



Carbon Carriers

The Impact of Rapid Decarbonisation
on the Shipping Industry

2019

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Executive Summary

The decarbonisation of global energy supplies to address climate change will have radical implications for the global shipping industry. If the Paris Agreement goals are met, the fossil fuel cargo base that shipping serves would undergo an aggressive and prolonged transformation.

The consequences for shipping markets of a major shift in energy consumption away from hydrocarbons and towards renewables and biofuels is the subject of a report prepared by MSI on behalf of the European Climate Foundation (ECF).

MSI's shipping market modelling systems enable analysis of how changes in energy demand will affect inter-regional commodity trade flows, and the associated shift in required shipping capacity, industry earnings and asset prices, across all segments of the shipping industry.

The analysis projects two demand frameworks – '*Reduction*' and '*Reference*' – designed to provide broad narrative and structure to long-term global energy demand.

Global energy consumption in the *Reduction* scenario is largely based on projections made for pathways consistent with limiting warming to 1.5°C above preindustrial levels, as described in the IPCC SR1.5 report. The *Reference* scenario is designed to provide a comparison to *Reduction*. Although it describes a more limited change in the global energy consumption profile, *Reference* still incorporates substantial restraints on future energy consumption.

The more extreme *Reduction* scenario is the focus of the report, under which fossil fuel demand sees radical decline over the next three decades. By 2050 world coal consumption falls by 80%, oil consumption halves, and gas demand drops by about a quarter.

Whilst some sectors of the shipping industry, such as containerships, would be virtually unscathed, those for which hydrocarbons comprise a significant proportion of (or all) the cargo mix would undergo decades of falling demand.

The results, detailed in the report, would be multi-decade declines in fleet capacity, earnings and asset prices across the affected sectors. Ship owners would be forced to slash new ordering and scrap uneconomic vessels.

The energy transition from fossil fuels to renewables means that investors in shipping and ports are exposed to substantial financial risks, which have not been adequately assessed before. Accelerated action at a governmental level, technological advances, increased renewable use, public pressure, and increased regulatory and financial constraints will all contribute to this process – the question is how fast?

In a rapid transition, as explored in this report, vessel selection will be critical, and divestment from sectors with the greatest exposure to fossil fuels may prove the only way to profitably navigate the changing landscape.

1.0 Introduction

Energy and shipping intertwined

Hydrocarbons remain at the core of meeting global energy demand. Coal, oil and gas account for close to 80% of global primary energy supply but pressure to reduce emissions and restrict global warming means that this position is not sustainable.

Shipping markets are integral to global supply chains, transporting energy, commodities, intermediate and manufactured goods in huge volumes.

As such, shipping is a key intermediary in facilitating the processing and consumption of hydrocarbon energy. Whilst carbon risk reports have tended to focus on upstream and downstream assets, this reports look to augment these analyses by concentrating on one of the main modes of energy transportation – seaborne flows – and the associated assets.

Nearly half of all crude oil is first shipped to refineries before it is processed for consumption, and a quarter of oil consumption consists of refined products that have been shipped from refineries to the point of end-use. About 15% of global coal production is shipped, while the proportion of gas moved in liquefied natural gas (LNG) carriers is over 10% and rising fast.

It is not just energy markets in which shipping plays a fundamental, if often understated, role. The value of global containerised goods shipped at sea is over \$7 Tn, about 9% of global GDP.

Other sectors such as agriculture and food supply, steel and chemical industries still provide the physical underpinnings of modern living and are also dependent on shipping. Seaborne transportation acts as the most flexible, economical link between sources of production and consumption of a wide range of commodities and goods.

Capital outlay amid volatile conditions

Shipping is capital intensive. The value of the merchant shipping fleet is in excess of \$0.7 Tn. Maintaining and growing this capacity requires large amounts of finance. Shipping investors also take on a large amount of risk. Markets are vulnerable to oversupply as excessive ordering of ships and large fluctuations in demand drive dramatic swings in capacity utilisation.

These conditions lead to major cyclical swings – most large commercial shipping markets have experienced conditions ranging from exceptionally high super-booms in earnings to chronically low market rates which have driven owners to huge losses, widespread bankruptcies and the premature scrapping of ships.

Associated with the high amplitude of shipping earnings are similar oscillations in asset prices. In a strong market, the price of ships can escalate rapidly as the earnings potential drives up sale prices. One of the most striking examples of this was in the boom of the mid-2000s. In August 2003 the



quoted price for a 5 year-old Capesize bulker (one of the larger dry bulk vessel classes, typically used to move iron ore into China from Brazil and Australia) was about \$33 Mn. Five years later in August 2008 the price of the same ship type had skyrocketed to \$155 Mn, nearly a five-fold increase. Another five years later in 2013 and the price had reverted to around \$30 Mn. Within the last five years the value has dropped below \$25 Mn, and in Q3 2018 was sitting back in the mid-thirties again.

For some, this volatility is what makes shipping an attractive market to invest in. Time it right and you can trade assets in and out of the peaks and troughs. Shipping's ability to create its own cycles through over-ordering provides volatility which operators can (or think they can) take advantage of.

However, whilst fluctuations in ordering and shipping demand have created tumultuous market conditions, shipping has been able to rely, in most major markets, on long-term trend growth in demand. Over time, cargo volumes have expanded. Cargo growth rates may vary with GDP and regional dynamics in supply and demand for the particular cargo, but the long-term trend is upwards.

In this report we will investigate what could happen to shipping markets should some shipping sectors see this broadly positive demand trend reversed as a result of a massive restructuring of global energy demand, in line with the most radical emissions targets.

2.0 Methodology

2.1 Energy Demand Scenarios

The emphasis of the report is looking at the consequences for shipping markets of a major shift in energy consumption away from hydrocarbons and towards renewables and biofuels. To analyse this MSI was commissioned by the ECF to project two demand frameworks, designed to provide broad narrative and structure to long-term global energy demand by fuel.

We will label these scenarios '*Reduction*' and '*Reference*'. Both scenarios are informed by projections made or commissioned by the Intergovernmental Panel on Climate Change (IPCC).

The report does not provide commentary or assessment of the likelihood of the projected scenarios occurring. Rather the scenarios are being used as frameworks to explore the implications on the shipping industry and associated capital markets of a major shift in energy demand.

The timeframe of the report is out to 2050, though the temperature targets associated with the IPCC scenarios have timeframe objectives that extend beyond this period. For example, 1.5°C-consistent emission pathways are defined as those that, given current knowledge of the climate response, provide a one-in-two to two-in-three chance of warming either remaining below 1.5°C, or returning to 1.5°C by around 2100 following an overshoot¹.

¹ IPCC

Cargo types

Demand for shipping is driven by geographical dislocation between points of supply and demand for:

- Primary commodities (raw materials extracted from the earth or grown, e.g. crude oil, natural gas, coal, agricultural commodities)
- Secondary commodities (processed from primary commodities, e.g. refined products, steel, chemicals)
- Manufactured goods (typically transported in container boxes)

In shipping terminology, various cargo types can also be defined in other ways, such as ‘wet’ cargo (various liquids such as oil, LNG, Chemicals etc.) and ‘dry’ such as iron ore, coal, steel and agricultural commodities.

For the purposes of this study, it is also important to distinguish cargo by another definition: whether it is used to provide energy or not. Broad categorisation of ship types involved in energy and non-energy transportation is shown in Figure 1. The specific cargo types that will be analysed are shown in Table 1.

Figure 2A: Shipping Sectors and Energy Market Exposure

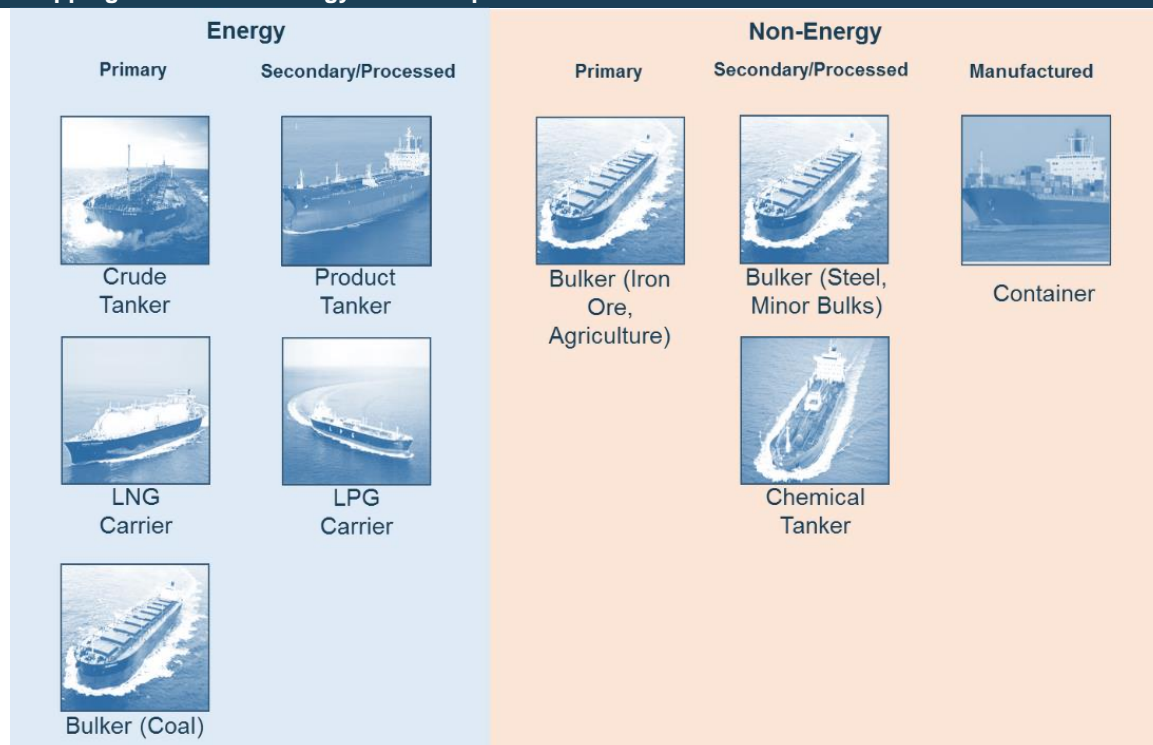




Figure 2B: Cargo Types

Dry Bulk	Tankers	LPG and LNG carriers	Manufactured Goods
Coal	Crude Oil	LPG	Container TEUs
Iron Ore	Refined Products	LNG	
Steel + Minor Bulks	Chemicals		
Agricultural			

The treatment of demand-side dynamics and scenario projections in the study will depend on whether a sector sits within the energy or non-energy category.

In the case of energy cargoes, the onshore consumption profile of the cargo type (e.g. oil) will be determined within the scope of the ‘*Reduction*’ and ‘*Reference*’ scenarios detailed below.

In these instances, we have structured the projections for shipping demand in four stages

1. Demand by fuel type – ‘onshore’ consumption – uses MSI market data combined with projected scenario rate of change. Where necessary, regional demand profiles are supported using plausible proportional distributions sourced from both IPCC and other prominent market reports²
2. Associated raw material production scenarios – output of cargo type – tracks consumption profile. Again, where necessary, regional production splits are supported using plausible proportional distributions sourced from prominent market reports³
3. Consequences for trade – deficits/surplus in production/consumption underpin import/export requirements. In turn these regional dynamics drive bilateral trade flows – i.e. the volume of cargo moving across a particular route. Bilateral flows are influenced by a wide range of factors including relative proximity, trading and diplomatic relationships, production specifications (exporter), processing capacity and configuration (importer).
4. Determining demand for shipping capacity – tonnage required. This is calculated primarily as a product of the cargo flow across routes and the associated distance travelled, as well as incorporating other assumptions such as vessel speed and time in port to convert the cargo volume (or more typically, weight) into an annual requirement for the relevant shipping tonnage.

Regions

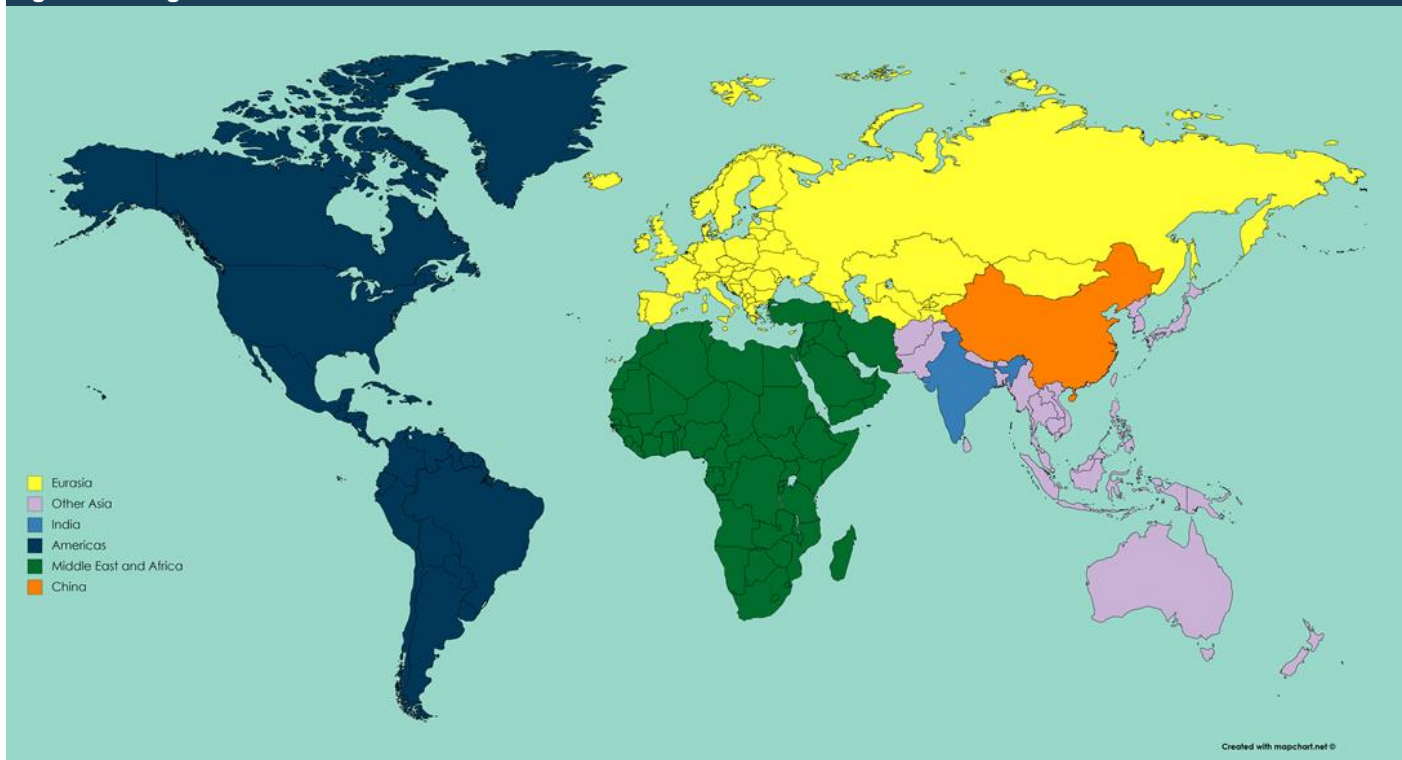
The regions used have been defined geographically, rather than in economic/social *blocs*. In most cases the following definitions have been used to provide consistency across sector demand modelling. In some cases though, given sector-specific characteristics in regional supply and

² International Energy Agency, Shell, BP

³ International Energy Agency, Shell

demand, it has been necessary to use alternative definitions, and these are outlined in the relevant sectors. Further in some market modelling, due to the geographical dependence of shipping demand, it has been either appropriate or convenient to modify the regional definitions to better model a particular market. As such the definitions should be viewed as representative rather than, in all cases, exact.

Figure 2C: Region Definition



Below we will look at the construction of the demand scenarios and associated outlook for energy consumption by energy source.

Reduction

The *Reduction* scenario will be the focus of this study. Global energy consumption in this scenario is largely based on projections made for pathways consistent with limiting warming to 1.5°C above preindustrial levels, as described in the IPCC SR1.5 report. Some key conditions and characteristics of this scenario include:

- Limiting warming to 1.5°C implies reaching net zero CO₂ emissions globally around 2050 and concurrent deep reductions in emissions of non-CO₂ forcers, particularly methane
- Such mitigation pathways are characterized by energy-demand reductions, decarbonisation of electricity and other fuels, electrification of energy end use, deep reductions in agricultural emissions, and some form of CDR with carbon storage on land or sequestration in geological reservoirs. Low energy demand and low demand for land- and GHG-intensive consumption goods facilitate limiting warming to as close as possible to 1.5°C.

- Limiting warming to 1.5°C requires a marked shift in investment patterns. Investments in low-carbon energy technologies and energy efficiency would need to approximately double in the next 20 years, while investment in fossil-fuel extraction and conversion decrease by about a quarter.
- 1.5°C-consistent pathways include a rapid decline in the carbon intensity of electricity and an increase in electrification of energy end use

The energy consumption outlook for *Reduction* is shown in Chart 2A. Under this scenario, global energy consumption is not projected to see significant growth out to 2050, but rather, fluctuate close to recent levels, with significant reduction during the 2020s.

Hydrocarbon use sees massive reductions. The most dramatic case is Coal which transitions from meeting about one quarter of global energy requirements to less than 5% by 2050. Over the same period the 'Oil+Liquids' share halves from about one-third to less than 20%. Of the major hydrocarbon energy sources, Natural Gas sees the least relative reduction, but nonetheless drops from about a quarter of global energy to close to 15%.

Meanwhile we see an explosion in the use of both Biomass/Biofuels and Renewables. Whilst the former presents its own environmental challenges, it also potentially offers alternative employment for ships. In the case of Renewables, this replacement of shipping demand is difficult to envisage. The key point is that currently it is the energy that is being shipped in the form of coal/oil/gas, not the infrastructure used to harness it (powerplants, refineries etc.). Mass renewable energy and vehicle electrification may require significant shipping of infrastructure materials and metals for batteries etc. but this would be a one-off event in the energy chain, as these are components not feedstocks. The majority of commodity shipping is associated with moving primary feedstocks.

Further, renewable energy in the form of wind, solar etc. cannot be shipped, only transferred electrically via fixed grid or battery once harnessed, so wouldn't generate any trade in secondary processed commodities, such as you see now in the form of e.g. oil products and steel. In essence this is one of the key benefits of renewables - they don't require a constant feed of extracted/polluting natural resources.

The resultant decline in shipping demand, and industry response, driven by the *Reduction* scenario will be one of the key themes explored in this report.

Charts 2A and 2B show the energy consumption profiles used in the *Reduction* and *Reference* scenarios.

Chart 2A: Reduction Scenario

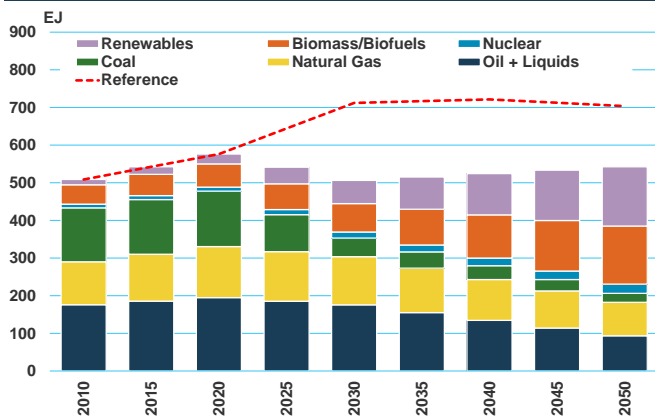
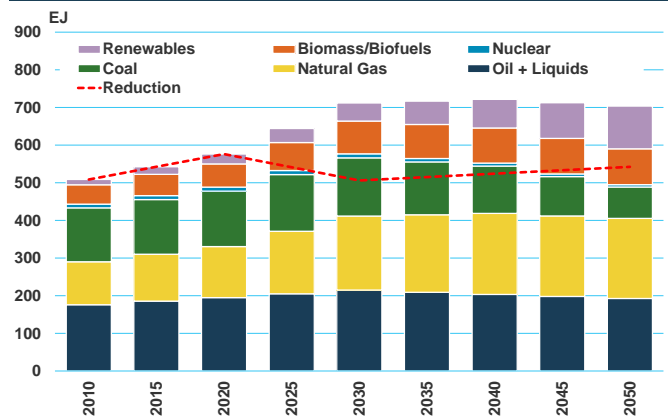


Chart 2B: Reference Scenario



Reference

The *Reference* scenario is designed to provide a comparison to *Reduction*. Although it describes a much more limited change in the global energy consumption profile, the *Reference* scenario still incorporates substantial restraints on future energy consumption. It has been derived using projections from the IPCC's 2.6 Wm⁻² radiative forcing scenario, as this produces temperature responses that are below a 2°C increase by 2100.

Under this scenario, global energy demand continues to grow robustly through the 2020s before stabilising in the 2030s. We do see a transition in the composition of the demand. Coal use declines whilst Natural Gas use increases substantially through the 2030s. Fossil fuels see an overall decline in their usage, from above 80% in 2020 to about 70% by 2050, but it is nowhere near as severe as in the *Reduction* scenario.

Renewables see the biggest net gain across the forecast horizon, increasing from 5% in 2020 to 16% in 2050, whilst Biomass/Biofuels see substantial growth to 2030, rising to 12% of global demand, but see little proportional gain beyond that.

2.2 Non-energy Related Demand

Shipping demand is in large part driven by energy demand. For some sectors, such as oil tankers and LNG carriers, this is almost entirely the case. In other sectors, such as dry bulk, energy cargoes constitute a large part of the total cargo (mainly coal) but the sector also carries other major non-energy cargoes such as iron ore, grains and steel.

Other sectors, such as containerships, carry almost zero energy related cargoes, and demand is driven primarily by manufactured goods.

Given the report's focus on energy transportation in major shipping markets, analysis of chemicals, grains and minor bulks demand under the scenarios can be found in the Appendix.

In the case of non-energy cargoes, the projections for demand have been determined using both MSI's Base Case assumptions, and subjective, reasoned assessments of the demand outlook in the context of shifting global priorities and consumption patterns. These have also been influenced by the sustainability pathways outlined in the ICPP reports. Details on the treatment of non-energy sectors are provided in their respective demand sections.



Looking at potential 'second order' effects of the energy consumption profiles established for the *Reduction* and *Reference* scenarios, we will use MSI's sector specific models, particularly Dry Bulk and Containerships, along with qualitative judgements, to determine consumption/production dynamics and seaborne trade profiles for the following cargoes

3.0 Oil Tanker Demand

3.1 Consumption and Production

Oil is used for a range of functions, primarily as transportation fuel but also industrial fuel, in power generation and feedstock for petrochemical production. Oil is shipped both as crude (unrefined) oil, and as refined products such as diesel, gasoline, naphtha etc.

Demand is global, but oil production is concentrated in regions such as the Middle East, Americas, Africa and FSU. Notably Asia and Europe have much lower production versus their consumption needs and require large amounts of imports, either as crude for refining or refined products. Oil trade is also dependent on regional refinery capacity and configuration.

Global oil demand's recent growth has typically been in the 1-1.5% range and is dependent on broadly benign global macroeconomic conditions. During times of economic recession, such as the global financial crash and ensuing economic downturn, global oil demand declined on an annual basis, but in 'normal' conditions it grows.

Growth in demand is primarily driven by non-OECD regions, particularly Asia, where economic growth rates have been highest and vehicle ownership rates are lower. OECD regions saw their oil demand levels peak around the mid-2000s, Demand then saw a decline, exacerbated by the global financial crisis. However, in recent years regions such as the US and Europe have started to see oil consumption grow again.

Long-term demand for oil will be dependent on the evolution of transportation technology, focused on road transport. Assuming demand for transportation will continue to grow with demographic and economic expansion, oil demand's role within this will primarily be determined by the increase in efficiency of the global vehicle fleet using either full combustion engines or hybrid technology, and the speed of the transition towards electrification.

Electric vehicles now comprise about 1.5-2% of global passenger car fleet. Vehicle electrification is growing rapidly in China – about 2% of new registrations in China were electric in 2017, representing around half of all plug in electric vehicles sold globally in that year. Vehicle electrification benefits from political and public backing, supports emission reductions, improves energy security and has technological momentum. Most electric vehicles likely to be hybrid – constraints on battery technology, required resources (lithium, cobalt) and infrastructure. Therefore important to distinguish between number of 'electric' vehicles and the amount of transport activity powered by electricity.

Views on oil demand peaking are currently more dependent on increased engine efficiency, rather than electric vehicle penetration. The increased requirement for power generation for electric vehicle

usage also implies that traditional power generation technology must rapidly switch away from fossil fuels to suppress GHG emissions generated by electric vehicles.

As a result of increased electrification, the proportion of oil demand driven by freight transport, aviation and petrochemicals is likely to rise.

Under the *Reduction* scenario, global oil consumption effectively halves between 2020 and 2050. Declines are most severe in regions which have a substantial component of OECD countries – in the Americas, Eurasia and Other Asia, the decline is close to 60%. Indian demand is flat across the period, whilst China and ME/Africa drop by close to 40%.

Global oil production is focused on the Middle East, Americas and Eurasia, with very limited output in Asia. Due to the shale boom in the US we continue to expect Americas output to grow in the near-term, but oil production will have to accommodate the projected decline in demand. Due to the dislocation between supply and demand, oil shipping will still be required.

Global refinery capacity is expected to see a lagged response to the slowdown in demand, due to the long lead time for new projects coming onstream in the Middle East and Asia, and the long-term economic considerations required to decide on capacity reduction. Non-energy demand e.g. for petrochemical feedstocks will also support refining activity. As oil demand decline becomes entrenched, the deteriorating commercial viability of refining, will drive rapid consolidation in the sector.

Under the *Reference* scenario, global oil demand remains close to recent levels. This assumes redistribution away from declining OECD regions and towards non-OECD regions. Absolute growth is restrained by this transition, alongside greater efficiency and technology transitions.

Chart 3A: Oil Consumption

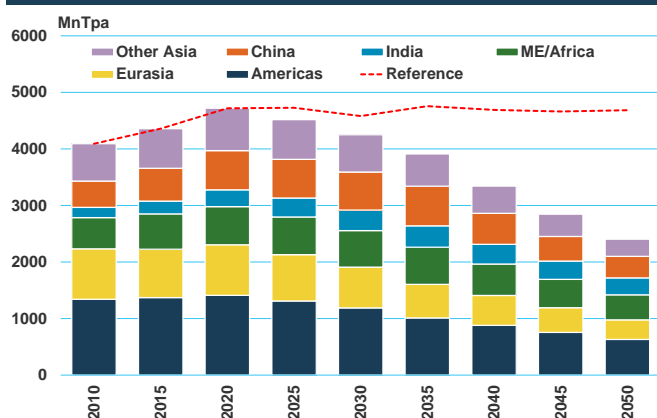
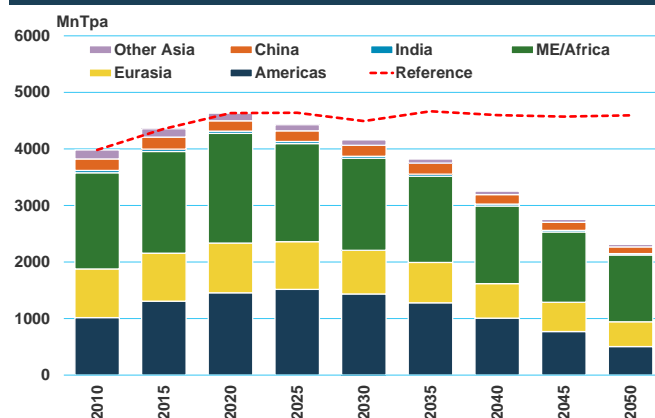


Chart 3B: Oil Production



3.2 Trade and Ship Demand

Global crude oil imports will almost solely be driven by Asian demand, and will closely track end-user consumption given limited domestic production in that region. West of Suez, Europe remains the only notable crude oil importer as American oil production is sufficient to meet regional demand.

The Middle East remains the swing crude exporter under the *Reduction* scenario, seeing the greatest reduction in crude exports out to 2030.

Reduced North American oil consumption, and lower Middle Eastern output, allows for continued increase in crude exports from the Americas to 2030, but by 2050 these have almost disappeared.

Chart 3C: Crude Oil Imports

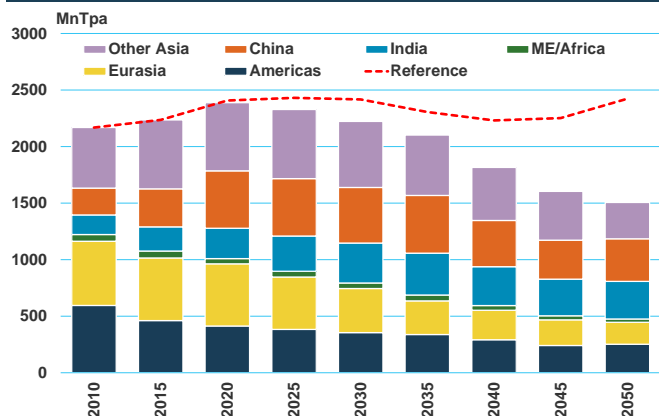
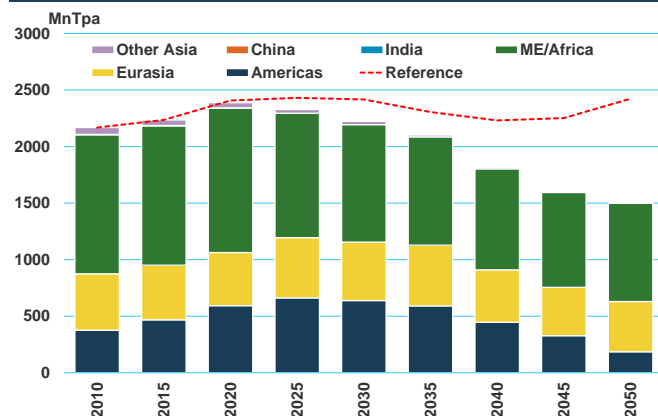


Chart 3D: Crude Oil Exports



Declining global oil consumption and upheaval in the refining system will bring about considerable uncertainty. Overall, we expect oil products trade to see substantial decline across the forecast horizon, reflecting the underlying reduction in oil demand

Refining capacity is expected to see the strongest declines in regions with older infrastructure and lower oil production base, notably Europe and Other Asia, which will support product imports. The dislocation between points of refining supply and demand is likely to increase as refining capacity is retained in areas with easily accessible local crude production, and/or more resilient oil demand. Oil products exports from Europe will see significant declines as its refining capacity declines. The Middle East and North America will see an increasing proportion of trade moving out as refined products.

Chart 3E: Oil Products Imports

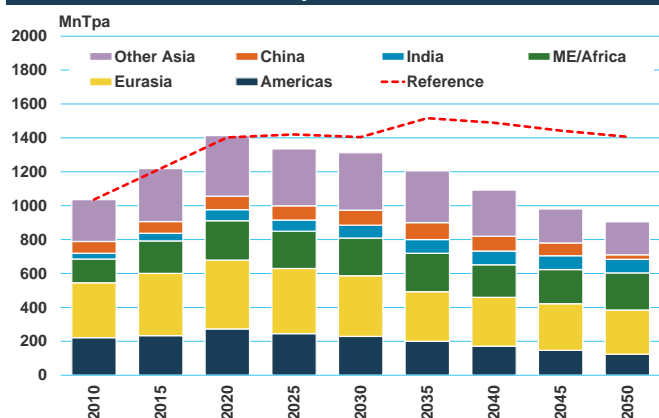
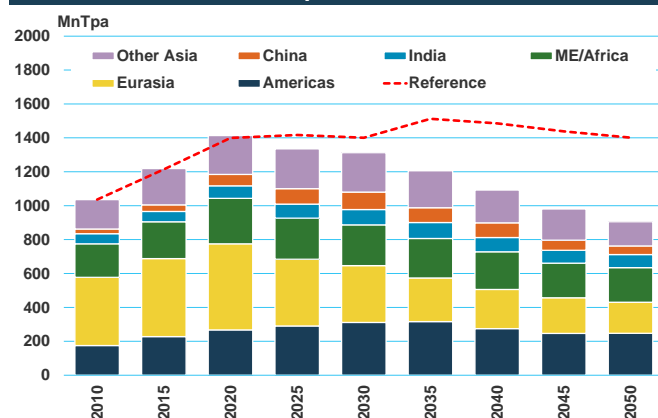


Chart 3F: Oil Products Exports



Following from the declines in overall trade, oil tanker deadweight demand (the requirement for tanker tonnage) sees an unprecedented decline. Over the period 2020-2050 crude oil tanker demand drops by 34%, whilst oil product tanker demand declines by 38%.

As described above, the scale of the decline in tanker demand, whilst massive, is less than the overall c. 50% decline in oil consumption for a number of reasons. Firstly, the changes in oil demand and production vary widely in different regions, therefore trade flows are still required to meet demand and may even increase where oil production is falling faster than demand. The resilience of American and Middle Eastern oil production means that satisfying Asian demand will depend on these regions. Furthermore, flows are likely to see growing average distances (even as volumes decline) due to the increasing market share taken by the Americas in seaborne oil flows. Movements from the Americas to Asia are among the longest routes used in tanker shipping and therefore will be supportive of deadweight demand.

However, despite these factors, the outlook for the oil tanker sector is bleak under the *Reduction* scenario. With demand falling by about one-third, the market will be forced to make stark choices, tracking the refining system, balancing capacity reduction with occasional investment.

Chart 3G: Crude Oil Deadweight Demand

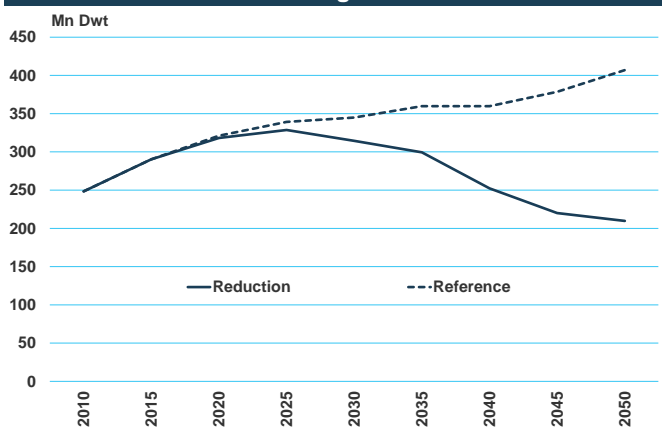
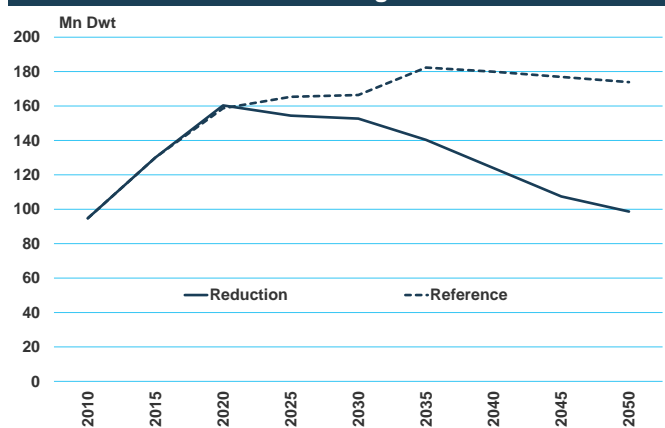


Chart 3H: Oil Products Deadweight Demand



4.0 LNG Carrier Demand

4.1 Natural Gas Consumption and Production, LNG Trade

Natural gas is, at least initially, seen as an alternative to coal and oil for electricity generation, local power and transportation. The dislocation between centres of supply and demand will continue to boost LNG trade and vessel requirements - pipelines are in general considered uneconomic over distances greater than 3,500 kilometres.

The largest gas consuming markets are the US (Americas), Russia (Eurasia) and China. All three have large-scale production volumes and pipeline networks to transport gas from producing regions to consuming regions (albeit to a smaller extent in China).

The largest gas reserves are located within Russia (Eurasia), Iran and Qatar (Middle East and Africa). Whereas the US (Americas) is the largest producer, followed by Iran (ME/Africa) and Russia (Eurasia).

The largest LNG producer is Qatar (Middle East/Africa), which accounted for approximately 28% of the LNG sector in 2017. Australia (Other Asia) is the next largest LNG producer. Malaysia is the third largest producer and exporter of LNG. US gas production is experiencing a significant increase as new extraction techniques (fracking) has enabled excess gas to be liquefied and exported as LNG.

The Americas contains the single largest gas consuming country in the world – the US – which accounts for 66% of the regional gas consumption. Under the *Reduction* scenario, the region's overall consumption is forecast to decrease by just over third by 2050, from a peak in 2020, as the shift away from fossil fuels focuses on gas after coal and oil have taken the initial hit.

With much of the decline in gas consumption focused on North America, LNG imports to the rest of the region are forecast to increase fourfold by 2050, compared to volumes in 2020. This is the result of growing local demand from countries in South America in particular, and reduced LNG exports heading out of the region. Overall exports are forecast to decline by approximately -85% from the high reached in 2022 through to 2050.

Eurasia is a major consumer of and a net importer of natural gas. Pipelines from North Africa supplement intra-regional supply from Russia. Overall consumption in the region is forecast to halve out to 2050, but LNG will be needed in the near-term while alternative fuels penetrate the power generation sector, but imports will decline from 2025, nearly halving by 2050. Eurasian exports are forecast to increase significantly, primarily from Russia. Overall LNG exports from the region are forecast to increase by over 300% during the study period.

ME/Africa has large-scale natural gas producing and consuming countries such as Iran and Saudi Arabia, but runs a surplus and will remain a key supplier to the international market. Qatar is planning to develop its liquefaction capacity, as to a much lower extent are Algeria and Nigeria, Egypt and

Israel. Under the *Reduction* scenario there will be continued export growth through to 2030, of 80%. Thereafter, export volume will decline (by approx. half) returning close to 2020 levels by 2050.

India sees demand from a growing and increasingly urban population drive gas consumption increases year-on-year through to 2030 – to a quarter above 2020 levels. Thereafter, a gradual decline in consumption volumes by 2040 is forecast, followed by a slight rise in consumption by 2050. This drives significant LNG imports, in line with the demand trends already outlined.

China is one of the fastest growing gas markets as it turns to cleaner burning gas to help reduce pollution and emissions within major urban centres. Volumes will continue to rise, with growth focused on the period to 2035. Thereafter, demand is anticipated to decline throughout the study period and end at similar levels as those of 2020. Demand for LNG is forecast to be positive for the majority of the forecast period and China will become the largest LNG importer. Through to the end of the study period, demand is anticipated to decline to less than half of the peak levels, but the country remains a significant consumer of LNG.

Other Asia contains several largescale consumers and producers of LNG. The former are concentrated in North East Asia (outside China), but these are forecast to reduce overall consumption of natural gas during the study period. However, this is anticipated to be offset by increased demand from countries such as the Philippines, Indonesia, Bangladesh and Pakistan. Overall, gas consumption levels are forecast to remain relatively stable during the study period, as the axis shifts from north east to south east. It is anticipated that LNG imports will continue to increase through to 2025, with an uplift in imports of approximately 20% compared to 2020 levels. Thereafter, imports are forecast to decline marginally, and then retain a stable profile throughout the rest of the study period.

The large-scale LNG producers of Australia, Indonesia, Malaysia and Papua New Guinea are forecast to provide an increase in LNG production and exports in the near-term, with the majority of the new volumes stemming from Australia. It is anticipated that exports will continue to increase through to 2025, with an uplift of approximately 13% compared to 2020 levels. Thereafter, exports are forecast to decline marginally, and then retain a stable export profile throughout the rest of the study period, focusing supply on East Asia.

In the *Reference* scenario, gas production will track the consumption profile in the *Reduction* scenario. There is anticipated to be increased consumption in the Americas, stemming from countries in both the north and south. Eurasian consumption will witness declining demand within Europe, whilst Indian demand more than doubles across the study period. Chinese consumption is forecast to peak in 2040, doubling over 2020 levels, followed by a slight decline through to 2050. Other Asia consumption is forecast to increase throughout the period. Overall consumption is forecast to increase by 72% during the study period.

Chart 4A: Gas Consumption

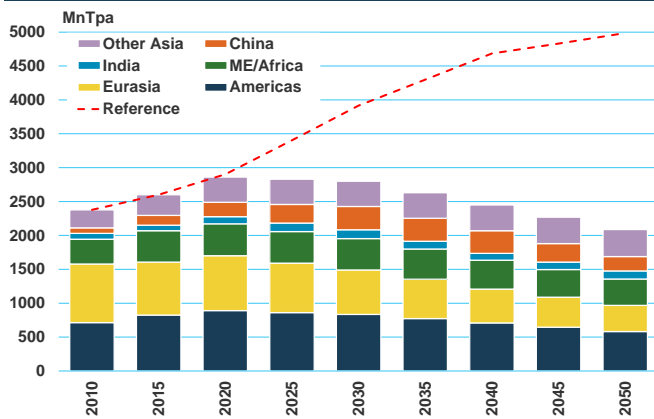
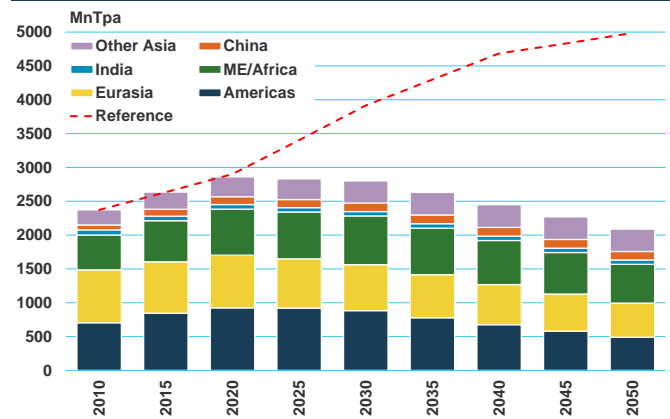


Chart 4B: Gas Production



There is continued development of gas reserves in the Americas (particularly the US and Canada) through to 2040, and throughout the study period in Russia (Eurasia) and ME/Africa. Overall gas production is forecast to increase by 72% between 2020 and the end of the study period in the *Reference* scenario.

In the Americas continued gas production developments within the US gas market will provide surplus volumes that can be exported, both within the Americas and to global markets. Eurasian exports are forecast to increase throughout the duration of the study period, as Russia increases LNG production and exports.

The ME/Africa region has significant gas production centres in Iran, Qatar and Algeria. Local gas production far exceeds local consumptions allowing considerable export volumes from the region. Exports from the ME/Africa are forecast to increase through to 2040, followed by a slight decline by the end of the study period.

Other Asia exports are forecast to peak in 2025, followed by a slight decline and then stable exports through to 2050. Overall LNG exports are forecast to increase by 138% between 2020-2050.

LNG import demand in India is forecast to grow continuously, with an increase of 173% by 2050 over 2020 levels. This contrasts with much more rapid growth in China, which is forecast to increase imports by over 500% between 2020-2040, though this is followed by a decrease in overall imports to 2050. Overall LNG trade is forecast to increase by 138% between 2020-2050.

Chart 4C: LNG Imports

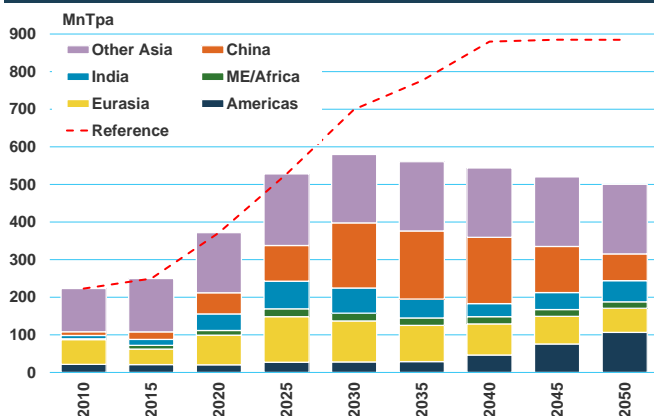
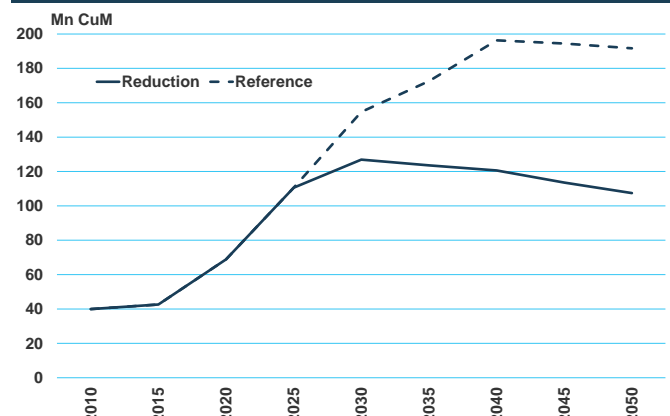


Chart 4D: LNG Carrier Demand



5.0 Coal Demand

5.1 Consumption and Production

Under the *Reduction* scenario, global coal consumption drops by over 80% between 2020 and 2050. The reduction is front-loaded, with global consumption falling 66% by 2030. Half of the reduction in consumption is attributable to China, although all regions of the world see consumption fall. The scenario's forecast for global coal consumption is derived from IPCC scenario data, with the regional distribution of consumption derived from analysis performed by Shell. Coal production forecasts, as well as trade flows, are derived from MSI's internal models.

Reduced coal consumption is driven primarily by the power-generation sector, which makes use of steam coal. In most regions of the world increasing efforts to improve air quality and initiatives to diversify the energy mix reduce demand for coal. A more efficient 'stock' of coal plants will also help lower demand.

Consumption of coal for industrial purposes also decreases under the *Reduction* scenario, mostly due to a switch within steel production from using basic-oxygen furnaces (which use coking coal) to other methods, most notably electric arc furnaces (which do not). This is discussed in more detail in this study's iron ore section.

China's share of global consumption falls from 47% in 2020 to 31% in 2050. The only regions which see an increase in their share are India and Other Asia. In India's case coal will be used for power generation as well as an input to increased steel and cement production. In South Korea and Taiwan (which have to import all the coal they consume) there will be continued demand for metallurgical coal and residual demand for steam coal for power generation.

Global production of coal falls in line with lower consumption. Regional shifts in coal production are driven by three factors: the cost curve of thermal coal production; extant supplies of coal in different regions; and the proportion of metallurgical coal (as opposed to steam coal) as a share of total coal production.

We assume that, at least initially, power plant closures or conversions will be a more significant driver of reduced coal consumption than the scrapping of basic oxygen furnaces in steel production. This implies more resilient demand for metallurgical coal than steam coal.

As a result of the mix of cost curve, reserve size, and coal type factors, coal production under the *Reduction* scenario sees a shift in market share toward Russia, the United States and China by 2050. This is at the expense of the Middle East/Africa, Latin America and Oceania. Over the first decade of the scenario India's share of global production expands rapidly, but it peaks in 2030.

Chart 5A: Coal Consumption

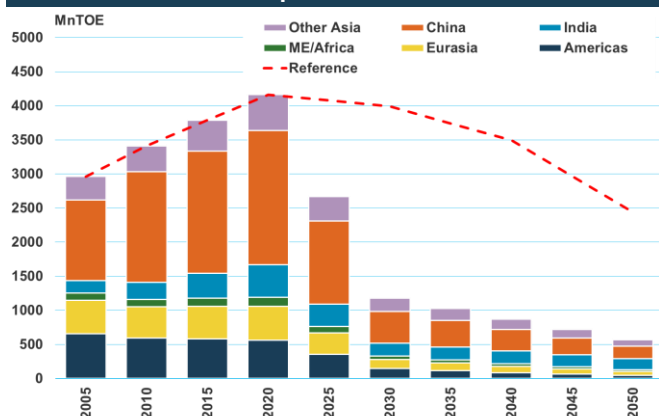
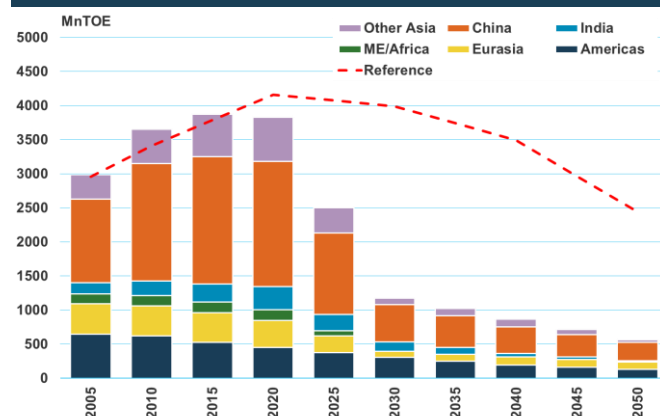


Chart 5B: Coal Production



5.2 Trade and Ship Demand

Given much-reduced levels of consumption, seaborne coal trade under the *Reduction* scenario is centred on countries unable to produce coal, or in particular unable to produce the metallurgical coal the scenario assumes will achieve a more dominant share of consumption. This applies firstly to India, which will continue to consume coal but whose own reserves overwhelmingly consist of steam coal. S. Korea and Taiwan cannot produce coal, so continued consumption will generate an equal volume of imports.

Elsewhere, OECD coal imports will shrink to very low levels by 2035. By 2050 China's consumption of coal will be roughly equal to India's, but Chinese production is able to provide the required volumes. North American coal exports will actually increase over the forecast horizon, rising from 9% of global exports in 2005 to 40% by 2050, reflecting a high proportion of metallurgical coal within extant reserves.

For similar reasons, Russian coal exports (see 'Rest of the World' grouping) will also retain their share of exports. Australian coal exports will fall significantly in volume terms, but Australia will still comprise 25-30% of global exports in 2050 even at its share of production falls (similar to the present-day). This is due to low breakeven costs for certain mines and healthy reserves of metallurgical coal (currently half of overall Australian coal exports).

In line with vastly reduced coal exports the required deadweight generated by the coal trade also falls dramatically under the *Reduction* scenario. Whereas under the *Reference* scenario the vessel demand generated by coal continues to climb until 2035, under the *Reduction* scenario vessel demand peaks in 2020 and falls sharply between 2020-30 and then more gradually between 2030-50. By 2050 vessel demand driven by the coal trade is half of its 2020 level.

Chart 5C: Coal Imports

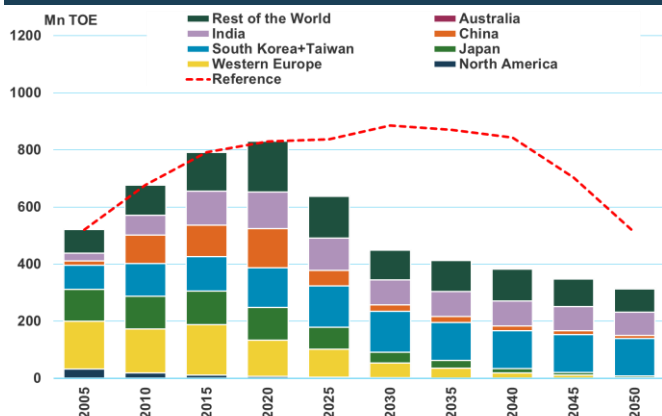
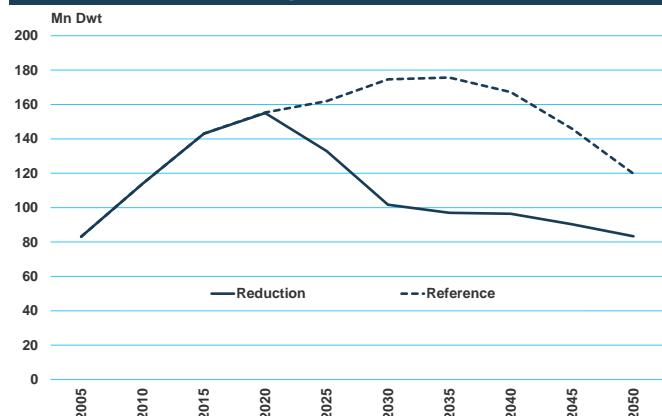


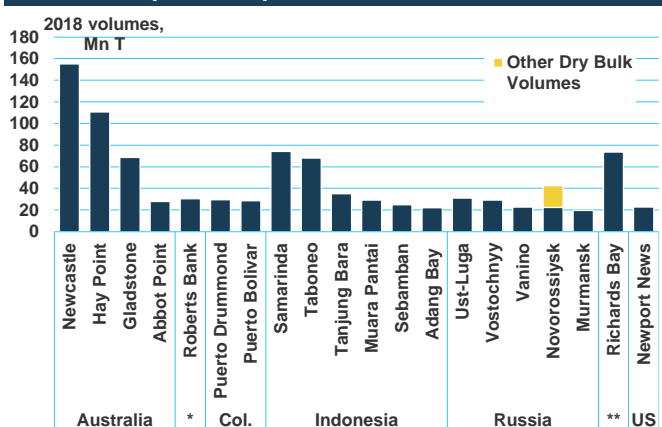
Chart 5D: Coal Deadweight Demand



6.0 Broader Industry Impact – Coal Ports

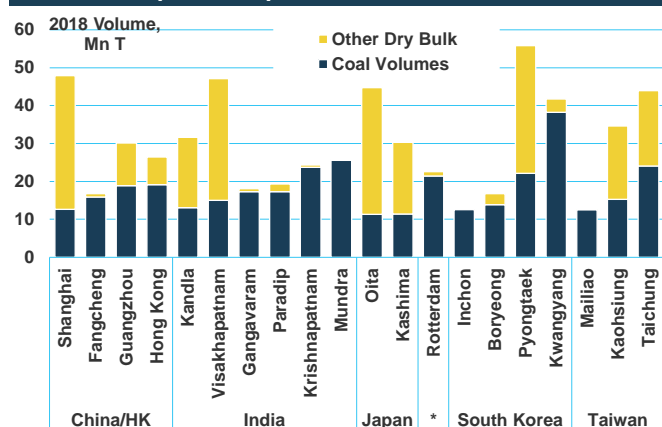
The significant impact on coal exports and coal trade has wider ramifications for the logistics supply chain beyond those impinging on vessel owners and their financiers. Some of the allied maritime sectors exposed to the shift in dry bulk trade are the port sector, as well as suppliers of port and vessel equipment (not to mention a plethora of land-based equipment and infrastructure providers). For the remainder of this section we focus on the port sector, looking at which ports are most exposed.

Chart 6A: Top Coal Export Ports



*Canada, **South Africa

Chart 6B: Top Coal Import Ports



*Netherlands

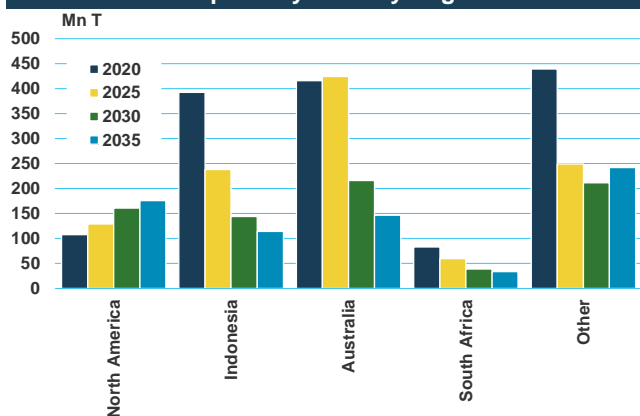
A key point is that, with a single exception, coal export ports are heavily dependent on coal and have very few alternative exports in the dry bulk space. Only the Russian Black Sea port of Novorossiysk exports significant volumes of other dry bulk cargoes – in this case, grains. Indeed, with the exception of the Russian ports, which in some cases have oil terminals or are bunkering hubs, coal ports have few alternative sources of cargoes, and those cargoes which do exist – for example, cars in the case of Newport News – have limited overlap with coal infrastructure

Chart 6A shows the top 20 coal loading ports, based on 2018 data. As it shows, Australia and Indonesia have the greatest exposure at a national level, with Indonesia looking particularly vulnerable as a consequence of its relatively low-quality coal. Indonesia has locked in relatively little high-cost fixed infrastructure as a result of the significant volumes of floating transshipment performed at anchorages; however, there is a huge volume of hinterland infrastructure (river loading ports, barges etc) which will become redundant.

By contrast, many of the coal discharge ports are far more diversified, both in terms of dry bulk cargoes and cargoes associated with other sectors of shipping. In part, this is a function of the fact that many of the major coal import ports are serving steel mills and therefore iron ore is by definition also a major cargo; in turn this means that demand will be more robust for such ports as a proportion of the coal imports will be for metallurgical rather than steam coal, which as discussed above are likely to be more resilient under the *Reduction* scenario. Other cargoes also buoy the volumes for dry bulk discharge ports; Shanghai, Guangzhou, Hong Kong, Rotterdam, Incheon and Kaohsiung are all homes to major container terminals and oil import hubs.

In other words, coal loading ports are far more exposed than discharge ports to the decline in coal trade projected under the *Reduction* scenario. From a loading port perspective, the ability to shift business model to a more sustainable one is limited, and the only realistic strategy is to limit further heavy capital investment in coal loading equipment to avoid the risk of asset stranding.

Chart 6C: Coal exports by Country/Region



As Chart 6C shows, the worst hit country in terms of quantity of decline in exports (which is a good proxy for total coal throughput at ports) will be Indonesia, although South Africa and Australia will also be hit hard. North American coal volumes will continue to increase however, principally as exports of metallurgical coal continue to rise.

7.0 Iron Ore Demand

7.1 Consumption and Production

While not a commodity used in the generation of energy, iron ore consumption, production and seaborne transportation is also affected under the *Reduction* scenario. Iron ore trade is expected to fall under the *Reference* scenario, but the decrease is larger under the *Reduction* scenario.

Throughout this study, scenarios related to non-energy commodities are based on the forecasts generated as part of the Shared Socioeconomic Pathways (SSPs). The *Reduction* scenario corresponds to the SSP1 pathway, and the *Reference* scenario to the SSP2 pathway.

Iron ore consumption is a function of the volume of steel produced and the method used to produce this steel. Lower steel production has two drivers. The first is lower steel intensity of economic growth. This largely reflects an expected change in China's growth model, with greater emphasis on services and consumer demand, and less on heavy industry, infrastructure and construction. The steel intensity of advanced economies will also decrease. This shift will be less pronounced in many emerging economies, whose industrialisation processes have further to run.

On top of this the scenario anticipates shifts in the way that steel is produced. There has already been a shift away from basic-oxygen furnace production toward alternative methods (especially electric arc furnace production), and this shift accelerates further under the *Reduction* scenario. Worldwide, the share of electric arc furnaces in production rises from 27% in 2017 to 43% in 2050.

China's share of global consumption falls from 47% in 2020 to 31% in 2050. The only regions which see an increase in their share of global imports are India and Other Asia, where continuing industrialisation supports growing use of steel.

Production of iron ore falls in line with consumption. Australia and Brazil remain the dominant producers (with around 80% market share across the forecast horizon) under both the *Reference* and *Reduction* scenarios. Changes in the distribution of production are smaller than changes in the distribution of consumption.

Chart 7A: Steel Consumption

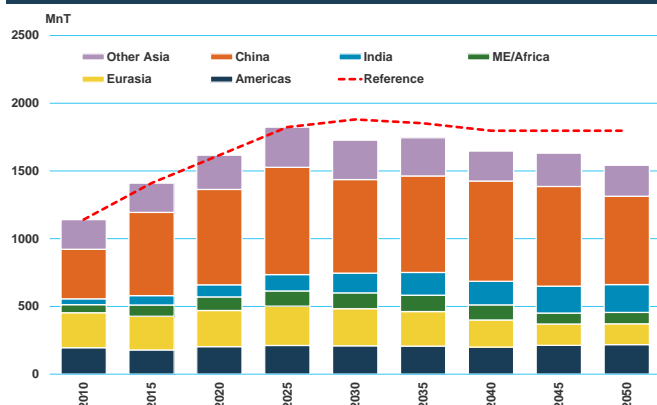
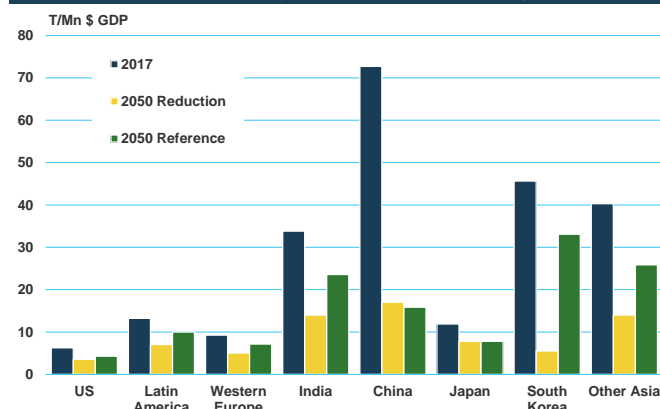


Chart 7B: Steel Intensity of Economic Activity



7.2 Trade and Ship Demand

Global imports of iron ore fall under the *Reduction* scenario. Iron ore imports are expected to decrease globally even under a 'business as usual' scenario, but the *Reduction* scenario accelerates the pace of decrease.

The reduction in imports is almost entirely driven by China, currently by far the world's leading importer. As discussed above, this reflects two factors: i) expected changes in China's economic model which will reduce the steel intensity of economic output and ii) a shift in steel production away from basic-oxygen furnaces. Large stocks of recyclable steel in China will further encourage this shift.

The reduction in exports is driven by the two largest current exporters: Brazil and Australia, although the share of global exports held by these two low-cost producers will remain steady at 80% of total exports. Exports from the Middle East and Africa (in practice meaning South Africa) reduce to nearly zero over the course of the scenario.

Chart 7C: Iron Ore Imports

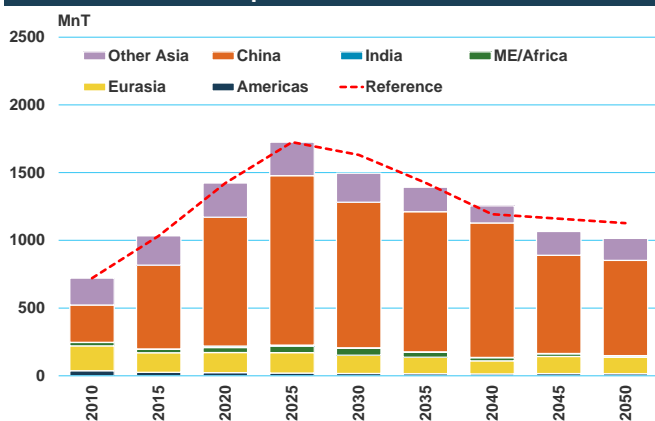
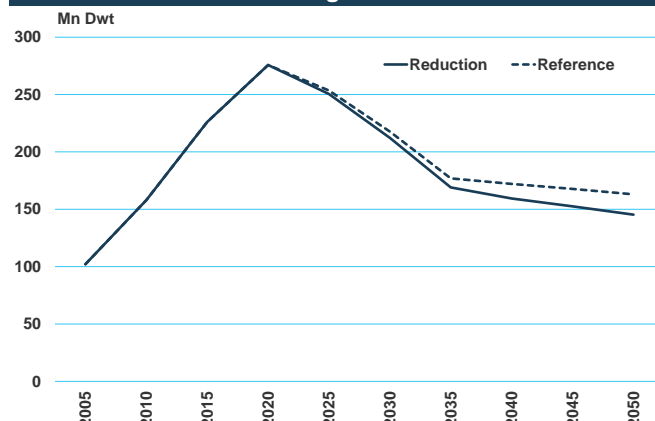


Chart 7D: Iron Ore Deadweight Demand



8.0 Containership Demand

Demand for container boxes is a function of consumer demand for manufactured (and, increasingly, agricultural) goods and business demand for semi-finished products, parts and select raw materials. With limited scope for further gains from the 'containerisation' of products not currently transported in containers, ongoing growth in box movements will be driven by macroeconomic growth and patterns of consumer and business expenditure.

Vessel demand is driven mostly by the number of container boxes shipped, as outlined above, but it is also affected by the distance these boxes have to travel from the point of manufacture or assembly to the location of the final consumer. For finished products imported into OECD economies (which provide a large proportion of aggregate containership vessel demand) these distances are close to their possible maximum following outsourcing of production to the Far East. Moves to 're-' or 'near-shore' production would tend to reduce vessel demand in TEU terms even if the overall number of container boxes moved remains the same.

In this study, macroeconomic outputs generated under the SSP pathways drive changes in container demand. The *Reduction* scenario corresponds to SSP1 and the *Reference* scenario to SSP2.

Under both scenarios we have not assumed environmentally- or policy-driven changes in the geographical location of manufacturing production. This is largely because we believe the carbon intensity of container shipping is extremely low.

If we assume that a 22 k TEU containership burns 140 tonnes of fuel per day on a 27-day voyage from China to Europe then that is equivalent to 0.63 tonnes of CO₂ per TEU assuming that the vessel is 85% utilised (3.11 kg being the weight of CO₂ emitted by burning one tonne of bunker fuel). This is equal to 0.63 tonnes of CO₂ per container. A T-shirt weighs 110 grams, so assuming 10 tonnes of T-Shirts per container, plus packaging that weighs an additional 90 grams, then a container can hold 50 k T-shirts. The CO₂ emissions of the ocean transport is 0.000013 Tonnes of CO₂ per T-shirt, or 0.01 kg. As a proportion of a T-shirt's overall carbon footprint ocean transportation comprises a small amount, and alternative transport modes will in many cases be more polluting.

Given changes in macroeconomic growth under the *Reduction* scenario that lead to relatively smaller economies in North America and Eurasia than under the *Reference* scenario (with a slower pace of growth proving more consistent with environmental sustainability), overall demand for containerships is lower in the *Reduction* scenario than in either the *Reference* scenario or MSI's standard Base Case. This is especially so as imports into these regions tend to travel long distances and so are associated with proportionally greater vessel demand. This trend, however, is partially offset by two factors.

The first, as outlined in the grains section of this study, is the movement of populations away from the planet's warmer regions and toward Europe and North America. Demand for containers is in part a function of population, and so a higher population will, all else equal, partially offset the slower pace of macroeconomic growth under the *Reduction* scenario.

The second is an increase in incremental demand for containerships generated on shorter routes. Under both scenarios emerging economies show greater economic dynamism than advanced economies, and in key cases (especially China) consumer-facing economies are expected to develop further and add to demand for container boxes. These end-consumers tend to be located relatively near to sites of production and assembly.

This will likely provide increasing vessel demand for what are currently classified as ‘feeder’ and ‘mid-size’ containerships (up to c. 10 k TEU), which are better suited to relatively short sailing distances than the mega-vessels of 20 k TEU and larger which dominate the long-haul trades. While these larger vessels will see their patterns of deployment change and adapt somewhat, the overall demand picture worsens under the *Reduction* scenario.

Chart 8A: GDP 2050 Scenarios

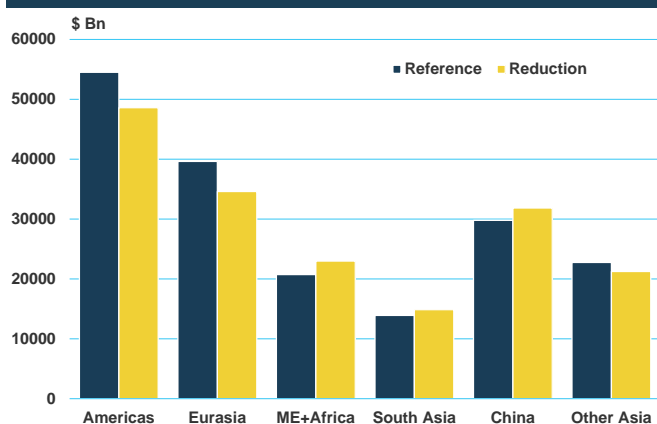
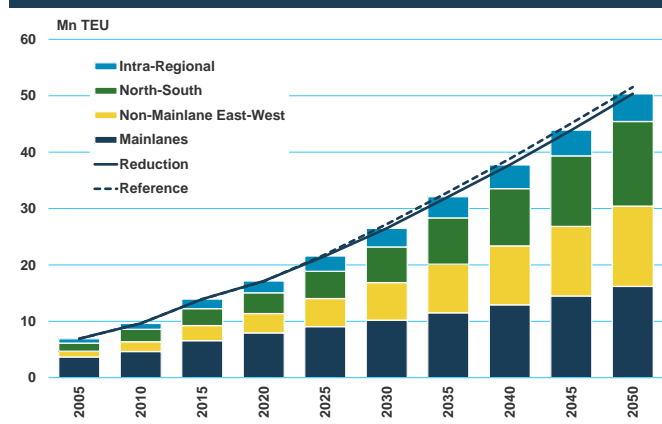


Chart 8B: Container Vessel Demand



9.0 LPG Carrier Demand

9.1 LPG Consumption and Production

LPG Carrier demand is generated by a range of cargoes – LPG itself (i.e. propane and butane), ammonia and chemical gases – the emerging seaborne trade in ethane isn’t considered here. Ammonia and chemical gases are part of the fertiliser and organic chemical industries respectively.

LPG is produced as a by-product of oil and gas production and oil refining. Production is, therefore, not ‘on-demand’ but depend on these other activities. Consumption is therefore ultimately constrained by activity in these other sectors.

As we have not found an explicit view on LPG within any IPCC or IEA scenario, we have linked LPG production scenarios to the oil and gas *Reduction* and *Reference* scenarios outlined in previous sections. Consumption tracks production in each case.

Growth in consumption and trade in chemical gases is informed by the IEA’s *Future of Petrochemicals* report in line with our liquid organic chemicals analysis. Ammonia trade is tied to fertiliser consumption and trade as covered in our SSP1 and SSP2 scenarios in the dry bulk section of this report. As relatively minor commodities these were not analysed in the level of detail afforded

to LPG itself. The repercussions of these trade growth scenarios have been tested in MSI's LPG Carrier Market Model.

LPG production by region under the *Reduction* scenario, has been tied to oil and gas production and refinery throughput by region as set out in the oil and gas sections of this report. Accordingly, the reduction in output is relatively evenly spread.

The most significant reductions are in regions with limited oil and gas production and a greater focus on refinery output. This impacts Eurasia most heavily, while strong gas production relatively supports the Middle East. Though minor in volume terms, India sees production growth due to persistent increase in refinery output.

LPG has a wide range of end-uses in the petrochemical, residential, industrial and auto sectors. Accordingly, consumption is very evenly spread by region and this is not expected to change dramatically.

The main trends are increased consumption in relative terms in India and Africa as LPG displaces wood for domestic fuel and a corresponding reduction in petrochemical use in the rest of the world.

Chart 9A: LPG Production

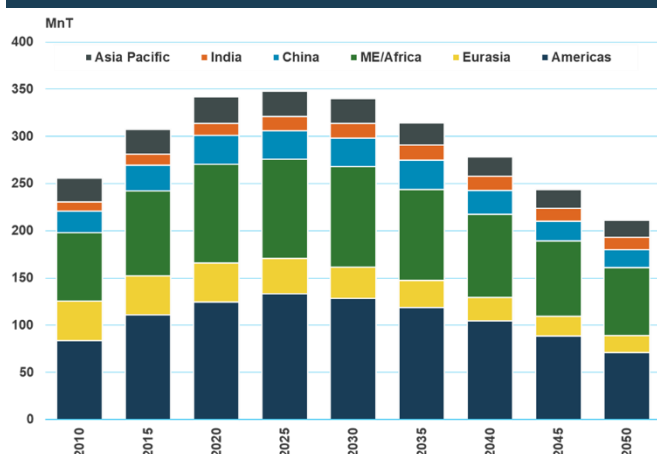
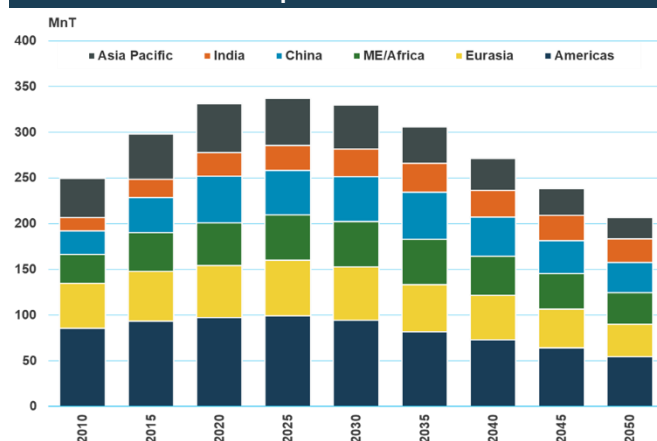


Chart 9B: LPG Consumption



9.2 LPG Trade and Vessel Demand

Exports of LPG are most closely aligned with regions showing the strongest oil and gas production. US shale gas is currently driving a huge increase in exports from the Americas, though these will plateau towards the end of the next decade and then decline along with North American natural gas production.

The Middle East and African will remain the dominant suppliers, but output will ultimately decline in line with trends in oil production and refining and gas output.

The pattern of importers follows that of consumption and remains relatively diverse. Imports will fall most quickly into regions where petrochemical use is highest.

ME/Africa imports are expected to nearly double between 2020 and 2050 but in an era of falling supply further upside is limited.

Indian imports also show strong growth and reach 20% of the total in 2050, up from 13% in 2020.

Chart 9C: LPG Exports

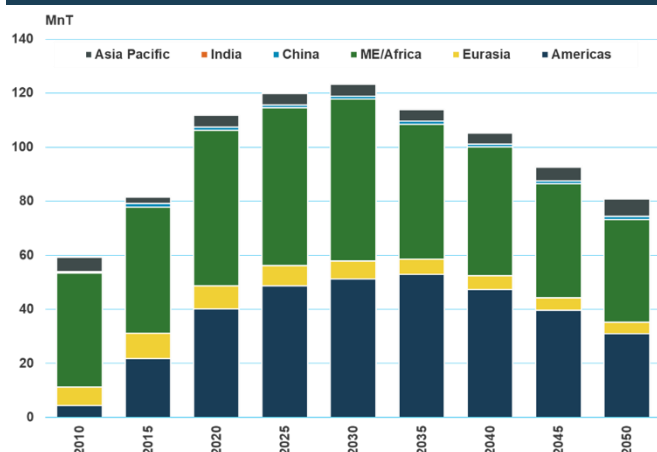
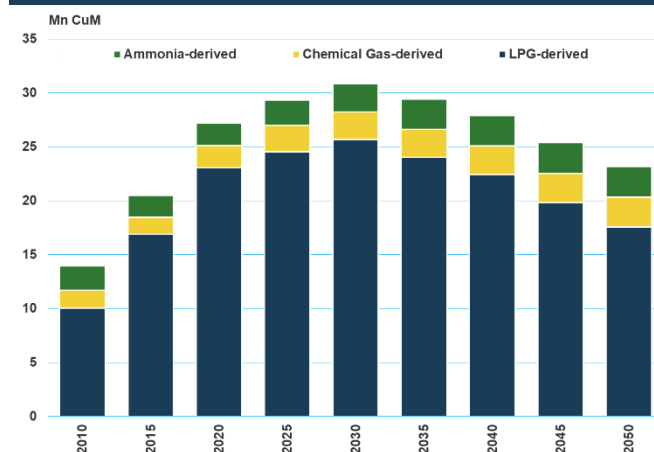


Chart 9D: LPG Carrier Demand



10.0 Renewables

Renewable energy has a fundamentally different profile of shipping demand than fossil fuel-based energy generation, since wind turbines, hydropower plants, etc. do not require shipments of fuel to operate. This is not to suggest that there is no demand for shipping stemming from renewables demand, as the equipment and materials required to construct the project will often have to be moved by sea. However, ongoing demand for shipping capacity from renewable energy projects which have already been installed is likely to be limited to spare parts or upgrades, with the exception of offshore wind.

Demand for shipping capacity for installation will differ by project type. Chart 10A shows the projected expansion of renewable energy by source (based on the GCAM4 model⁴ and the Shell Sky⁵ scenario). As it shows, hydro-electricity will drive the biggest increases in renewable generation capacity out to 2030. After 2030 both solar and wind will make greater incremental contributions to renewable power generation, with hydro power generation actually contracting in the 2040s whilst solar becomes the dominant source of renewable power generation. Chart 10B meanwhile plots renewable energy generation by region.

⁴ <http://www.globalchange.umd.edu/gcam/>

⁵ <https://www.shell.com/energy-and-innovation/the-energy-future/scenarios/shell-scenario-sky.html>

Chart 10A: Renewables by Source (Reduction Scenario)

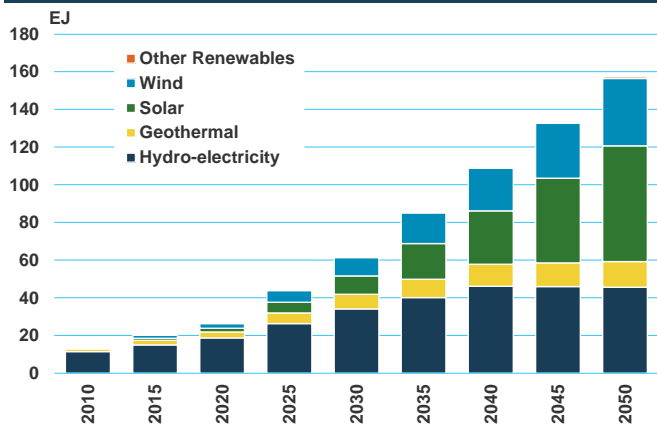
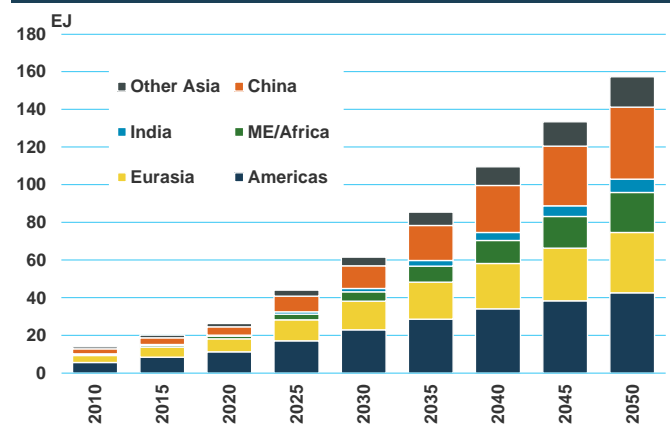


Chart 10B: Renewables by Region (Reduction Scenario)



The shipping demand created by renewables does depend on the technology used for electricity generation. Traditional hydroelectric power generation would necessitate large amounts of concrete and steel to construct the dams – generating demand for bulkers – as well as cargoes for MPPs or possibly containerships in shipping the turbines and additional generation equipment. However, the rise of ‘run of the river’ hydro implies less steel and concrete – reducing bulker demand – and a greater proportion of cargoes shipped on MPPs or containerships. Tidal energy schemes would have a similar profile of shipping demand to hydroelectric schemes.

For solar and onshore wind energy, the primary demand for shipping capacity stems from moving the equipment from the manufacturer to place of installation. In the case of solar, nine out of the top ten solar panel manufacturers are based in China (although many of these source at least some components from SE Asia); hence solar panel installations will contribute to container trade volumes in and out of China. The global wind turbine market is more balanced; Chart 10C below shows the relative market share of wind turbine production in 2016 against the total installed capacity by region. As it shows, whilst Asia is the largest producer of wind turbines it also has the highest amount of energy generated by wind. However, even when turbines are installed in the same region they are produced they may generate shipping demand; a notable source of demand for short sea vessels in Europe is shifting wind turbine blades.

Offshore wind is a far smaller market than onshore, but one which is fast growing. The growth in offshore wind is being driven in part due to issues with onshore installations – principally driven by local opposition – but also due to improving technology lowering the cost of offshore installations and the more reliable wind levels offshore in many regions. The rapid upsizing of wind turbines is only likely to contribute to this trend. Offshore wind turbines generate demand for vessels through their lifecycle, from wind turbine installation vessels and construction support vessels in the installation phase to crew transfer and service operation vessels in the operational phase. However, these classes of vessels are highly specialised. Chart 10D shows how offshore wind installations, though far smaller than onshore wind installations, are increasing at a faster rate.

Geothermal and other renewable sources of energy excluding tidal (such as wave energy) are not likely to lead to significant shipping demand expect for the equipment required for initial installation.

Chart 10C: Wind Turbine Production and Installed Power

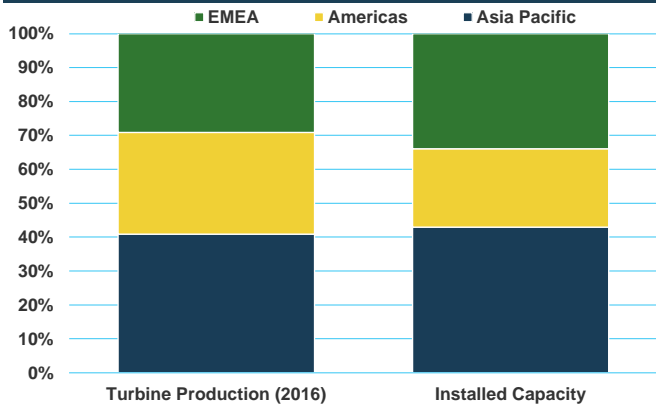
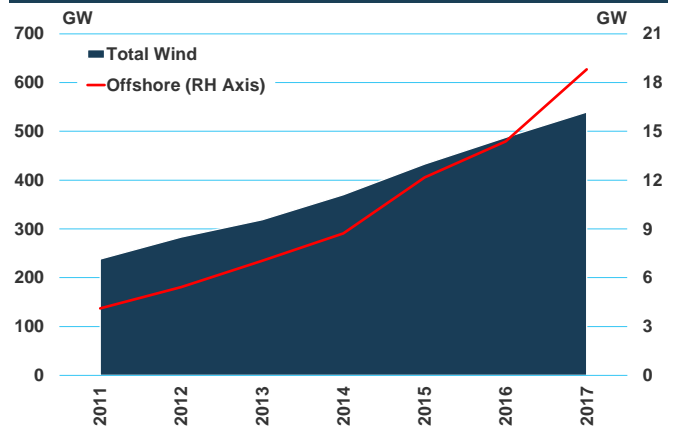


Chart 10D: Offshore and Total Wind Capacity



11.0 Biofuels

Given the extreme duress the tanker market is put under in the *Reduction* scenario, are there alternative cargoes which could come to this market's rescue? One area we could view as a potential support is liquid biofuels. Global consumption of ethanol and bio-diesel is shown in Chart 11A. The use of biofuels in transportation has seen strong growth. Since 2000, global consumption of ethanol and biodiesel has increased to over 2.5 Mn b/d, from under 0.5 Mn b/d. Over the last decade, traded biodiesel and ethanol has seen little growth, rising to about 0.5 Mn b/d in 2015, with the proportion of volumes imported compared to consumed averaging about 9%.

Under the *Reduction* scenario, bioenergy consumption sees a huge increase – approximately threefold increase in usage by 2050 from 2015 levels (see Chart 11B). The majority of this consumption increase is likely to be biomass though, which is typically consumed locally and, if shipped, it uses dry bulk carriers (e.g. wood pellets for power generation). Global primary energy usage of biomass currently accounts for about 10% of primary energy supply, but this is not shipped in large quantities, comprising of burning or waste agricultural products, wood etc.

Chart 11A: Bio-diesel/Ethanol Consumption and Trade

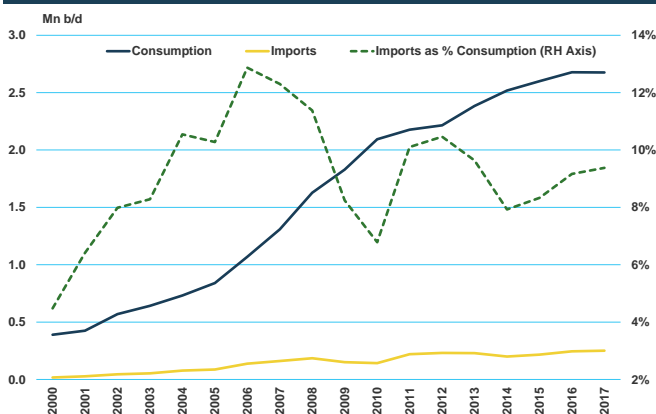
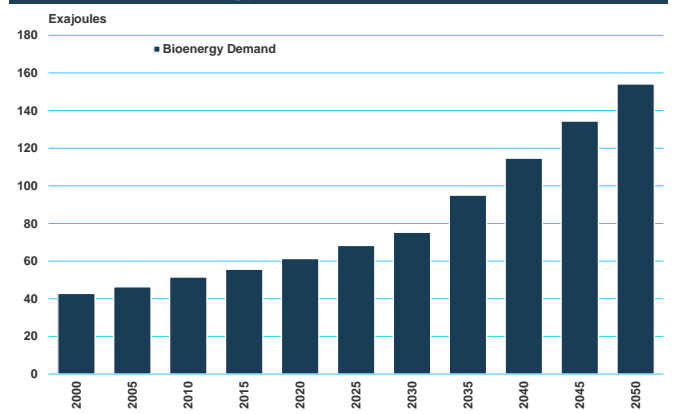


Chart 11B: Bioenergy Demand (Reduction Scenario)



We have modelled the increase in liquid biofuels using firstly the broad assumption in bioenergy demand outlined in the *Reduction* scenario.

In order to focus on the upside for liquid biofuels, we have aligned consumption growth in ethanol and biodiesel with the increased overall consumption, and increased their relative share threefold between 2020 to 2050 (from 6% to 18%) as shown in Chart 11C.

In order to generate significant liquid biofuels upside, we have also increased the trade volumes as a proportion of consumption, from around the 9% level currently (of which ethanol is the largest component) to 40% in 2040 and 60% in 2050, shown in Chart 11D.

This reflects the potential for an increasingly complex biofuel market, and sees traded volumes of biodiesel and ethanol rise to over 250 Mn Tonnes by 2050 (c. 6 Mn b/d).

Chart 11C: Bioenergy Demand (*Reduction* Scenario)

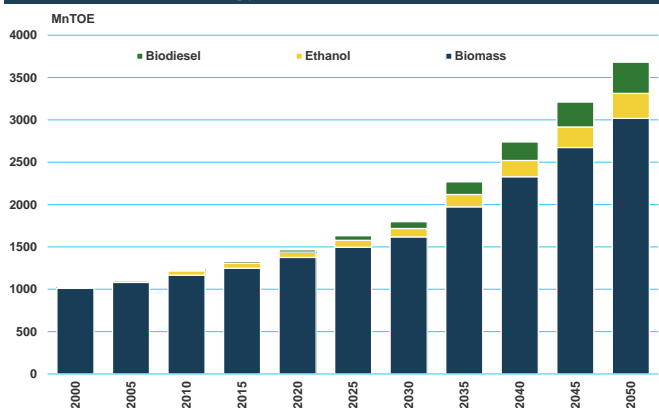
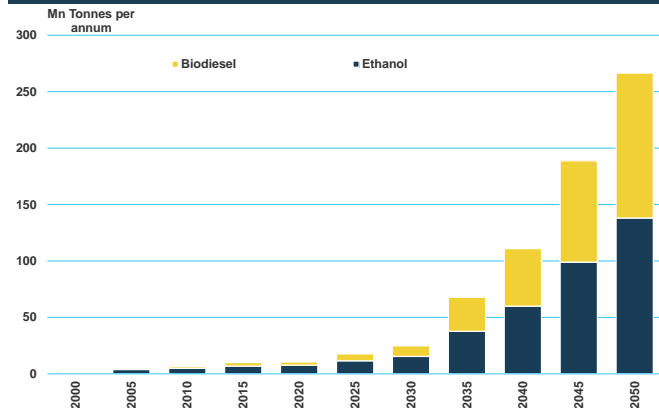


Chart 11D: Bio-diesel/Ethanol Consumption and Trade



Despite the amplification of liquid biofuel use and trade with respect to overall bioenergy use and liquid biofuel consumption respectively, the proportion of traded liquid biofuels relative to trade in oil (shown as total of crude and products in Chart 11E) remains relatively low.

Although the percentage of liquid biofuel to oil trade exceeds 10% by 2050, this comes too late in the day with respect to the long-term down turn in the tanker market, evident through to 2040 in the *Reduction* scenario, shown in Chart 11F. Under the *Reduction* scenario, the worst period for the tanker market is in 2035-45, and in this period the rise of biofuel trade is only just gaining traction

Chart 11E: Impact on Tanker Market - Trade

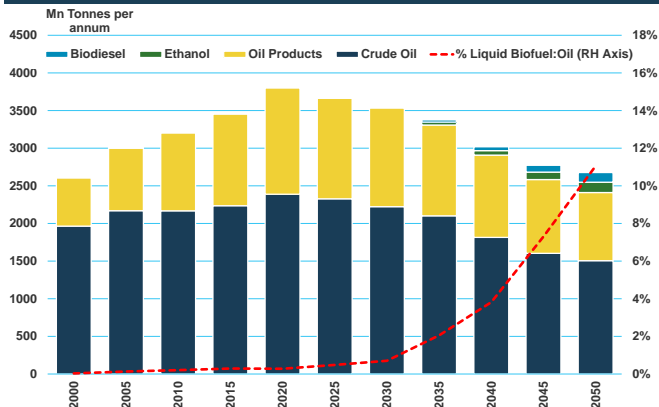
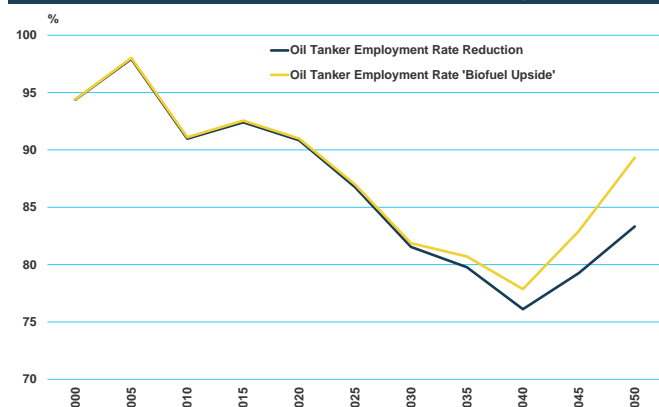


Chart 11F: Impact on Tanker Market – Employment Rate



12.0 Fleet Supply Response to the *Reduction* Scenario

Shipping markets are driven by geographical dislocations between sources of demand and sources of supply for commodities and manufactured products. This requires ships to move cargoes from one region to another. Shipowners influence the state of shipping markets through the construction of vessels (tonnage). When tonnage capacity broadly meets wider demand, the market is said to be balanced. Deficits and surpluses of tonnage are historically common features of shipping markets, where owners either fail to anticipate a need for additional capacity, or over-order vessels to meet demand that fails to materialise. Owners will (ostensibly) act in their own interest, and therefore collectively the market often over- or under-shoots its optimum capacity. The associated swings in freight rates and asset prices are typically referred to as shipping cycles, although the timing and amplitude of such 'cycles' are not regular.

In assessing the impact of the downturn in trade under the *Reduction* scenario we have assumed that initially owners do not have prior knowledge of the impending events, but that once the impact of falling demand is transmitted via the impact on earnings, then supply responses will adjust accordingly. The longer and more pronounced any reduction on profitability is the more severe the response. However, that is not to say that all newbuilding investment would cease under the *Reduction* scenario. There will be an ongoing need for new tonnage to replace a proportion of vessels being scrapped but more importantly it must be assumed that investment in new technologies will be an important driver of investment. Another factor will be the impact of short-term rallies in earnings even during a period of prolonged downturn.

Chart 12A presents the impact of the demand scenarios on newbuilding contracting volumes (presented as average annual Gross Tonnage ordered in each five-year period).

Whereas historically dry bulk has dominated contracting, in GT terms, its market share shrinks under the *Reduction* scenario, as the sector readjusts to lower coal carrying requirements out to 2050. Oil tankers share of contracting remains resilient until 2030, primarily driven by replacement tonnage demand, before there is a notable downturn.

Containership contracting has been dictated by the continuing pressure to upsize vessels, and has been characterised by spurts of ordering as liner companies have raced to the bottom in terms of unit costs as was seen in 2015. Contracting will both be driven by increasing container trade, but also by the increase in vessel sizes. Whilst MSI is not as bullish as some in anticipating 50 k TEU vessel in the fleet by 2050, we do believe that vessels in excess of 30 k TEU are likely by this time. With strong demand growth, the *Reduction* scenario for container shipping is not massively dissimilar to either the *Reference* scenario or MSI's Base Case.

Although chemical tanker contracting picks up on recent levels, it remains masked by ordering in the main shipping sectors.

Oil tankers and dry bulk carriers dominate scrapping forecasts out to 2050. Owners will be forced to part with tonnage early, when compared to average historical scrapping ages, driven by a reduction in demand for their primary cargoes in the medium to long term. One factor limiting the upside to bulker scrapping, however, is the age of the fleet – in 2020, the average age of the bulker fleet will be around 9 years old, from a peak of 12-13 ten years earlier. Only by 2030 onwards to we envisage

scrapping to increase as the fleet ages. At this time (post-2030), new vessel contracts will emerge, partly to replace tonnage scrapped. Accordingly, there will be a steady requirement of 17 Mn GT per annum to stabilise the fleet in the context of ongoing demolition.

Tanker demolition totals will remain robust, as old, inefficient tonnage is removed from the fleet during an extended period of market weakness. With scrapping outpacing deliveries in each five-year window from 2030 onwards the tanker fleet will enter a period of retrenchment, dropping 200 Mn GT by 2050, from around 275 Mn GT in 2030.

Chart 12A: Newbuilding Investment (Reduction Scenario)

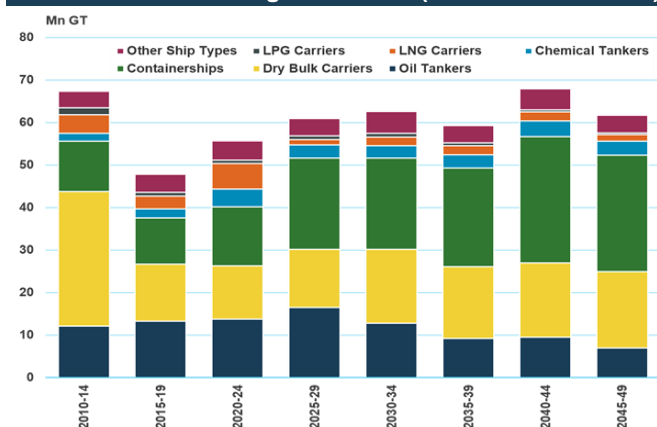
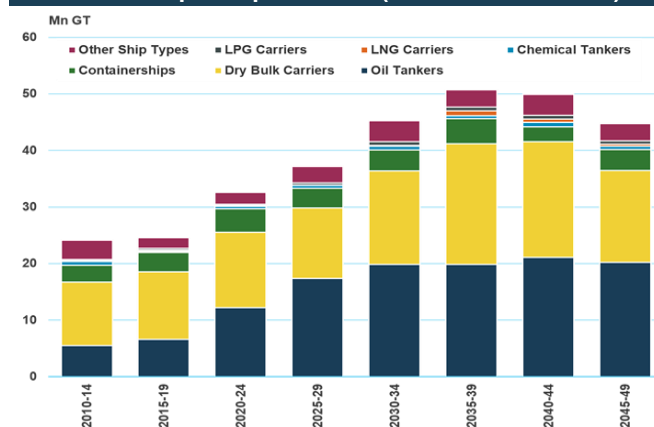


Chart 12B: Ship Scrap Volumes (Reduction Scenario)



Given the delay between contracting and delivery and the requirements for shipyards to ‘manage’ their output in order to prevent troughs and booms in operating rates, the orderbook remains relatively stable over the course of the forecast period. Fewer opportunities for asset play investors under the *Reduction* scenario will, however, prevent orderbooks regaining the 200 Mn GT level that was witnessed in the 2010-2014 period.

Even with substantially increased scrapping volumes, the overall merchant shipping fleet will continue to expand over the course of the first half of the century. Strong containership ordering and high bulker and tanker demolitions will result in containerships representing nearly half of all tonnage on the water by 2050.

With the specialist sectors of shipping typically having a longer life expectancy, when compared to tankers, bulkers and containers, their representation in the fleet will continue to grow, primarily driven by LNG carriers and chemical tankers.

Chart 12C: Global Orderbook by Sector

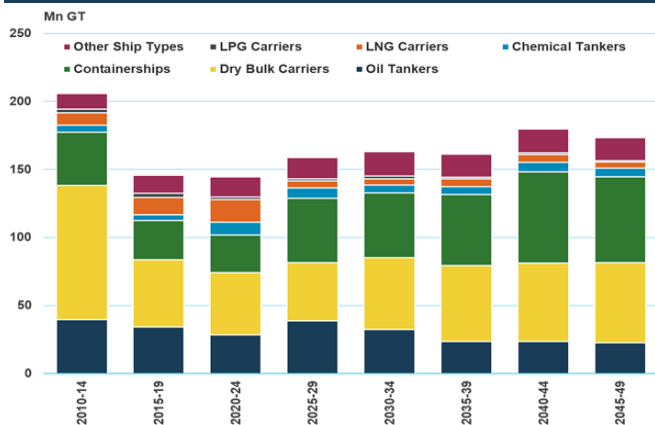
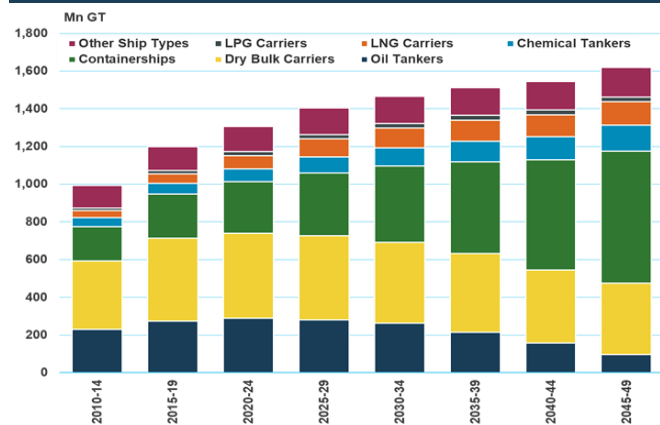


Chart 12D: Global Fleet by Sector



Newbuilding prices are driven by two underlying factors, shipyard costs (e.g. wages, energy prices, steel plate prices, exchange rates, machinery costs, etc.) and yard forward cover (the relationship between the orderbook and shipyard capacity measured in compensated gross tonnes (CGT)).

In the short term, costs will peak at the start of the next decade, driven by rising wages and exchange rates before exhibiting a slight downward correction, in line with MSI’s macro-economic cycle. Thereon in, there will be a steady development in costs with advances in shipbuilding technology and productivity offsetting wage inflation and increases in machinery and technology costs.

The relatively steady orderbook will result in forward cover also remaining relatively constant, on average, over the period under the *Reduction* scenario, trending down marginally as global shipyard capacity also sees slight increases over the period.

With containerships and specialised vessels making up the majority of shipyard orders builders will be able to maintain prices at levels around USD\$2,000 CGT, given the relative complexity of construction compared to oil tankers and bulk carriers.

The key message from this analysis is that something close to the current capacity of the shipbuilding industry will remain sufficient to meet newbuilding requirements over the period to 2050 under the *Reduction* scenario. With steady demand there is no radical dislocation in the shipbuilding industry as a result of decarbonisation of the energy sector.

Chart 12E: Cost Index and Newbuilding Price

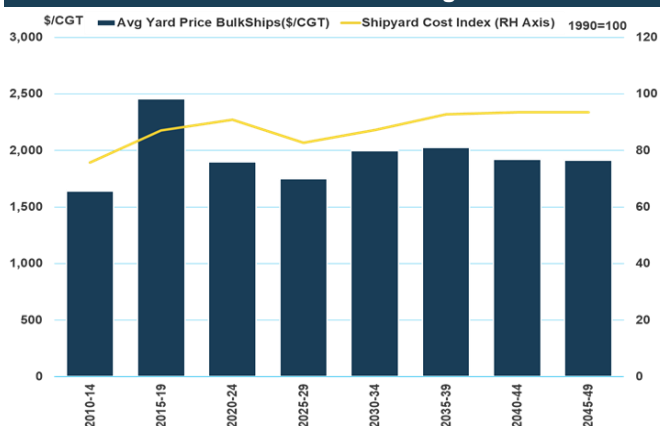
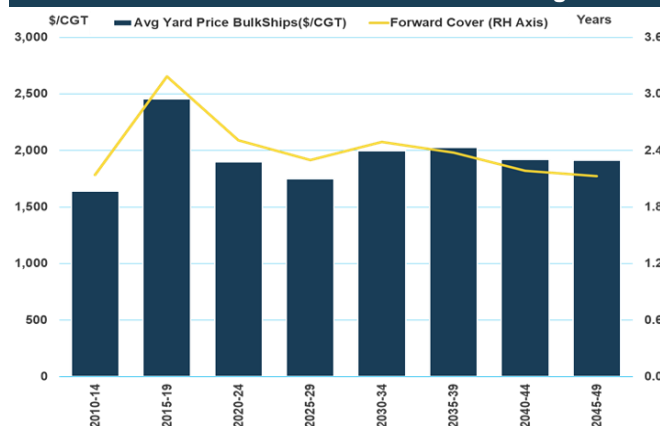


Chart 12F: Yard Forward Cover and Newbuilding Price



13.0 Sector Employment Rates and Earnings

13.1 Shipping Cycles and the *Reduction* Scenario

As outlined in the previous sections, under the *Reduction* scenario there are significant decreases in seaborne trade. MSI has a proprietary set of models which translate seaborne trade in tonnes into annual vessel demand (based on speed, distances, port times, canal transits and congestion amongst other factors). This annual vessel demand is then directly comparable to the fleet capacity derived in Section 14, and the employment rate by sector is the ratio of demand and supply. The employment rate in turn drives the vessel earnings cycle.

Cycles are an enduring feature of all bulk shipping markets. In its simplest form, the shipping cycle is principally driven by the lag between contracting and new vessel delivery. Typically triggered by favourable economic conditions, acceleration of commodity trade (and consequently vessel demand) to a pace faster than vessels can be built leads to increased freight revenue for shipping companies. In turn, this brings about an increase in new vessel contracting as a) revenue prospects increase and b) financing becomes more readily available.

With lead times between six months and four years from contract signing to final vessel delivery, depending on shipyard capacity, the upstroke of the freight earnings cycle can theoretically run for a long time (particularly if new shipbuilding capacity is required to be constructed to satisfy the new contracts), exacerbating excessive ordering of new ships in the interim. The cycle upstroke finally ends when delivery of excessive tonnage ordered during this period brings about a peak and fall in earnings. New vessel contracting subsequently falls to a more sustainable level before the start of the next demand-driven upswing.

In practice though, cycles in shipping are rarely so simple. Chart 13A takes a very long run view on the freight market for dry bulk carriers, the most liquid of shipping sectors. Unpredictable economic events often bring about falls in the freight market before supply-side drivers have an impact. Heavy orders can also be seen during periods of very low freight rates (often aligned with low vessel prices), chiefly from speculative owners cash-rich following the previous market upturn.

This was typified by events in the late 1970s and early 1980s. Oil prices spiked following the Iranian revolution of 1978 and many power stations worldwide switched to coal as a fuel source – this accelerated coal trade and led to heavy port congestion at coal ports, leveraging increases in bulker earnings which peaked in 1980. A severe global recession followed in the early 1980s, coal trade declined, and bulker earnings collapsed. In 1983-4, huge numbers of bulkers were contracted, led by a massive speculative order for 120 vessels by Sanko Steamship, confident that the market had reached a floor and a new generation of fuel-efficient vessels would be the first to benefit from an imminent market upturn.

History has shown, however, that the heavy contracting in that period only resulted in many years of a bulker market in the doldrums before a slow-growing global economy accelerated trade to a level strong enough to re-float the bulker market in the early 1990s. Contrary to hopes of a strong upwards cycle, the 1990s was a period where no clear up or down cycle appeared to take place, until the Asian currency crisis in 1997-98. There is of course a clear correlation between freight rate cycles and supply and demand fundamentals, measured by the fleet employment (utilisation) rate.

To demonstrate the effect of historical employment rates on freight rates, the former can be broken down into three zones as shown in Chart 13B: 'Slump Zone' for employment rates up to around 85% (marked in red), 'Market Balance Zone' for freight rates between around 85-91% (shown in blue), and 'Boom Zone' for employment rates above this. Chart 13B also illustrates the impact on earnings during each period.

Chart 13A: Typical Shipping Cycles (Dry Bulk Carriers)

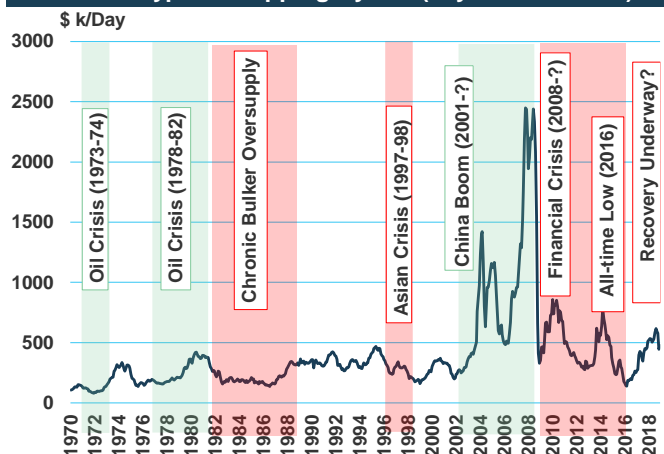
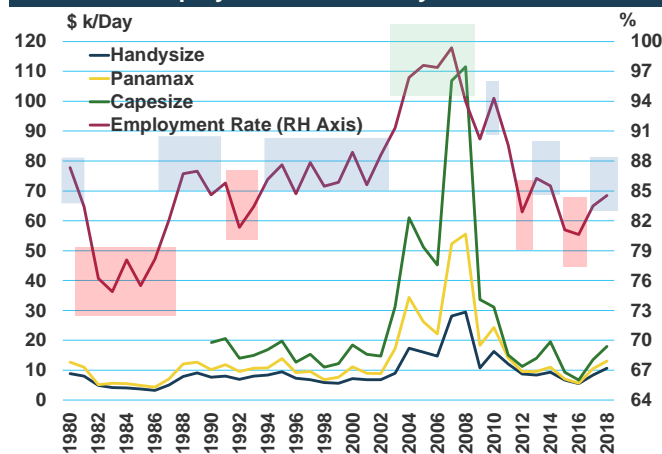


Chart 13B: Employment Rate and Cycles



Over history, demand cycles have been key drivers for the freight market. These can be highly complex, related to individual supply/demand/price dynamics across multiple bulk commodities, potentially influenced by relatively opaque drivers such as government policy and regulation. Multiple underlying demand cycles can vary widely in amplitude and length.

Chart 13C below plots the employment rate by sector, under the *Reduction* scenario and based on the supply side response laid out above.

Chart 13C: Sector Employment – Reduction Scenario

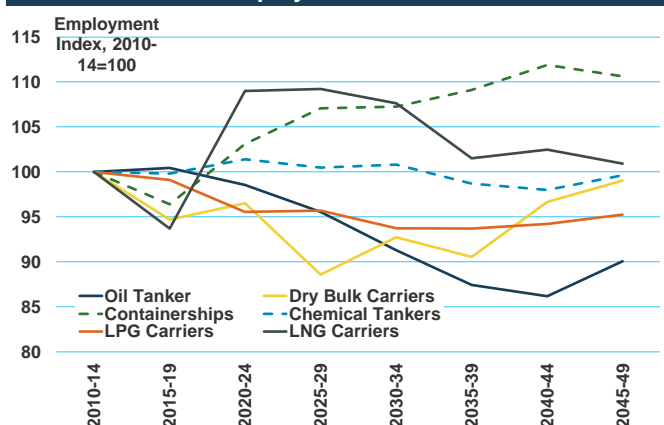
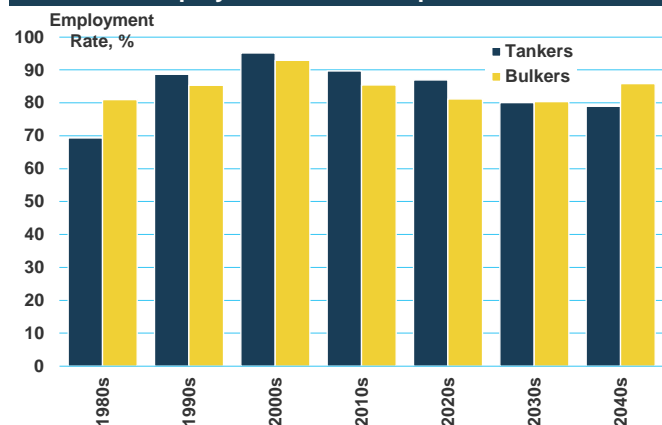


Chart 13D: Employment Rates Compared



As Chart 13C shows, the impact of the *Reduction* scenario on chemical tankers and containerships is limited, with both sectors following a relatively steady trajectory, albeit with the container sector following a healthier trajectory largely as an artefact of how bad container markets have been from 2010-19. Based on this conclusion, the remainder of this report focuses on exclusively the bulker, and tanker markets.

The *Reduction* scenario represents new ground in that the tanker and bulker markets have effectively never had to contend with shrinking cargo volumes for a prolonged period – the only example within living memory was in the wake of the 1980s oil shock when seaborne crude trade collapsed (tanker demand fell from 245 Mn Dwt in 1980 to 150 Mn Dwt in 1985). The *Reduction* scenario instead envisages tanker demand falling on a sustained basis from 2025 for the next twenty five years, whilst seaborne dry bulk trade will peak in 2020 and remain stable within a relatively narrow band (with vessel demand totalling between 600-700 Mn Dwt out to 2050) as increases in minor bulks and grains trade offset falls in coal cargoes.

Chart 13D plots the evolution of employment rates, contrasting the projected employment rates under the *Reduction* scenario with the evolution of historical vessel employment. As it shows, whilst although under the *Reduction* scenario the employment rate significantly deteriorates relative to the average seen this decade, the shipping markets would not enter entirely uncharted waters, with the 1980s seeing average vessel utilisation sink to similar lows for both tankers and bulkers.

This extremely weak utilisation environment sets the backdrop for vessel earnings. Charts 13E and 13F below present the outlook for tanker and bulker earnings for three benchmark vessels. As they show, both sectors are severely impacted by the readjustment through the 2020s and 2030s, with earnings in the 2030s averaging similar levels to those seen in the 1980s. However, by the 2040s we do see a divergence in fortunes. Earnings for bulkers, helped by the stabilisation in dry bulk cargoes, actually see earnings mount something of a recovery whilst tankers continue to see their earnings under extreme pressure throughout the forecast period.

However, even for bulkers the shift in cargo composition – away from coal and, to a less extent, iron ore and towards grain and minor bulks – will also benefit smaller bulkers which are more exposed to these cargoes, at the expense of larger vessels.

Chart 13E: Dry Bulk Vessel Earnings

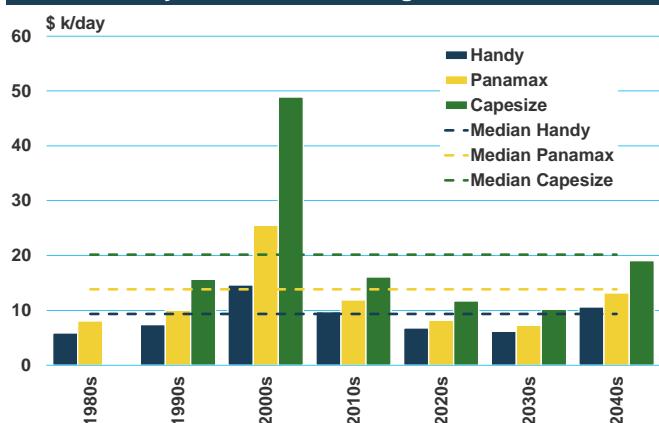
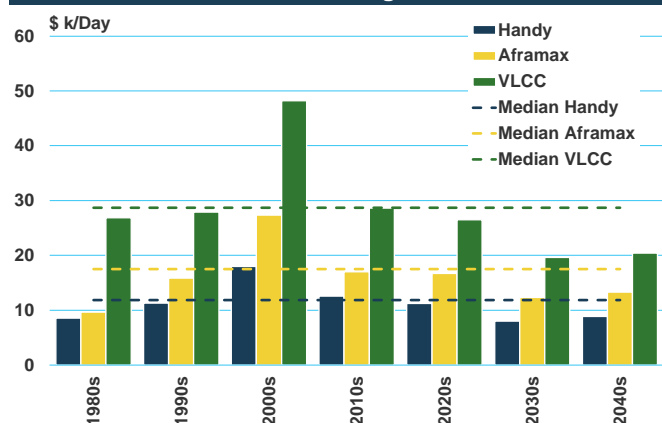


Chart 13F: Tanker Vessel Earnings



13.2 Scenarios: Alternative Contracting

The response of the industry to the sustained deterioration in demand set out in the *Reduction* scenario is crucial in determining future earnings conditions. Under the *Reduction* scenario, ordering of tanker tonnage continues at high levels through the 2020's with participants yet to discover the long-term secular decline in the demand base. This posits a propensity in shipping markets to 'over

order'. However, it is plausible to see a more rapid response and recognition of the sustained, weaker demand environment.

This is shown in Chart 13G, where tanker ordering peaks in the early 2020's. Volumes in the period 2025-35 are significantly reduced and ordering levels see a decline coinciding (rather than following) the decline in the demand profile.

The impact on the tanker employment rate is substantial. Although the market sees a decline in the employment rate through much of the forecast, the level is significantly higher, with a trough at close to 85% in 2035-39.

Although this would still be characterised as a weak market, the catastrophically low market conditions seen under the *Reduction* scenario are avoided. Even under long-term decline in demand, the tanker market can avoid disaster by restraining ordering.

Chart 13G: Tanker Contracting – Lower Ordering

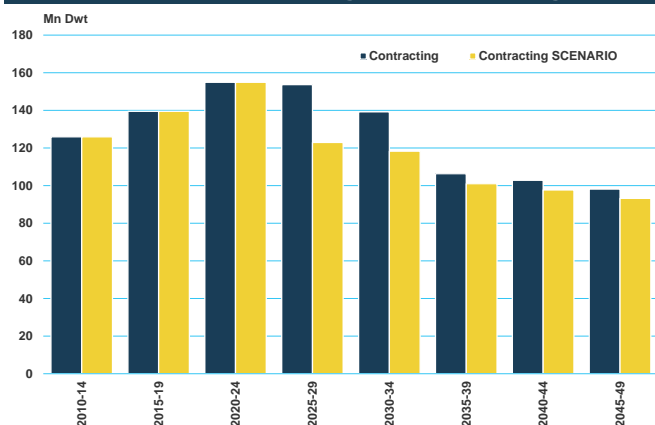
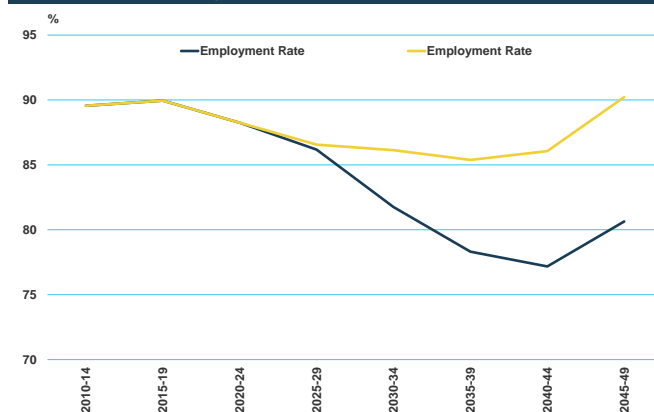


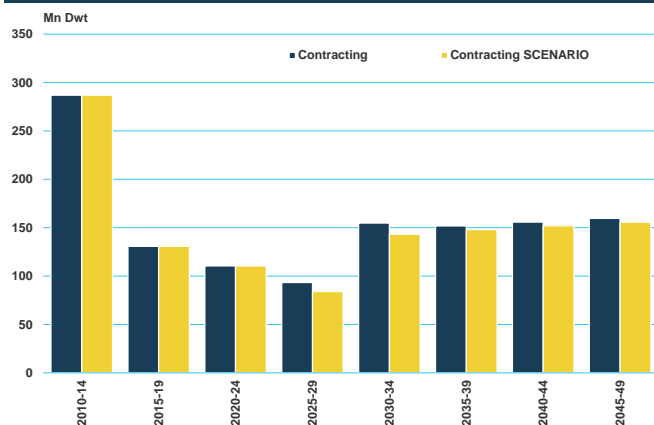
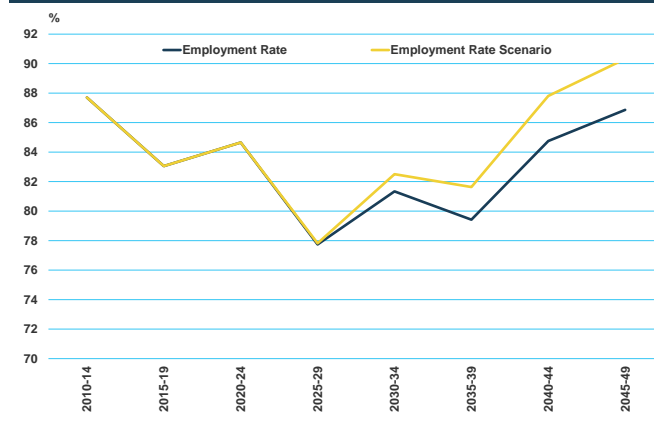
Chart 13H: Employment Rates Compared



Similar results are shown for the dry bulk market in Charts 13I and 13J. Compared to tankers, the contracting scenario for bulkers sees less relative reduction, given the stronger demand profile of this sector (supported by non-energy related cargoes).

As with tankers, contracting reductions are focused on the period 2025-35. The impact on the bulker employment rate is positive, rising to 90% by the end of the forecast period and displaying a clear uptrend from a low point in the late 2020s.

This market benefits from non-energy demand and could potentially see further demand support from e.g. higher biomass cargoes associated with power generation

Chart 13I: Bulker Contracting – Lower Ordering**Chart 13J: Employment Rates Compared**

14.0 Asset Values

14.1 Asset Price Formation

The severe impact on vessel earnings of course has a significant knock-on impact on vessel prices. However, earnings are not the only factor impinging on price formation. MSI categorises the drivers of second hand vessel prices into four, largely independent, components: newbuilding prices, scrap prices, earnings and life expectancy. We discuss below the impact of each of the drivers on pricing.

14.1.1 Newbuilding Price

Current yard contracting prices effectively impose a guide ceiling on prices for second-hand tonnage, though when a tightening in employment rates coincides with lengthening delivery lead times for newbuildings, resale values can exceed contracting prices.

If newbuilding prices skyrocket, the price of second-hand ships may rise if arbitrage causes sufficient demand to switch into the Sale and Purchase market. On the other hand if newbuilding prices plummet below those for modern second-hand ships, resale prices will fall as the value of a used asset will almost invariably be lower than the cost of its replacement by a new one with a longer working life expectation.

Shipyards prices are dictated by the economics of shipbuilding, including the balance between aggregate newbuilding capacity and forward orderbooks along with shipbuilding costs. The latter are a function of productivity, steel plate and equipment prices, wage inflation and exchange rates. MSI makes explicit forecasts of newbuilding prices by vessel type and size by utilising its proprietary Shipbuilding Economics Model (SHIPS).

14.1.2 Scrap Price

The residual scrap value of any ship effectively sets the floor to its resale value. The level of this market floor is determined largely by forces external to shipping markets. Steel scrap is a commodity, whose price is subject to global demand and supply conditions in the steel rather than the shipping industry, with shipping only a marginal supplier of used scrap globally.

14.1.3 Earnings



The price differential between newbuilding price and scrap price offers ample room for resale prices to fluctuate. Ships are valued on the basis of their earning power, with vessel resale prices typically highest at the top of the earnings cycle and lowest at the bottom.

During strong or “peak” earnings environments the net replacement depreciation curve (depreciation normalised for newbuilding prices and with scrap price excluded) will approach a straight-line depreciation, whereas in poor or “trough” earnings environments the depreciation curve will display a concave profile dropping below the straight-line equivalent.

The relationship is best modelled and subsequently forecasted by utilising the Net Replacement Value Depreciation metric; this normalises secondhand prices against changes in the newbuilding price and removes the residual scrap price from the assessment, thus capturing the sole impact of earnings on relative secondhand value. MSI’s proprietary econometric models incorporate algorithms that depict the relationship between historical earnings and depreciation curves based on historical price and sales data for each vessel size class. Chart 16A shows all Capesize vessel transactions since 1990.

14.1.4 Life Expectancy

The life expectancy of the vessel is dictated by market conditions with generally a shorter life expectancy in weak earnings environments. Variations in earnings and therefore life expectancy are captured as part of the market modelling process described above.

Chart 14A: Capesize Sales Expressed as % NRV⁶

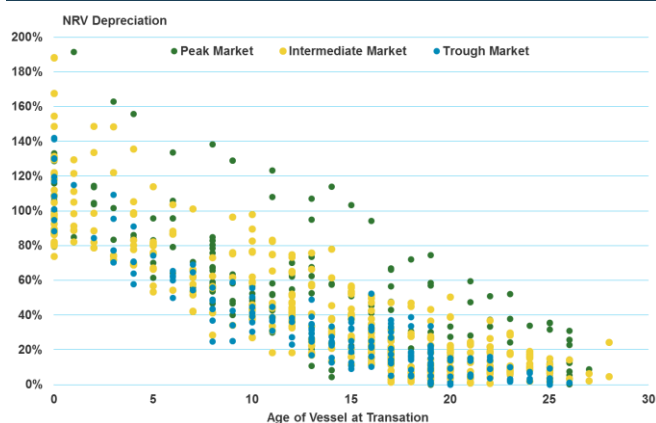
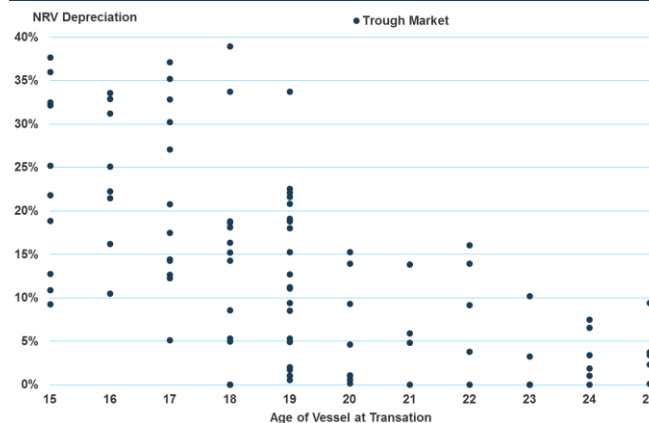


Chart 14B: Capesize NRVs in a Trough Market



Charts 14A and 14B above illustrate how earnings impact Net Replacement Values and life expectancy. Chart 14A plots all secondhand sales of Capesize bulkers since 1990, converting each sale price into a net replacement value and colour coding each point by the earnings environment. As Chart 14A illustrates, in peak earnings environments asset prices are a larger percentage of Net Replacement Value, whilst in trough markets the depreciation curve sags. This is emphasised in Chart 14B, which shows just Net Replacement Values for older Capesizes in trough markets. As it

6
$$NRV = \frac{\text{Secondhand Price in Year of Sale} - \text{Scrap Price in Year of Sale}}{\text{Newbuilding Price in Year of Sale} - \text{Scrap Price in Year of Sale}}$$

shows, a significant proportion of transactions for vessels older than 18 years in trough markets take place at or close to 0% Net Replacement Value, or in other words the scrap price.

14.2 Asset Price Evolution

Of the four determinants of newbuilding prices, two are adversely affected under the *Reduction* scenario. Scrap prices are assumed not to have been impacted, while as Section 14 lays out, we expect newbuilding prices to broadly stabilise, with bulk vessel newbuilding prices remaining steady at close to \$2000/CGT from 2030 onwards. In other words, the key channel of impact on secondhand prices is the reduction in earnings and concomitant fall in the economic life expectancy of vessels.

Charts 14C and 14D plot the impact of the *Reduction* scenario on representative bulker and tanker depreciation curves. As they illustrate, dry bulk asset depreciation curves will sag to a similar level seen in 2016, which represents among the worst dry bulk market in recent history. However, as Chart 14C shows, the recovery of the dry bulk market during the 2040s will see the dry bulk depreciation curve improve, with dry bulk carrier depreciation curves approaching their current levels by 2045.

The situation for tankers is even worse, as shown by Chart 14D. 2018 is included as a comparator in both charts, but whereas 2018 was a year of recovery for dry bulk carriers – with both prices and earnings at reasonable levels – for tankers 2018 was a very poor year. Notwithstanding that, from 2030 onwards tanker depreciation curves will be considerably lower than their 2018 levels

Chart 14C: Capesize Depreciation Curves

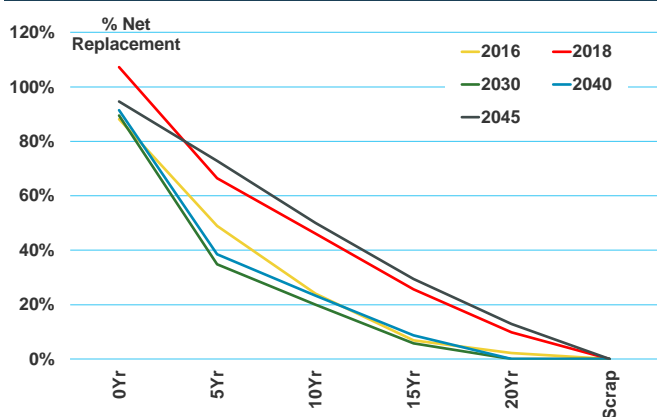
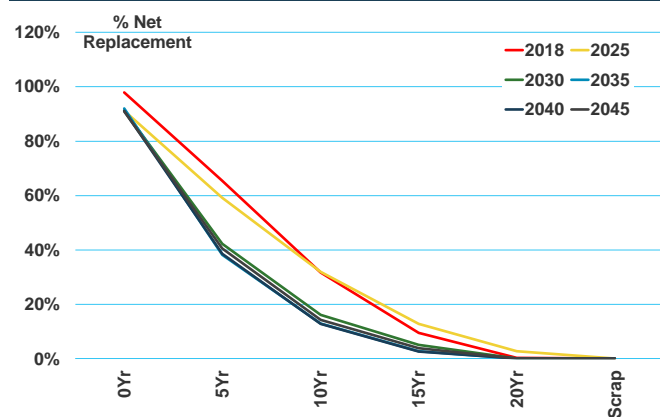


Chart 14D: Tanker Depreciation Curves



Charts 14E and 14F below translate this impact into asset prices, plotting the evolution of 5 Yr Old and 15 Yr Old Prices for representative classes of tankers and bulkers. As it shows, under the *Reduction* scenario we expect 5 Yr Old Capesize bulkers to lose 40% of their value from 2018 to 2030. However, by the 2040s a recovery will be underway and Capesize 5 Yr Old prices will shift into recovery and by 2045 will be 25% above their 2018 levels.

However, it is important not to understate the changes that the dry bulk market will have to undergo to enjoy that level of asset value appreciation. Dry bulk scrapping will boom through the 2030s, with less efficient assets seeing their economic life expectancy shrink markedly. Capesizes will have to

become increasingly flexible, diversifying their cargo base to include some of the minor bulks, and in order to do so will need changes both in design and in efficiency.

Tanker prices will see a similar downside, but with no subsequent upside. 2018 prices are already depressed, but by 2035 5 Yr Old Prices will drop by 29% relative to 2018's low levels (and by 44% relative to 2015, the recent high). However, there is fairly minimal upside; even after heroic levels of vessel scrapping, tanker 5 Yr Old prices will only gain 15% from their 2035 trough over the following ten years, remaining at extremely low levels.

Chart 14E: Capesize Asset Prices

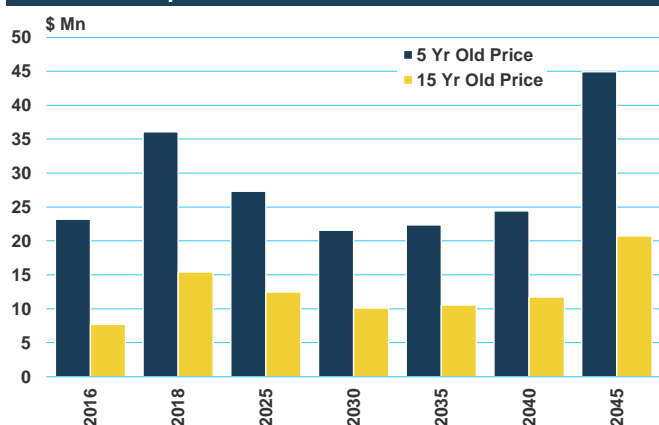
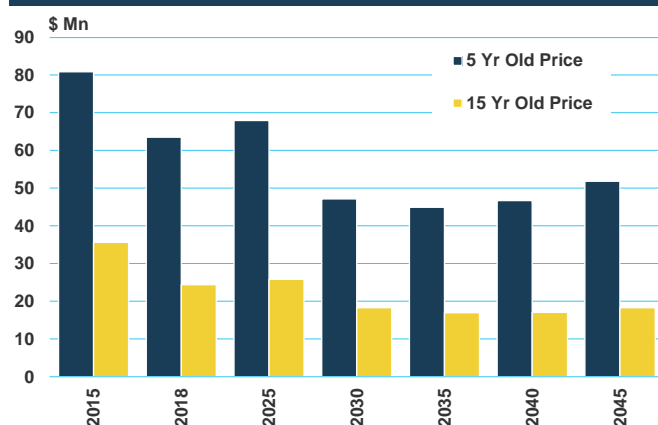


Chart 14F: VLCC Asset Prices



This also implies a significant impact on the overall value of each industry. Charts 16F and 16G below present the evolution of the total industry value of the tanker and bulker sectors (based on MSI's projections of both number of vessels by fleet segment and asset values). As it shows, both sectors will have a violent adjustment to make relative to current practices.

For the bulker sector, the pain will be relatively swift and concentrated, with the value of the bulker sector more than halving from 2018 to 2030 both as a consequence of declining asset values and as a result of a shrinking fleet. For tankers, the pain is more prolonged. Relative to the depressed markets of 2018, the value of the tanker market will marginally recover by 2025, but then enters a prolonged period of decay, with the value of the tanker fleet sinking from over \$160 Bn in 2018 to \$114 Bn by 2045.

Chart 14G: Market Value – Bulker Sector

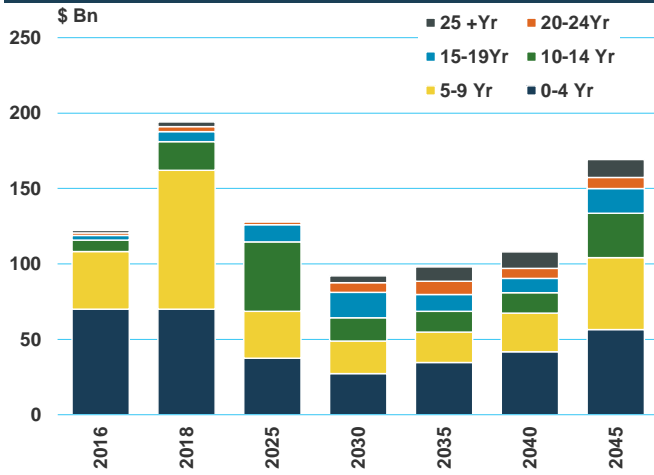
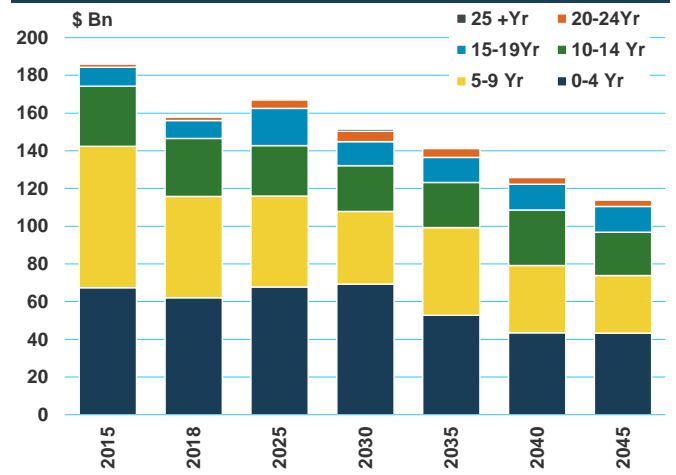


Chart 14H: Market Value – Tanker Sector



How can shipowners - and their financiers – prepare for such a radical shakeup? Providing a comprehensive answer would require a lengthy report in itself, but we would note some likely ingredients for survival. The first is investing in more flexible assets. In the case of tankers the crude market is projected to nosedive before that of refined products, so companies operating coated tankers may be exposed to less near-term downside risk (although for the coated tanker market to enjoy good earnings whilst uncoated vessels remain in the depths of a downturn would be unprecedented). For bulkers, smaller geared vessels are likely to see less downside than the larger, gearless Capesizes and Panamaxes which have traditionally been focussed on the iron ore and coal trades.

The second ingredient for survival is focusing on more efficient assets. Vessels which are able to earn a premium in the charter market, for example due to lower fuel consumption, are likely to see their valuations less badly impacted than other vessels, in part as their life expectancy will be longer.

The final ingredient for survival will be a lack of speculative ordering. It is difficult to overstate the transformation that static or shrinking cargo demand will inflict on the bulk shipping industry. However, the significant supply side adjustment – with the concomitant early scrapping and destruction of shareholder value envisaged – will prove fruitless if speculative orders continue to be placed. Ultimately, if governments meet their commitments and enact the low carbon transition, the shipping industry itself will need to undergo a total change in mind-set.

15.0 Conclusions

The commitments made by the world's governments to address climate change have radical implications for the global shipping industry. If these commitments are kept, the global cargo base that shipping serves would undergo an aggressive and prolonged transformation. World consumption of oil would halve, coal consumption would fall by 80% and LNG demand would peak in the near term before declining. Whilst some sectors of the market would be relatively unscathed – containerships and chemical tankers being the most significant ones – sectors in which hydrocarbons make up a significant proportion of the cargo mix would undergo decades of stagnant or falling demand.

The tanker market is most exposed to the low carbon transition as its entire cargo base is made up of fossil fuels. Overall, MSI's models suggest that under the *Reduction* scenario, tanker demand would fall by slightly more than a third. Bulk carriers would also see demand from coal transportation fall by around half, but overall demand for bulkers would fall by 14% from 2020 to 2035 before returning to modest growth in the latter part of the forecast as the expansion of grain and minor bulks trade outweigh shrinking coal cargoes.

Whilst falling demand is not unprecedented in the shipping industry, the sustained nature of the decline is. Setting aside the possibility of short-term factors driving spikes in demand, our models suggest that tanker demand would fall year-on-year every year from 2025 onwards under the *Reduction* scenario. Bulker demand would fall every year for fifteen years up until 2035. By contrast, although the scale of the collapse in tanker demand in the 1980s is of a similar scale at 39%, it was only five years before tanker demand began to pick up again.

This of course has significant ramifications for owners and financiers of vessels. Falling demand will hurt fleet utilisation, and the earning power of tankers and bulkers would collapse in the *Reduction* scenario. Earnings for a Capesize bulker would spend the 2030s averaging roughly half of their long-term median earnings, whilst for a VLCC earnings would underperform their long-term median by around a third.

Of course, such dire markets would provoke a significant supply side reaction, as owners slashed new ordering and scrapped uneconomic vessels. The tanker fleet would fall by around a third over the two decades after 2030, whilst the dry bulk fleet would shrink for nineteen out of twenty years from 2025, shedding 14% of capacity relative to its 2024 peak. Asset prices would also be hammered, with a benchmark 5 Yr Old Capesize bulker losing 40% of its 2018 value by 2030 under the *Reduction* scenario, whilst a VLCC would slide by 29% over the same period (with the lower decline being a function of the current weak tanker market rather than any real resilience).

In aggregate, under the *Reduction* scenario by 2030 the dry bulk shipping industry would be worth half what it had been a decade earlier, although 2030 would mark the nadir and the industry would subsequently return to growth. The impact on the valuation of the tanker industry would be less dramatic but without respite, with the industry shedding 28% of its 2018 value by 2045.

Given the scale of the potential challenge, what can the wider shipping industry do to position itself to survive? Supply side restraint is key; as we lay out above reduced ordering would mean that both tankers and bulkers would recover from the shock of the low carbon transition and see the fleet employment return to around today's levels. The second is vessel selection. The exposure of larger bulkers to coal implies a particularly negative outlook under the *Reduction* scenario, whereas smaller geared bulkers would show more resilience.

Allied industries will not be spared; the port sectors of certain countries would be absolutely decimated; Indonesia's coal exports would quarter over a fifteen year period. Ship financiers would also find themselves caught in a vice, with earnings unable to cover debt repayments and falling life expectancy reducing the runway to recover a loan before the vessel is scrapped. Financiers of more efficient vessels may be somewhat better placed, as greater efficiency should lead to longer life expectancy. However, overall the prospects for successfully recouping a loan, never mind an equity investment, in a vessel heavily exposed to fossil fuel cargoes seem challenging under a *Reduction* scenario.

Accelerated action at a governmental level, technological advances, increased renewable use, public pressure, and increased regulatory and financial constraints will all contribute to this process – the question is how fast?

In a rapid transition, as explored in this report, vessel selection will be critical, and divestment from sectors with the greatest exposure to fossil fuels may prove the only way to profitably navigate the changing landscape.

Furthermore, if the timeline posited above is accurate then the time to react is now. Most owners would assume a minimum vessel lifespan of twenty years when evaluating an investment, which means that investing in anything other than the oldest vessels today implies significant exposure to this transition. Notwithstanding this, the amount of discussion of these potentially disastrous demand side dynamics is almost totally absent from the shipping industry.

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Grains and Minor Bulks Demand

Grain Trades

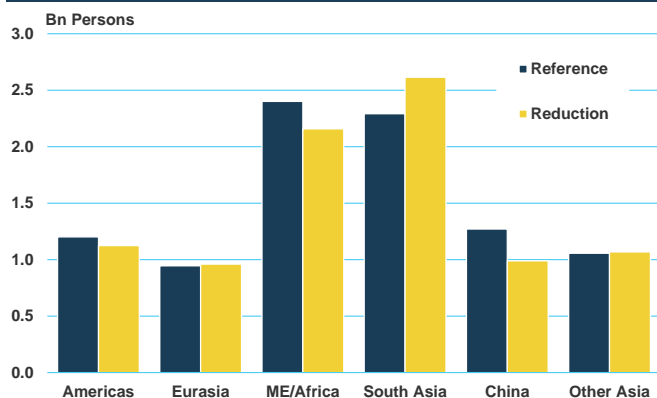
Changes in the consumption of grains follow population growth, economic growth and population movements. The key shift in consumption patterns results from the relocation of population away from the Middle East and Africa and toward OECD economies and South Asia. Global consumption of grains (excluding storage) decreases in the *Reduction* scenario. The scenarios are based on the SSP1 and SSP2 scenarios, as outlined above.

Shifts in grains production in response to climate change are assumed to be limited, as the major production centres will not shift and incremental production will be sourced from increasing acreage or yields in these locations.

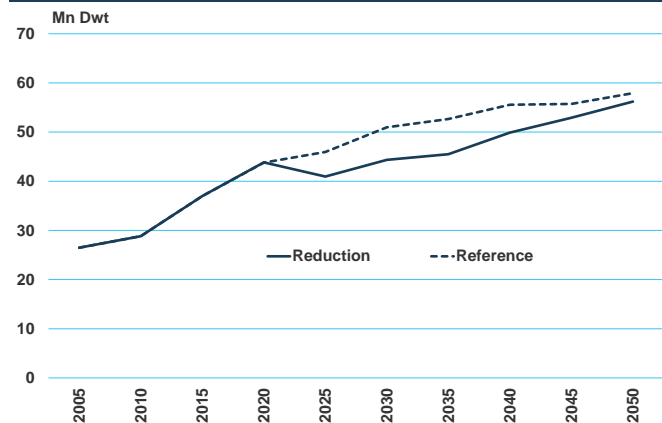
Changes in trade flows derive from a picture of changed patterns of consumption but few changes to patterns of production. Under the *Reduction* scenario grains imports into Europe and South Asia increase, while imports into other regions decrease, with large decreases of imports into Sub-Saharan Africa and China. Global trade in grains is lower under the *Reduction* scenario than the *Reference* scenario at first, but by the 2040s aggregate trade is at a similar level under both scenarios.

Due to changes in trade routes as well as lower overall consumption toward the start of the forecast period (with generally shorter sailing distances involved after consumption shifts are accounted for), required vessel demand falls under the *Reduction* scenario. By the end of the forecast horizon, however, the difference between the *Reduction* and *Reference* scenarios is negligible.

2050 Population Changes



Grain Trades Deadweight Demand



Minor Bulk Trades

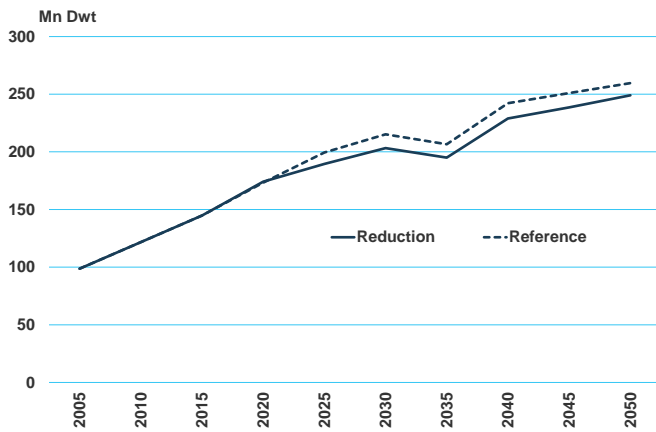
The effect of the *Reduction* scenario on minor bulk trades is limited, as these trades are not directly tied to energy production. The scenario for minor bulk trades draws on the SSP1 pathway for the *Reduction* scenario, and the SSP2 pathway for the *Reference* scenario, using both scenarios for population and economic growth.

Changes in agribulk trades track closely the changes described above for the grains trades, and are driven by changing geographical distribution due to population movements and a relatively unchanged production picture.

Unlike other minor bulk trades, the fertilizer trade drives an increase in vessel demand under the *Reduction* scenario. This is a function, once again, of shifts in population not being matched by shifts in production. The net effect of these shifts is the need to increase yields, providing a boost to trade volumes (although greater use of genetic modification could limit the need to increase yields in practice).

Demand for ores and metals products (and, due to the fixed nature of production, trade patterns) is expected to fall slightly given expected changes in economic growth models under the *Reduction* scenario. The overall impact on vessel demand here is small, however. Much the same applies for forest product trades.

Minor Bulk Deadweight Demand



Chemical Tanker Demand

Consumption and Production

The chemical industry is included in IPCC scenarios in terms of sectoral energy consumption and is therefore included in the other sections on oil, gas and coal demand. However, there is no accepted scenario for how the chemical industry itself will adapt to climate change. In this context, MSI have looked at climate change reports produced by bodies such as CEFIC (European Chemical Industry Council) and the IEA.

In order to generate a low case analogous to the *Reduction* scenario, we have used a recent IEA report⁷ on the sector as a guide. This posits two scenarios that look at the impact of recycling and other mitigations to reduce per capita consumption of chemicals in the long term. The scenarios - a *Reference Technology Scenario (RTS)* and a *Clean Technology Scenario (CTS)* - are similar in terms of aggregate consumption and both are significantly lower than those provided in 2013 IEA report on the same issue⁸. The latter can be considered a high, 'business as usual' case and constitutes the basis of the *Reference* scenario, while the CTS underpins the *Reduction* scenario.

Our analysis of the chemical sector is based on a consumption analysis and does not take account of the impact of changing carbon feedstocks. The industry is currently undertaking significant research into alternative carbon-neutral feedstocks, but though these will drastically reduce the CO₂ emissions of the sector, they are unlikely to fundamentally alter the pattern of consumption and trade nor impact on chemical tanker demand.

Our organic chemical forecasts under these scenarios were extrapolated from an explicit view of consumption and trade methanol and the BTX aromatics stream (benzene, toluene and xylene) to cover the whole liquid organic sphere. Aromatics and methanol account for about half of all organic chemicals trade and face significant structural change in production location. A forecast for other key organic chemicals was derived based on co-production or consumption relationships with the BTX stream or methanol. For example, monoethylene glycol (MEG) correlates with paraxylene, as both feed into the polyester industry.

Inorganic chemicals trade and chemical tanker employment was aligned with economic growth rates seen under the SSP1 and SSP2 scenarios, aligned with the grains, iron ore and containership

⁷ The Future of Petrochemicals, 2018

⁸ Technology Roadmap, Energy and GHG Reductions in the Chemical Industry via Catalytic Processes, 2013

sections of this report. A similar approach linked seaborne trade in grains to edible oil trade and demand.

Under the *Reduction* scenario, global BTX and methanol consumption continues to grow, with a two fifths increase between 2020 and 2050. Under the *Reference* scenario consumption almost doubles over the same period.

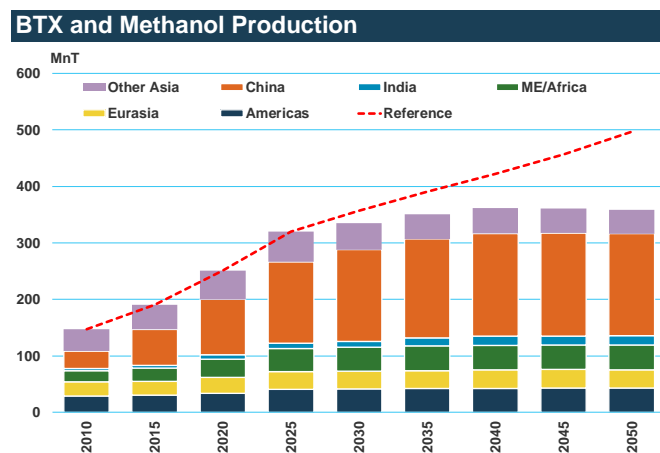
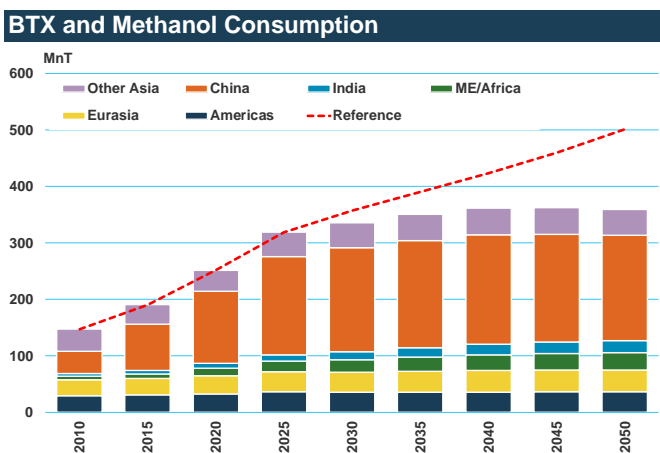
Under the *Reduction* scenario, consumption of paraxylene will continue to grow strongly until 2040 in existing polyester hubs in China and India, and new hubs in Middle East and Africa. Decline will set in thereafter, as these regions develop processes to reduce consumption of plastics by increasing recycling and reusing products. The overall increase in demand is close to 75% between 2020 and 2050.

Developed regions, in particular the OECD countries will be the first to reduce consumption of plastics: first, they have slower population growth, and second, policies and initiatives to limit the damage to the environment are assumed to gain traction earlier. The decline in BTX stream consumption is close to 50% between 2020 and 2050 for these regions.

In both scenarios, production is focused on regions with a focus on expanding existing capacities, such as the recently planned mega refineries in China and India, and regions with easy access to oil, such as the Middle East. Crude oil to chemicals is seen as a major alternative use of oil reserves by countries in the latter region.

Methanol demand is forecast to grow by 60% between 2020 and 2050, with China accounting for 60-70% of global consumption for these periods, as it continues to utilise its reserves of coal in producing chemicals and plastics. Post 2025 we expect a slowdown in methanol consumption growth in China, with contraction after 2040.

As is the case for the BTX stream, OECD countries will be the first to reduce consumption in methanol, but at a slower rate since methanol's use as a clean fuel alternative increases.



Trade and Ship Demand

The largest structural change in seaborne trade of these cargoes is the decline in Chinese imports. This applies to both the *Reduction* and *Reference* scenarios and reflects construction of refineries and plants that will increase production and reduce imports of paraxylene and methanol. These two cargoes will account for 27 MnT of seaborne trade in 2020, but fall to 3 MnT by 2050 in the *Reduction* case.

India, Europe and Other Asia will see increased methanol imports as they lack the capacity and access to cheap reserves to produce methanol efficiently and sustainably. US imports will also decline as domestic production increases.

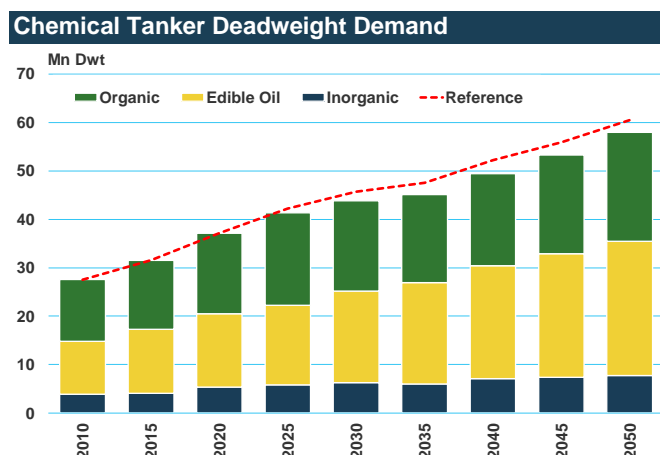
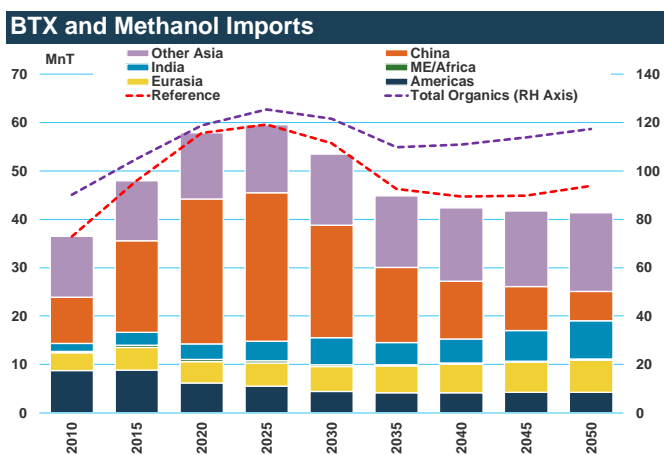
With Chinese imports of organic chemicals falling, its main supplier, North East Asia, will face reduce production and export across the forecast, returning to levels seen before the rise of Chinese imports.

Middle Eastern countries have started to look further downstream, seeking to gaining more value from each barrel of oil. Several new petrochemical projects have started in this region, causing an increase in exports in the near term. Exports from this region are closely tied to trends in aggregate demand, and will trend down longer-term, while maintaining market share.

The rise in organic chemical imports by India, Europe and Other Asia will sustain trade post 2035, offsetting the decline in Chinese demand.

Consolidating the trends in all cargoes that are carried in chemical tankers, decarbonisation is expected to have a relatively low effect on the chemical tanker sector long-term. Though organic chemicals trade declines, this is offset by trends in other key commodity groups.

Inorganic chemicals will remain critical for a wide range of industrial activity, whether in mining and other industrial uses and consumption and trade correlate with our projections for minor dry bulk cargoes, as outlined in Section 9. The growth in edible oil demand, whether for food consumption or as biofuel, offsets in part the projected drop in organic chemical trade under the *Reduction* scenario. The forecast highlights that there will be continued growth in the chemical tanker fleet, with 60% growth by 2050, compared with the 2020 base year





Maritime Strategies International Ltd
24 Southwark Bridge Road
London
SE1 9HF

Tel: +44(0)20 7940 0070

info@msiltd.com
www.msiltd.com