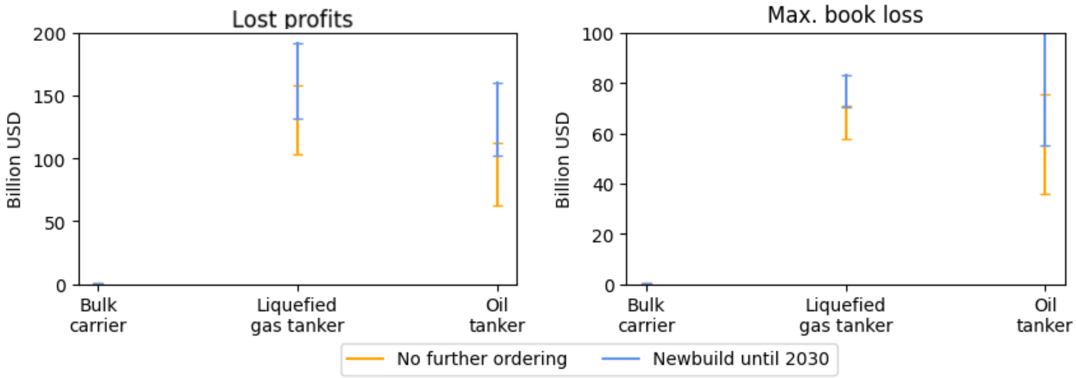

Figure 17: Cumulative demand-side risk until 2050. Demand aligns from 2025 onwards.

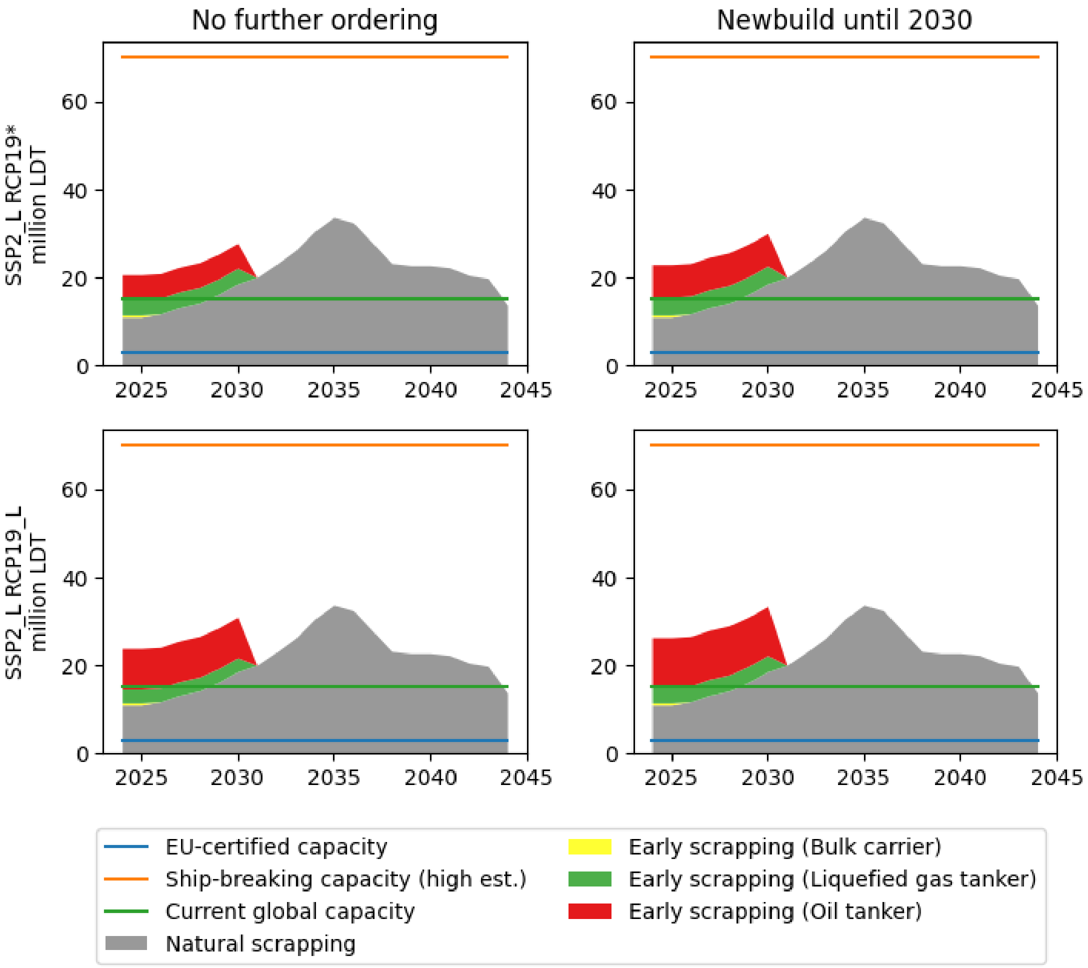

Figure 18: Estimated demand for ship breaking in the ordered scrapping scenario. Natural scrapping and capacity estimates are taken from (Solakivi et al., 2021)

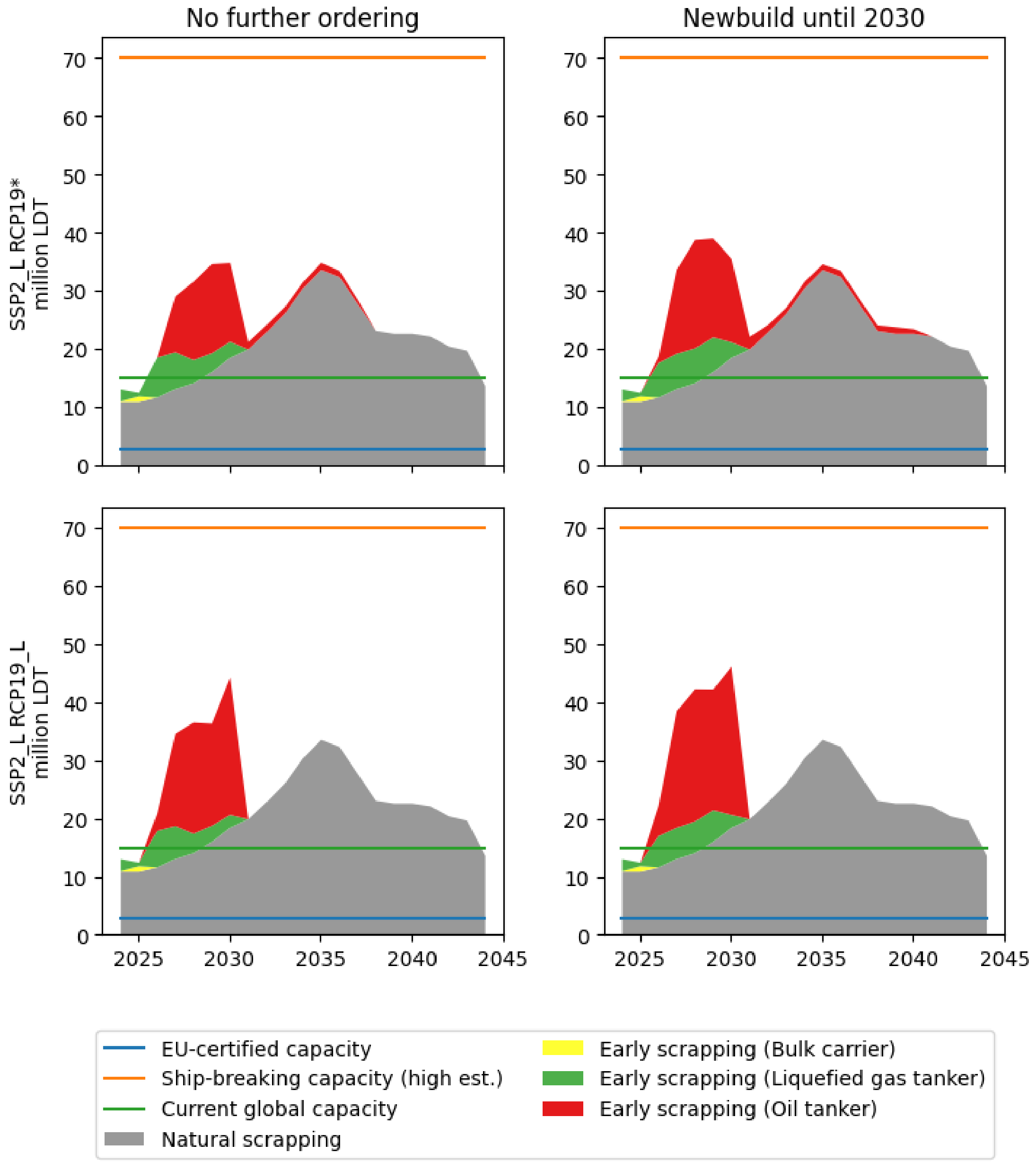

Figure 19: Estimated demand for ship breaking in the disorderly scrapping scenario. Natural scrapping and capacity estimates are taken from (Solakivi et al., 2021)

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