ARUP

Foresight

Future of Goods Movement

November 2023

Contents

Why do we need to think about the future of goods movement?

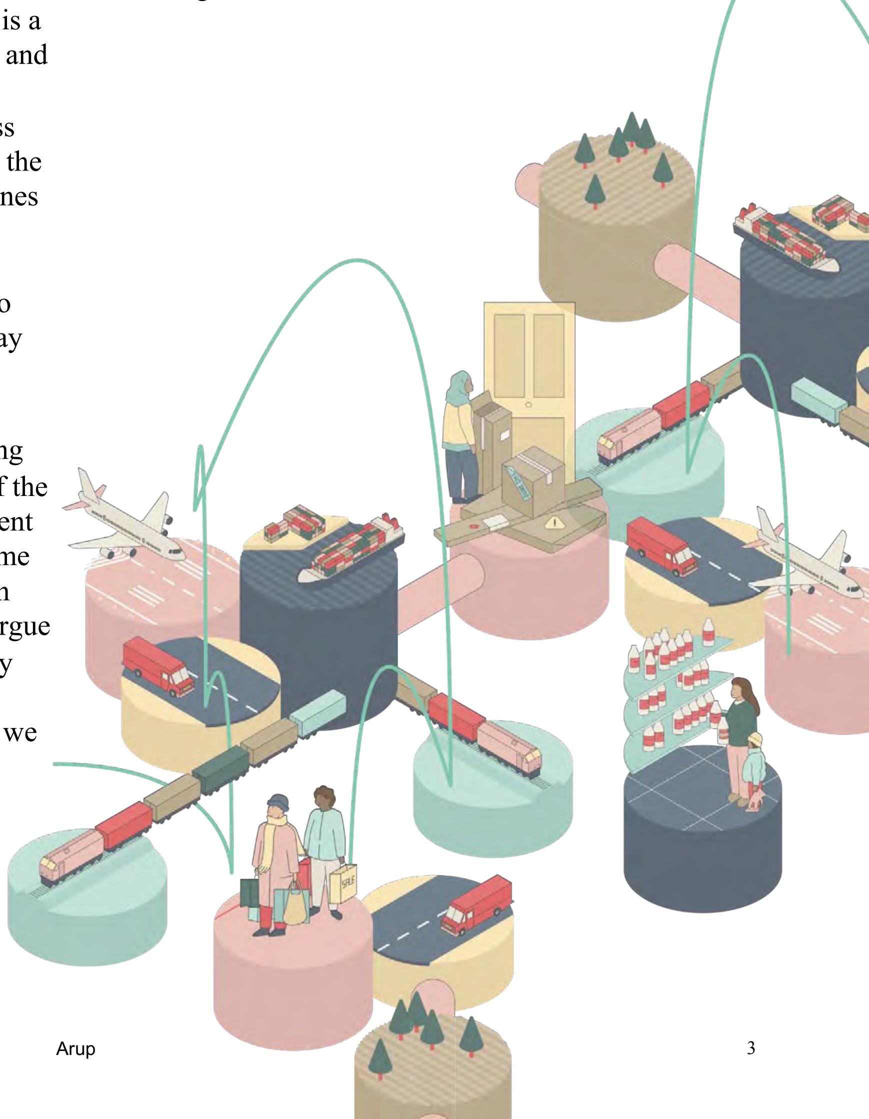
Introduction

When most people think of transport, they think about their everyday experience using trains, buses, cars, or walking and cycling to go to work, school, the shops, and other local and far-off destinations. Transport is about meeting their daily needs, getting access to services and goods, and meeting family and friends.

However, there is another side to transport that is just as important, but which gets far less attention. Every activity we engage in to sustain our lives, businesses, leisure, health, and relationships is facilitated by goods and resources – materials, products, food, fuel, energy, assets. These goods are the end products of highly complex and largely invisible supply chain networks, all relying on extensively coordinated operations and transport networks comprising of multiple modes of delivery. Typically, these behind-the-scenes transport systems only gain mainstream attention when there is a critical break down in the network, and populations and key industries are suddenly cut off from the daily resources they otherwise expect uninterrupted access to. The Ever Given, a container ship which blocked the Suez Canal for nearly a week in 2021 earned headlines internationally – highlighting both the intricacy of global freight and its integral value to economies worldwide. This one incident alone was estimated to have held up $9 billion in global trade value each day of the blockage.[1]

This report aims to highlight the importance of taking note of and rethinking how we plan for the future of the freight transport system – the long-distance movement of goods. We take a global perspective, but with some region-specific focus on the dynamics playing out in the UK and EU freight and transport markets. We argue that a focus on the often invisible, but fundamentally integral freight systems which are responsible for delivering secure access to the goods and resources we all rely on is particularly crucial at this time.

The key contextual drivers for goods movement – consumption, trade, manufacturing, and energy – are all witnessing major transformation and will change the requirement for and demands on today’s freight network. Due to segmented decision-making and priority-setting, the freight network serving most regions of the world today is a highly precarious system, poised to experience significant disruption with increasing frequency. Understanding the changes and shifts that the future of goods movement is likely to be subject to, and the priorities and processes which should be in place, will be critical to the global economy and a more sustainable planet. Dialogue and consideration of this system must emerge from the background and into the spotlight for both everyday people and the decisionmakers planning the future of cities, regions, access to resources and infrastructure.



Emerging challenges for the movement of goods
Context

Freight transport moves goods (materials, products, foods, etc.) from a location where they are available to another location where they are required. The freight world is complex in terms of who operates, invests, and controls the network for different modes of transport, the types of goods carried by different modes, and the key characteristics of goods which travel over different parts of the freight network (origin/destination, volume, value, etc.). There are usually many different types of stakeholders involved in the process of delivering goods to their final destination - from providing and maintaining the necessary infrastructure, through to running services to process and transfer goods across international borders.

Freight movement is dominated by the private sector for each mode – services are planned and optimised with a fragmented view (based on the individual entities which operate and plan a specific component on the freight network) and to date has primarily been driven by market demand, rather than systemwide strategic planning and consideration of long-term requirements and risks. This private-market driven nature of many freight networks globally and within nations has led to an overall system in most countries and regions which has developed piecemeal and organically.

Over several decades, this fractional development and the absence of an overarching national or regional freight strategy in most countries has arguably made the freight sector highly vulnerable to major disruption from sudden, unexpected changes. Supply chains have favoured increasing speed and cost-based optimisation in recent decades and the result has been diminished resilience (back-up inventories, secondary options, etc.) in the freight network at a systemwide level. The combination of privately driven, fragmented attempts to optimise a segment of the system and a lack of strategic systemwide planning means that, to some extent, the freight industry today is characterised by highly complex operations and reactive decision making.

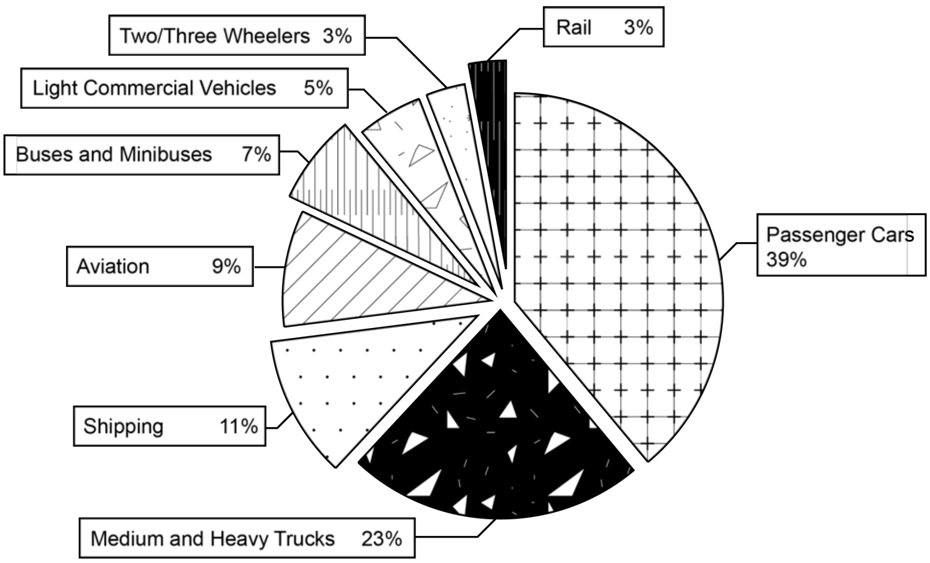


Figure 1
Breakdown of CO_2 emissions in the transportation sector worldwide 2021, by subsector[3]

Emerging challenges for the movement of goods
Context

A report published in June 2022 by Logistics UK, a trade association, found that global and local factors have created new issues for all aspects of the supply chain – with problems such as disruption to the supply of shipping containers, increased fuel costs, a shortage of HGV drivers and a lack of semi-conductor microchips all having an impact on the way that goods are moved around the world.[2] There is an emerging view across the freight and logistics industry that there is over-reliance on just-in-time management systems and cost-based optimisation at the expense of operational resilience.

The freight system that has taken shape over recent decades is also highly inefficient from a resource and energy perspective. Heavy goods vehicles (HGV) and light duty vehicles (LGV) together accounted for 23% of global greenhouse gas emissions from transport in 2021. Shipping accounted for a further 11% while all rail transport accounted for only 3% of emissions. It is estimated that if all passenger and freight traffic (2021 figures) by rail shifted to road vehicles, global GHG emissions would increase by 1.2 Gt of CO2-eq, or 12% more than total emissions from the transport industry today.[4]

According to the UK Department for Transport (DfT) and Eurostat, empty running alone (not taking into account the many freight vehicles travelling with significantly low loading-factors) is at 30% in the UK (as of 2022)[5] and an average of 20.2% in the EU (as of 2021).[6] This equates to millions of unnecessary HGV miles needlessly congesting the roads, costing money and emitting CO2. The majority of empty running is associated with national transport (23.7% EU average), with international transport performing better on this metric (12.5% EU average).[7]

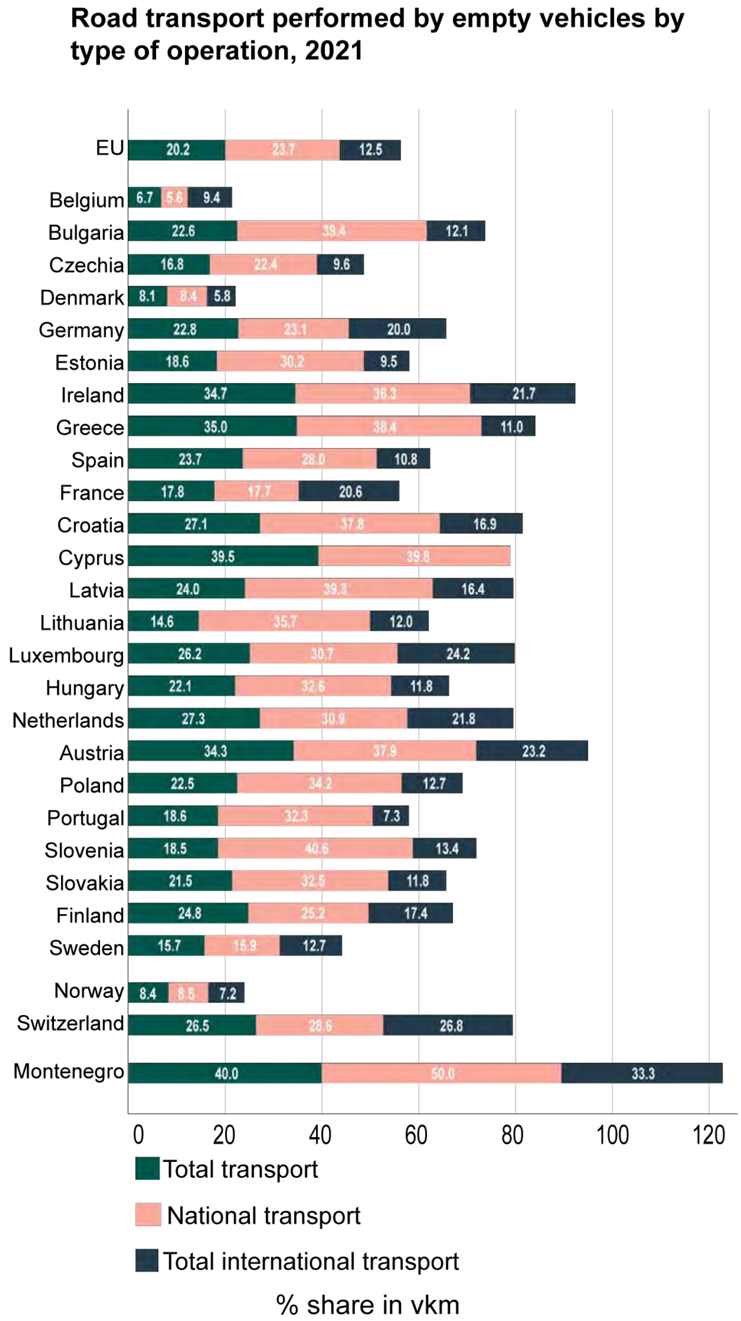
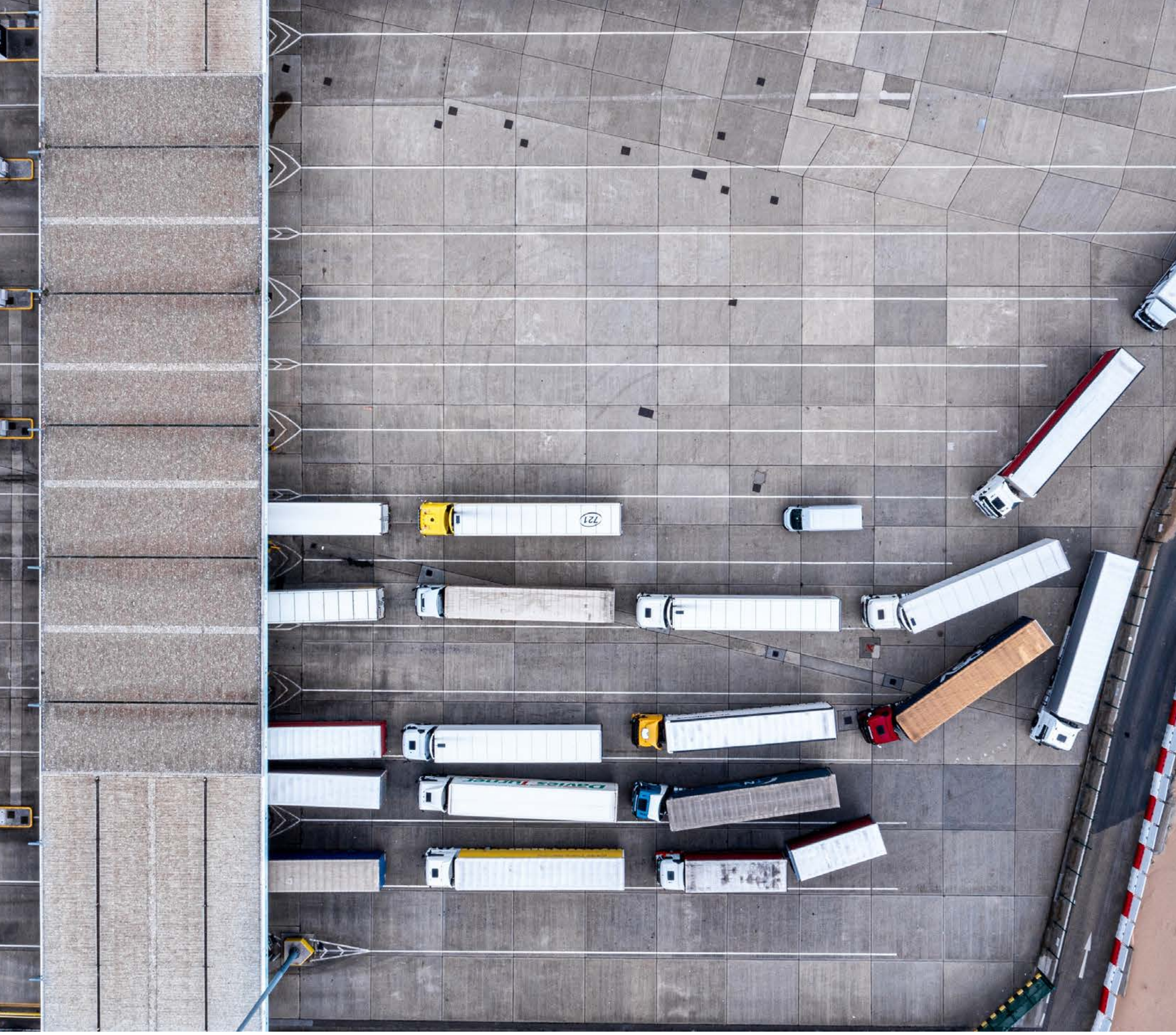


Figure 2
Road transport performed by empty vehicles by type of operation, 2021 (% share in vkm)[8]



Long-Term Future of Freight Plan

UK Department of Transport

The UK Department for Transport has made a first attempt at addressing the lack of whole system strategic thinking around freight through the publishing of a long-term future of freight plan in 2022. This identifies five priority areas and actions around the following points:

1
Development of a National Freight Network

2
Transition to net zero

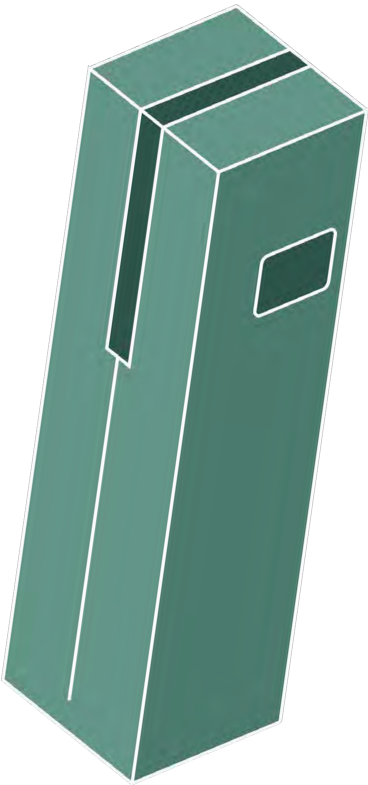
3
Improving planning processes for the needs of freight

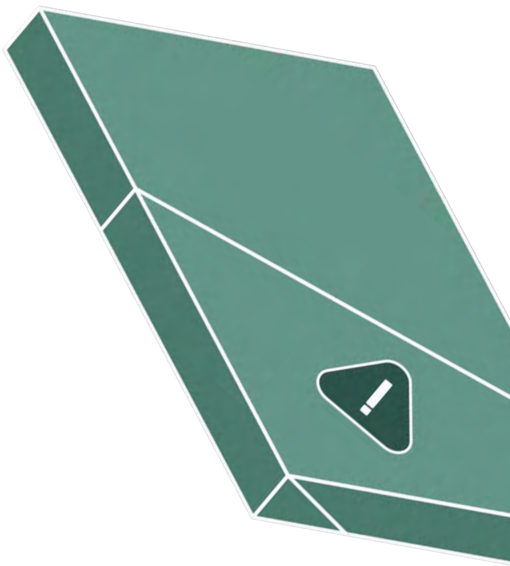
4
Developing people and skills in the freight sector

5
Using Data & Technology to drive innovation (including a new £7m cross-modal Freight Innovation Fund

While the success of this strategy remains to be seen, the intention to consider and plan for the entire freight system is long overdue.

1
Understanding the Freight System





Understanding the Freight System

Overview

The movement of goods across long distances in most parts of the world is generally enabled through one, or a combination, of four main transport modes: road, shipping, aviation, and rail. We also consider pipelines in this study, due to their role in transporting key energy products and affecting the demands on other mainstream freight modes. The particular characteristics of the freight system, and the relative prominence of specific modes in different parts of the world vary based on production, trade, geography, and precedents of investment in different systems and infrastructure. To give the reader a sense of the on-the-ground challenges, the particular complexities and the opportunities emerging in different regional contexts, we supplement an overarching global perspective on the freight network with specifics from the UK and continental Europe.

Each mode has a unique set of strengths, specifications, as well as constraints and developing challenges due to historic planning and investment coupled with ongoing contextual changes. The suitability of a particular mode is dependent on local factors but a general guide of the core strengths of each major mode is shown below.

It should also be noted that freight transport is influenced by a range of stakeholders. From everyday individuals ordering goods to be delivered to their homes, to large retailers and manufacturers, to shippers, operators and infrastructure provides, to government setting policies that shape the parameters of the freight world. For every mode, 'freight forwarders' act as the intermediaries between the sending and receiving parties and the shipping, rail, or airline service provider. Each of these stakeholders have their own key interests – shippers, and transport operators are business-led. Shippers are most concerned with the timeliness and cost effectiveness of their trips. Infrastructure providers are primarily concerned with the efficient use of the network (often each entity's authority and interest is confined to a limited segment of the overall freight network).

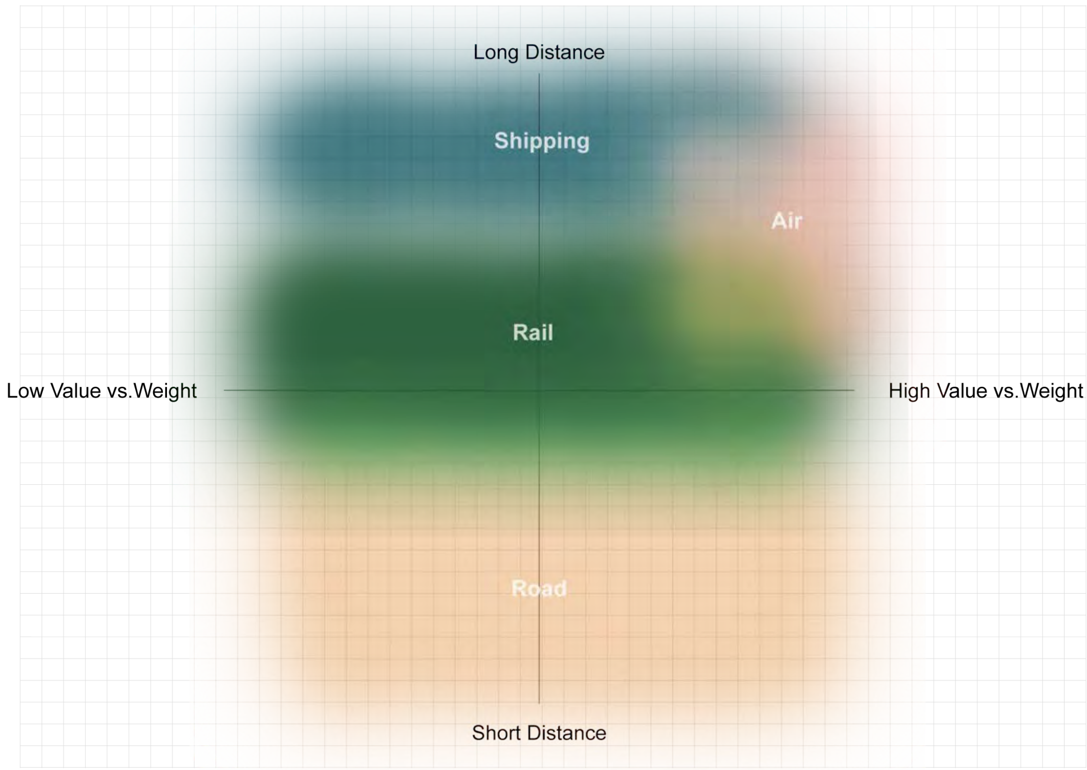
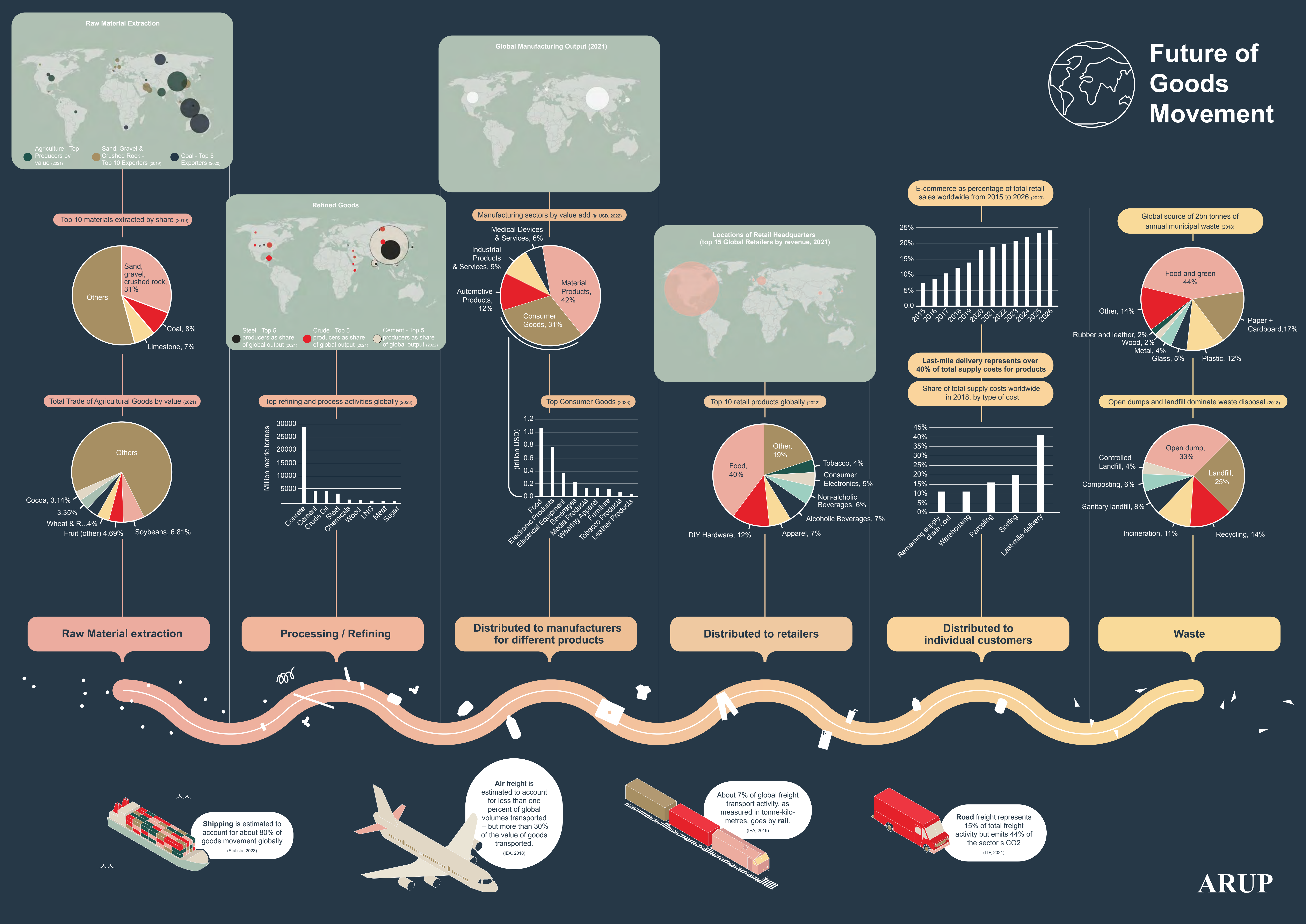
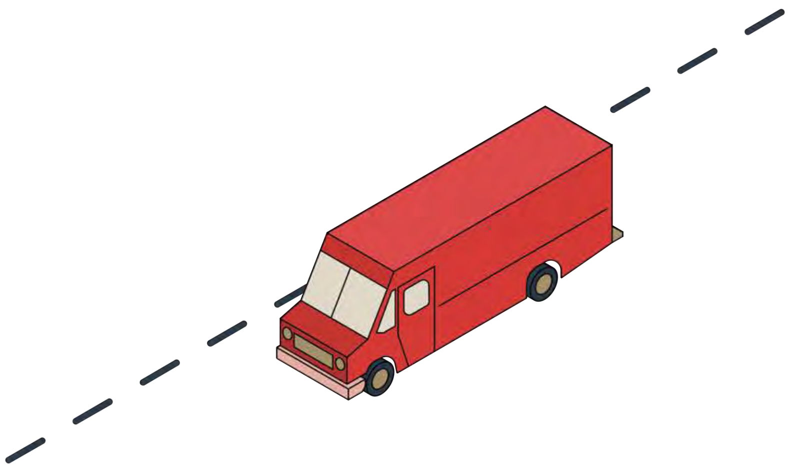


Figure 3
Core strengths of transport modes



Future of Goods Movement
Raw Material Extraction
Agriculture - Top Producers by value (2021)
Sand, Gravel & Crushed Rock - Top 10 Exporters (2019)
Coal - Top 5 Exporters (2020)
Top 10 materials extracted by share (2019)
Sand, gravel, crushed rock, 31%
Coal, 8%
Limestone, 7%
Others
Total Trade of Agricultural Goods by value (2021)
Others
Cocoa, 3.14%
3.35%
Wheat & R...4%
Fruit (other) 4.69%
Soybeans, 6.81%
Refined Goods
Steel - Top 5 producers as share of global output (2021)
Crude - Top 5 producers as share of global output (2021)
Cement - Top 5 producers as share of global output (2022)
Top refining and process activities globally (2023)
Million metric tonnes
30000
25000
20000
15000
10000
5000
Concrete
Cement
Crude Oil
Steel
Chemicals
Wood
LNG
Meat
Sugar
Global Manufacturing Output (2021)
Manufacturing sectors by value add (in USD, 2022)
Medical Devices & Services, 6%
Industrial Products & Services, 9%
Automotive Products, 12%
Material Products, 42%
Consumer Goods, 31%
Top Consumer Goods (2023)
(trillion USD)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Food
Electronic Products
Electrical Equipment
Beverages
Media Products
Wearing Apparel
Furniture
Tobacco Products
Leather Products
Locations of Retail Headquarters (top 15 Global Retailers by revenue, 2021)
Top 10 retail products globally (2022)
Other, 19%
Tobacco, 4%
Consumer Electronics, 5%
Non-alcholic Beverages, 6%
Alcoholic Beverages, 7%
Apparel, 7%
DIY Hardware, 12%
Food, 40%
E-commerce as percentage of total retail sales worldwide from 2015 to 2026 (2023)
25%
20%
15%
10%
5%
0.0
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
Last-mile delivery represents over 40% of total supply costs for products
Share of total supply costs worldwide in 2018, by type of cost
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Remaining supply chain cost
Warehousing
Parceling
Sorting
Last-mile delivery
Global source of 2bn tonnes of annual municipal waste (2018)
Food and green 44%
Paper + Cardboard,17%
Plastic, 12%
Glass, 5%
Metal, 4%
Wood, 2%
Rubber and leather, 2%
Other, 14%
Open dumps and landfill dominate waste disposal (2018)
Open dump, 33%
Landfill, 25%
Recycling, 14%
Incineration, 11%
Sanitary landfill, 8%
Composting, 6%
Controlled Landfill, 4%
Raw Material extraction
Processing / Refining
Distributed to manufacturers for different products
Distributed to retailers
Distributed to individual customers
Waste
Shipping is estimated to account for about 80% of goods movement globally
(Statista, 2023)
Air freight is estimated to account for less than one percent of global volumes transported – but more than 30% of the value of goods transported.
(IEA, 2018)
About 7% of global freight transport activity, as measured in tonne-kilo-metres, goes by rail.
(IEA, 2019)
Road freight represents 15% of total freight activity but emits 44% of the sector s CO2
(ITF, 2021)
ARUP



1.1 Road freight

1.1.1 Context

Road freight forms the backbone of freight and logistics capacity within smaller countries and across almost every major economy. It is flexible as vehicles of many sizes and types can carry goods, allowing road freight to be used even where road infrastructure is poor. Whilst congestion can significantly impact journey times for road freight, diversionary routes are often available to allow for resilience even if a specific piece of infrastructure fails. According to a report by the OECD's International Transport Forum (ITF), road freight transport represents about 40% of the tonne-kilometres across the OECD's 51 member countries (the top 15 world economies are all members), in comparison to 24% by rail, 16% by coastal shipping, 13% by inland waterways, and 7% by pipelines. Road freight's share rose from 25% in 1980 to 40% in 2017 when analysed across these countries.[9]

In the UK, nine times more freight is moved by road than by rail,[11] despite the fact that freight transport by rail on average emits 76% less carbon per tonne than transport by road.[12] Similarly, in the EU road freight dominates inland mode share, accounting for 77.4% of tonne-kilometres,[13] Road freight is responsible for 15% of all European CO2 emissions, of which about 70% comes from medium- and heavy-duty trucking (MDT/HDT).[14] Since these vehicles have to carry loads many times their own weight often over hundreds of kilometres a day, they are operationally well suited to being powered by diesel engines.

The domination of road freight in the domestic movement of goods can be attributed to the mode's flexibility and the ease with which access to road infrastructure can be achieved compared to other modes. In the UK, transport of freight on roadways has also benefited from huge investment in the country's strategic road network over the last 50 years – giving it much more extensive coverage than any other mode. In the majority of cases, road freight is also the cheapest option for transporting goods. For example, in China due to an expensive government owned rail freight monopoly compared to a fiercely competitive road freight market, road is the cheapest option for moving goods over distances under 800 km (the equivalent of driving from Aberdeen to London).[15]

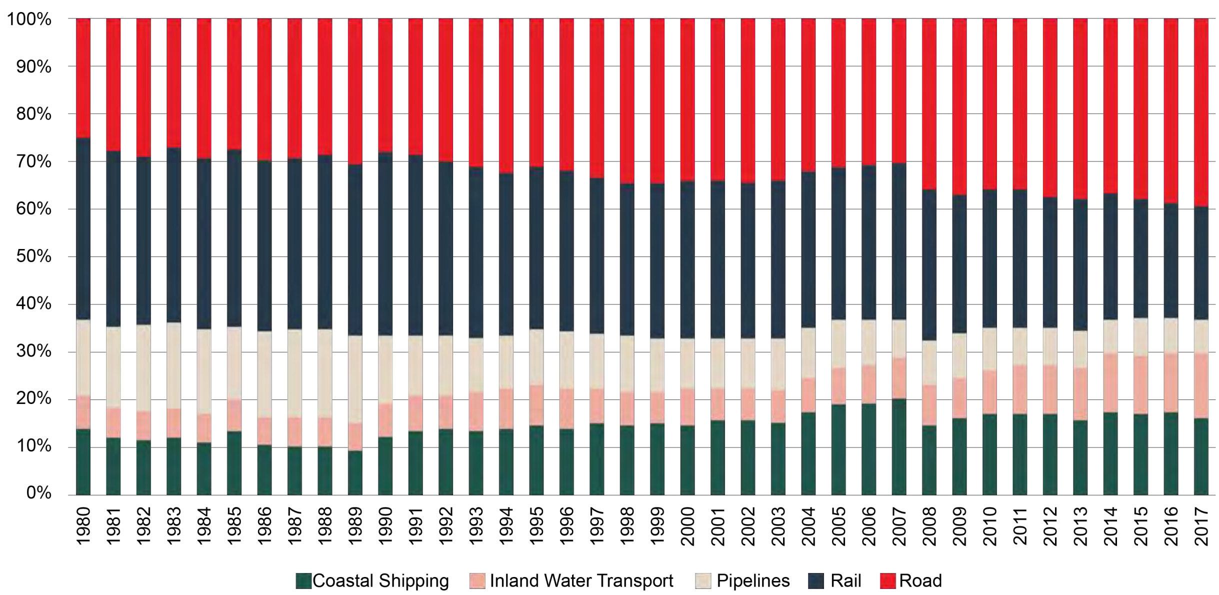


Figure 4
Modal Split Shares in Freight Transport in 51 ITF Countries, 1980-2017[10]

The Fehrman Belt Tunnel

Danish-German Border

The Fehmarn Belt Tunnel is a major infrastructure project that will connect the Danish island of Lolland with the German island of Fehmarn through an 18-kilometer road and rail tunnel under the Fehmarn Belt strait providing a key link between Scandinavia and mainland Europe.

This will shorten travel time from a 45-minute ferry to 10 minutes by car or 7 minutes by train. This is expected to boost trade between the regions and reduce the need for shipping and air travel between Denmark and Germany. When built, the Fehmarn Belt tunnel will be the longest road and rail tunnel in the world at a total cost of around €7.4 billion. Construction of the tunnel started in 2021 and is expected to be completed by 2030.

1.1 Road freight

1.1.2 Opportunities and constraints

The OECD predicts that global freight demand will grow by around 3% every year[16], meaning that it will have almost doubled between 2015 - 2030 and tripled between 2015-2050. The pace and scale of decarbonisation of road vehicles – particularly heavy goods vehicles – has significant implications for the perception of road transport in a world oriented towards net zero targets and for the optimal role of road transport in enabling sustainable goods movement. Electric roads might be part of the solution for HGVs. For example, a six-mile e-highway trial in Germany installed overhead lines to allow hybrid trucks equipped with pantographs to operate. This trial is being expanded and the DfT has awarded £20m of funding to a consortium to undertake a feasibility study into implementing the same technology in the UK.[17]

Hydrogen is also a potential option for decarbonising road freight but is reliant on the provision of refuelling infrastructure – the UK government is currently funding a feasibility study for the Tees Valley area. A study by the management company McKinsey estimates that globally supporting a larger and faster rollout of zero emission fleets (cars, buses, light commercial vehicles, etc.) and accompanying infrastructure in a 1.5°C pathway could require €75-90 billion in additional investments (above the current growth trajectory) by 2030.[18]

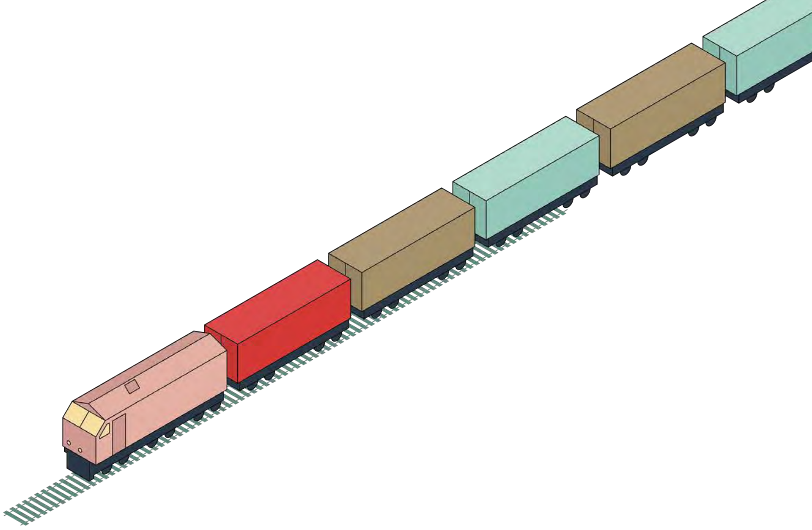
However, the OECD predicts that, measured in vehicle-kilometres, 50% of freight transportation will take place in urban areas and will be related to urban delivery by 2050.[19] Decarbonising trucks and vans will help reduce carbon emissions, but continued growth in the number of these vehicles to support growth in freight volumes will continue to add to road and urban congestion, air pollution (from tyres), and necessitate the reservation of scarce and valuable urban space for accommodating large vehicles. A clear understanding of the role road freight should play, the scale at which it should operate, and where utilising alternative modes to transport goods is better for the environment and people is critical for a more sustainable future of goods movement.

EV Charge Point Provision

UK

UK Government and industry have supported the installation of around 29,600 publicly available charging devices. This includes more than 5,400 rapid chargers at around 3,300 locations servicing over 0.4 million battery electric vehicles. In comparison, the UK has around 8,300 petrol station locations[20] (as of 2022) supplying 37 million petrol and diesel vehicles.

The UK has the fastest charging points per 100km of motorway of any country in Europe. The government has plans to increase the number of public charge points to 300,000 as a minimum by 2030. This follows the decision to ban the sale of new petrol and diesel HGVs by 2040 with the aim of transitioning delivery and freight fleets to EV.



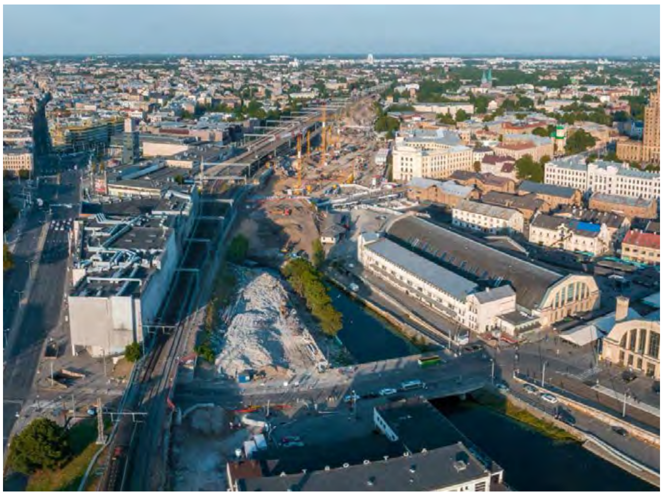
1.2 Rail freight

1.2.1 Context

About 7% of global freight transport activity, as measured in tonne-kilometres, goes by rail.[21] The share of total goods moved by rail varies widely across countries. Russia has the highest share with over 75% of all surface goods transport being moved by freight trains. In China the share is 39%, in North America and India, rail makes up over 30% of surface freight transport.[22] In the United States there has been a major expansion of rail freight capacity over the last few decades, and significant growth in intermodal traffic which has required construction of new facilities and considerable rolling stock investments. From 1980 to 2021, America's freight railroads spent approximately $760 billion of their own funds (not taxpayer funds) on capital expenditures and maintenance expenses related to locomotives, freight cars, tracks, bridges, tunnels and other infrastructure and equipment.[23]

In the UK and EU, rail freight constitutes about 9%[24] and 17%[25] of all freight tonne kilometres travelled respectively. Major rail freight flows in Great Britain are currently concentrated on the major north–south link of the West Coast Main Line, between the two major deep-sea container ports of Felixstowe and Southampton and to/from the port of Immingham. Freightliner and DB Cargo have the largest portions of the total number of terminals in the UK.[26] In the UK, for goods movement via rail, timetabled services set by rail operators run between rail freight terminals, and between terminals and ports. Freight forwarders work with the rail freight operators to aggregate loads to optimise them and keep costs down.

There are 11 clearly defined rail freight corridors in Europe connecting major economic centres, ports and logistics hubs in different European countries.[27] DB Cargo is the biggest rail freight company in Europe by a significant margin while Germany, Poland and France move the highest volume of rail freight.[28] Rail mode share has changed minimally across Europe over the past two decades, but the EU's Sustainable and Smart Mobility strategy aims to increase rail freight traffic by 50% by 2030, and double it by 2050.[29]



Rail Baltica

Europe

Rail Baltica aims to improve freight connections between the Baltic states and Western Europe through the construction of an 870km continuous rail link connecting five countries and five capital cities.

The cost of the project is expected to be around €5.8 billion with significant funding coming from the EU and the rest coming from the governments of Estonia, Latvia and Lithuania as well as private investment.

The railway will be fully electric and will be built to integrate with three new intermodal terminals in each of the Baltic states.[30]

1.2 Rail freight

1.2.2 Opportunities and constraints

High rail freight transport activity is normally related to the existence of large landlocked resources that can be effectively exploited if traded widely and often over long distances and at high volumes.

The capacity of one freight train on the Great Britain (GB – England, Scotland and Wales) rail network can be equivalent to that of 76 HGVs[31] (freight trains in other parts of the world tend to be substantially larger) and rail freight does not cause the sort of congestion and pollution in urban centres that road freight does. Due to the carbon intensity of road transport, the EU has a goal to shift 30% of transport over distances of 300 km to low carbon modes.[32]

To estimate the potential of shifting road freight to rail, the EU takes the percentage of road tonne-km that travels a distance greater than 300 km and, due to rail's effectiveness over large distances, assumes that these are trips that have the potential to shift modes. In 2021, 41.8% of the EU's road transport fits this criteria and could shift to rail compared to 34.1% in 2019 the UK (no data beyond 2019 due to the UK's exit from the EU).[33]

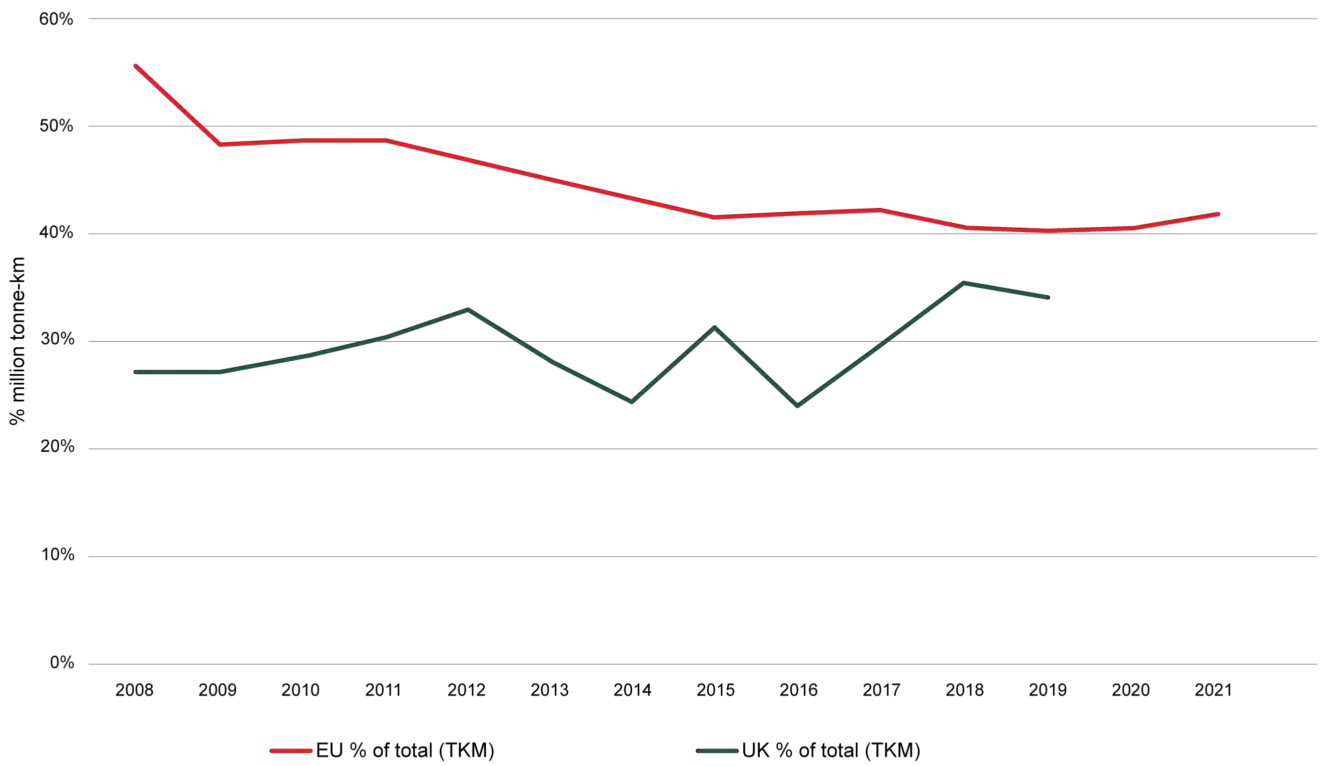


Figure 5
Modal Shift Potential of Road Freight to Rail in the EU and UK from 2008 to 2021[34]

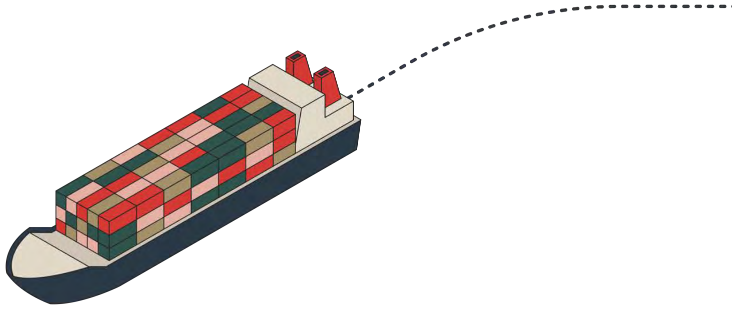
1.2 Rail freight

1.2.2 Opportunities and constraints *continued*

Rail is likely to continue to have a key role in transporting bulk goods and raw materials along with considerable opportunities in the transfer of containers between ports and logistics hubs via intermodal trains. While the inherent strengths of rail freight give it clear advantages in certain market segments, there are numerous constraints that currently prevent rail freight from being competitive in broader market areas. Some specific challenges with expanding rail freight in the UK and EU include:

- 92% of the GB rail network is shared by freight and passenger trains, and historically passenger services have had greater political priority, as greater benefits are seen locally due to passenger service. This has meant that where the network is constrained in capacity, freight services may be reduced or compromised.
- Rail freight services are provided in response to demand, rather than being timetabled in advance of demand like passenger rail services. This prevents private industry from considering the role of rail to transport goods at a scale beyond its current function (which is relatively small).
- A key challenge for rail is the need for extensive infrastructure along its line of route that is not generally adaptable to major change. Accompanying infrastructure along the rail network which is capable of handling large volumes of goods is expensive and a potential stumbling block to the competitiveness of rail. Warehouses and intermodal facilities need to be built in areas where the railways expand and need to be expanded along the existing rail freight network to increase handling capacity.
- The UK lags behind its European counterparts when it comes to rail freight electrification with only 10% of British freight trains hauled by electric locomotives,[35] partly due to electrification gaps in the rail network. Investment in electrification is needed to aid in the decarbonisation of rail freight and would have the added benefit of decarbonising any passenger services that share the same track.[36]
- Due to track access charges, which make up a large percentage of the costs borne by the rail freight customer, rail is typically more expensive than road transport of goods.
- Track and loading gauge varies between countries, preventing the rail network from being seamlessly integrated across borders. The independent development of railway systems in different countries has led to the adoption of a variety of track gauges (i.e., the spacing between rails), power systems (using alternating or direct current and voltage) and signalling conventions. This is especially relevant in Europe and the Eurasian corridors, where, at switch of gauge locations, cars must exchange their bogies for the different sized tracks. If this is not possible, goods are transferred from one train to another – adding time and cost to the journey. Even where track gauge is the same, the loading gauge (the size and shape of the train's profile) varies, further complicating interoperability.
- As well as the issues around different gauging, signalling and electrification systems, cross-border rail transport in Europe suffers from the fact that countries' timetables are often built up independently and without consultation with neighbouring countries to ensure that paths are available without significant border delays.
- A lot of rail freight's potential comes from its relatively lower environmental impact compared to road driving and a widespread ambition for modal shift towards rail. However, road freight is decarbonising and is expected to gain a cost advantage of around 20 – 30 % by 2050 thanks to technological advancements, meaning that rail will need to match or better these savings to remain competitive.[37]

Due to the constraints above, road freight continues to enable greater flexibility in freight operations, as it requires far less advanced planning and coordination.



1.3 Shipping freight

1.3.1 Context

Shipping is the primary mode of transportation for international trade, with sea freight carrying more than 80% of the international commodity trade by volume and over 70% of global trade by value.[38] There are significant differences in world trade of commodities: most countries are either large net importers or large net exporters. As a result of this imbalance, research suggests that at any point in time, around 42% of ships are traveling without cargo.[39] Shipping companies demand a premium to travel towards a destination with low exports, to compensate for the difficulty of finding new cargo there.

The global fleet of ships that carries seaborne trade is made up of dry bulk ships, container ships and oil tankers. The different types of vessels tend to be used for transporting distinct types of products. The fleet can be divided into two categories: those that operate on fixed routes and those that operate on flexible routes. Containerships tend to operate on fixed routes, while gas/oil tankers and dry bulk ships operate on flexible routes. Dry bulk ships account for about half of seaborne trade and 45% of the total world fleet,[40] and are the main mode of transportation for commodities, such as grain, ore, and coal.

The UK ports sector is the largest in Europe, in terms of tonnage handled.[41] The ports sector in the UK operates on commercial principles, independently of government, and largely without public subsidy. The private sector operates 15 of the largest 20 ports by tonnage and around 80% of the UK's port traffic.[42] Goods are typically moved from ports by road and/or rail to National Distribution Centres (NDCs) which act as medium-term storage (average 4–6 weeks) for international and domestically sourced goods. Regional Distribution Centres (RDCs) redistribute goods to retail outlets and direct to homes and typically have much shorter dwell times – distribution frequently takes place within 24 hours.

While the entire UK ports sector is the largest in Europe, all of the top 25 busiest ports in Europe are located on Continental Europe.[43] These ports are strategically located and act as vital gateways to the rest of the world. Their importance is highlighted by the fact that 74% of goods entering or leaving Europe travel by sea.[44] The governance structure of ports in the EU can vary. Some ports are owned and operated by private companies, but the vast majority are in public ownership, especially since the UK left the EU when the share of public ownership in European seaports rose from 87% to 93%.[45] European ports can also feature a mix of public and private ownership, as is the case with the Port of Antwerp, the second busiest in Europe, which is owned by the Antwerp Port Authority but operated by various private companies that provide terminal and other services.

Seine-Scheldt Inland Waterway Project

Europe

The Seine-Scheldt Inland Waterway Project is one mega inland waterway freight infrastructure project currently underway in Europe. The basins of the Seine and Scheldt rivers are two of Europe's most important industrial regions, but there is currently no way for large container ships to navigate them. The project aims to open up new freight corridors between Le Havre, Paris, Dunkerque, Antwerp, Liège and Rotterdam by creating a 1,100 km network of wide gauge waterways and building a 107 km canal connecting the Seine and the Scheldt. The project is set to be complete in 2030 making the waterways navigable for vessels of up to 4,500 tonnes. The project has primarily been endorsed and supported on the prospect of reducing road congestion and emissions and promoting sustainable freight.[46]

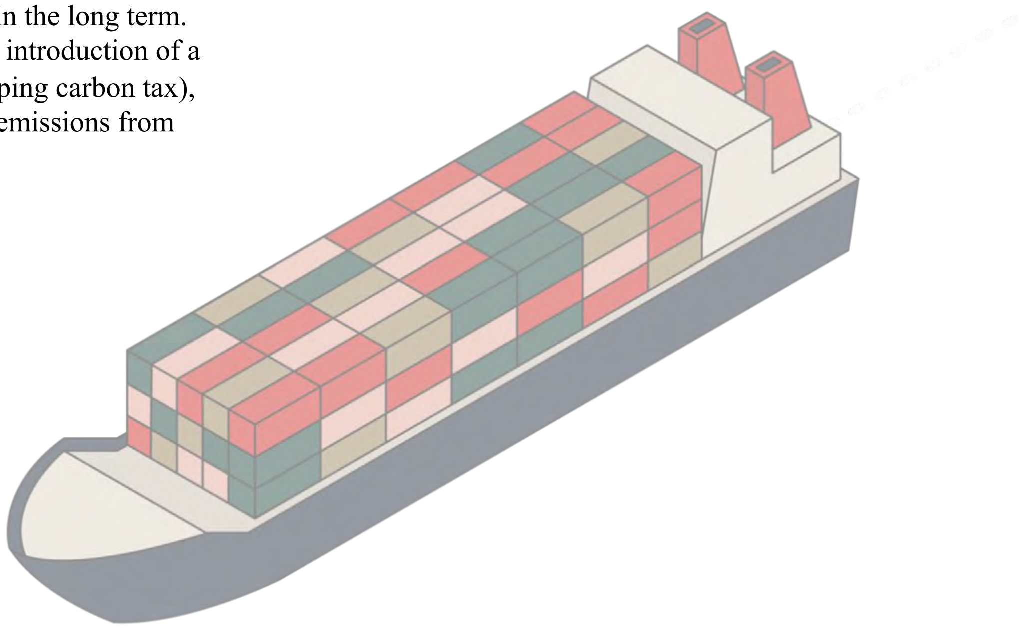
1.3 Shipping freight

1.3.2 Opportunities and constraints

Studies suggest increased transport costs or longer shipping times in the context of a carbon tax on shipping may drive a modal shift from maritime to rail or road transport, especially in the case of trade in valuable or perishable goods. Recent research has shown that close to $2 trillion of global investment is required to decarbonise shipping, and around 85% of this cost is related to landside infrastructure and production facilities for future fuels.[47]

With the growth of trade activities, decarbonisation of shipping has become an ongoing concern for the maritime industry, even though shipping is often considered to be the most energy-efficient way to transport large quantities of goods. Technical and operational measures approved in recent years at the International Maritime Organisation (IMO) are not perceived to be sufficient to curb greenhouse gas emissions from international shipping in the long term. As a result, the IMO is considering the introduction of a market-based measure (the global shipping carbon tax), which would be paid based on carbon emissions from ships in global trade.[48]

The resilience of ports to disruptions and climate hazards is also increasingly crucial and gaining recognition from the shipping and freight industry. The short planning cycles for port infrastructure (typically five to ten years) constrains proper consideration of long-term resilience over the life of the infrastructure (typically 30 to 50 years). There is some degree of oversight in the wider industry regarding the return on investment on the expenditure related to planning and building in physical and operational resilience.



1.4 Air freight

1.4.1 Context

Air freight is a highly specialised sector of the freight industry, which handles relatively low volumes of high value freight. While air freight forms a very small percentage of the overall freight market when measured in terms of tonnes-lifted, it forms a much larger proportion when measured by the value of the cargo lifted. Air cargo moves around $6 trillion worth of goods every year, accounting for nearly 35% of global trade by value.[49] Goods shipped by air have high values per unit or are very time-sensitive, such as documents, medical supplies, production samples, inputs to meet just-in-time production, emergency shipments of spare parts, electronics, perishables, etc. These specific goods are continuously transported by air due to the security, speed, and reliability of air transport.

It has been estimated that, by value, air freight accounts for around 40% of the UK's imports and exports.[50] Heathrow is the most important airport in the UK in terms of freight, with 1.59 million tonnes handled annually compared to 0.34 million tonnes from its nearest competitor.[51] For perspective, the UK's busiest ports (London and Grimsby & Immingham) both handle over 60 million metric tonnes of freight annually.[52] Heathrow ranks fourth in terms of the busiest cargo airports in Europe, with Frankfurt, Paris-Charles De Gaulle and Schiphol respectively recording 2.30,[53] 2.03,[54] and 1.67[55] million tonnes annually. Within these figures, the majority of air freight is carried on passenger flights in the belly hold rather than cargo-only flights meaning that, to a certain extent, cargo is subsidising air travel for passengers and passengers are subsidising air cargo for shippers.

In the UK, the major players are British Airways, DHL and Virgin Atlantic with a combined market share of 79% (36.4%, 30% and 12.6% respectively).[56] In Europe, the flag carriers of the busiest air cargo airports are unsurprisingly major market players, with Lufthansa and Air France-KLM having the largest cargo volumes in the EU.[57] Many low-cost airlines have developed business models that do not cater for cargo to be carried on board as it adds weight and loading time. For this reason, airports that mainly serve low-cost airlines see far less cargo and may not even feature any cargo processing facilities.

Global air cargo traffic is forecast to grow by 4.1% per year over the next two decades, with a significant proportion of that growth being focused within East Asia.[58] This is driven by China's enormous e-commerce market which is by far the biggest in the world. E-commerce revenue in China sits at $2,029 billion a year compared to $960 billion in the United States and $496 billion in the EU. Air freight is well suited to the requirements of e-commerce due to its speed, global reach and reliability.

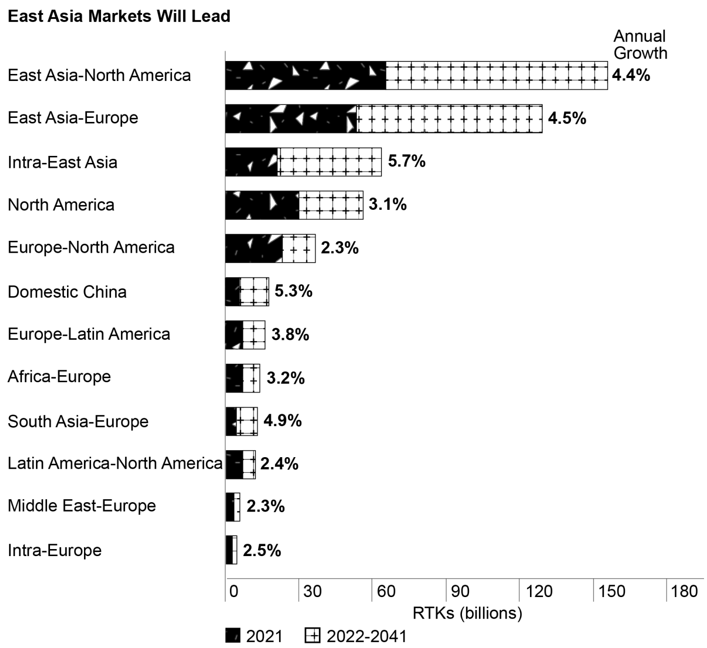


Figure 6
World Air Cargo Traffic Flows Forecast 2022-2041[59]

1.4 Air freight

1.4.2 Opportunities and constraints

During the COVID-19 pandemic, air freight played a crucial role in maintaining the global supply chain and ensuring that essential goods such as medical equipment, personal protective equipment (PPE), and food supplies were delivered quickly and efficiently around the world. While traditional shipping methods were disrupted and borders were closed, the aviation industry converted passenger aircraft to carry vital goods resulting in air cargo only seeing a 21% reduction in a time where passenger volumes dropped by 75%.[60] While this represented a success for the air freight sector, it also highlighted the importance of diversifying supply chains and investing in resilient logistics systems to better prepare for future crises.

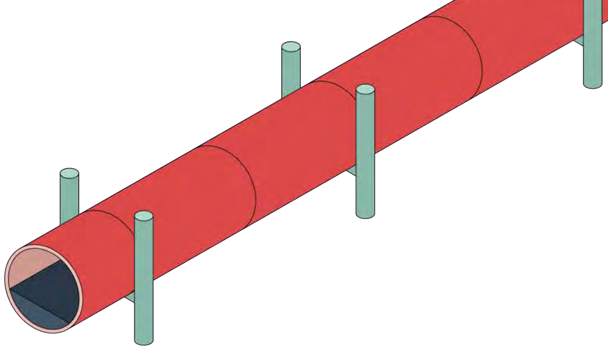
Since the advantage of air freight is much shorter transit times, cargo must move quickly through an airport – requiring significant coordination between the private sector operating goods movement to and from airports, and airports themselves. The future of goods movement by air is heavily dependent on the wider future of aviation – the demand for passenger travel, green aviation fuels to reduce the carbon cost of air transport, and future aircraft to accommodate different types of goods. Ultimately, the use of air transport for freight is likely to continue to be limited by the price, which is often several times higher than for transporting the same volume of goods by sea, road, or rail. Due to this fact, commodities shipped by air are those which have high values per unit or are very time-sensitive. A continued growth in e-commerce could contribute to a rise in the air freight sector with online shopping increasing the demand for fast and reliable shipping.

One way the air cargo industry could absorb and encourage even more growth from e-commerce in the future would be through implementing new disruptive technologies at scale, for example the development of pilotless drones.

Zipline

Rwanda & Ghana

Zipline is a logistics company that specializes in the delivery of medical supplies and blood products using unmanned aerial vehicles (UAVs), commonly known as drones. The company operates in Africa, specifically in Rwanda and Ghana, where it provides on-demand and scheduled delivery services to hospitals and health facilities in remote and hard-to-reach areas. This has revolutionised the transport of time sensitive products and has shortened blood product delivery times by 61% in Rwanda. Zipline has succeeded in a space where others have failed with other notable attempts at delivery drones being abandoned such as DHLs 'Parcelcopter'.[61]



1.5 Pipelines

1.5.1 Context

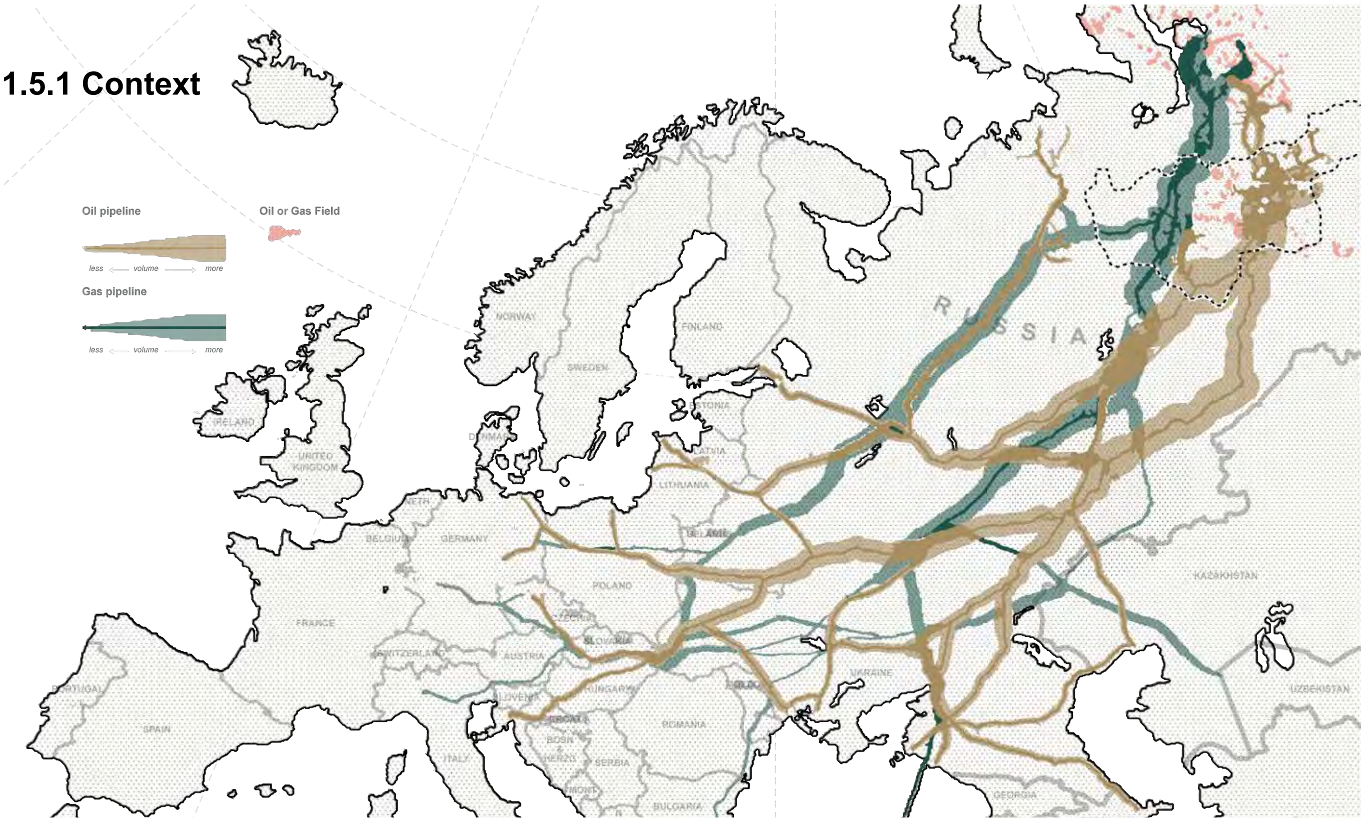


Figure 7
Oil and Gas Pipelines from Russia to Europe[66]

Pipeline infrastructure can be used to move a variety of liquids and gasses and plays a critical role in the oil and gas industry. As discussed in previous sections, each mode of freight transportation has its own unique set of strengths and weaknesses which define its suitability to move specific commodities. Pipelines are perfectly suited to the job of moving liquid or gaseous goods and can, in one day, move the equivalent amount of liquid petroleum as 750 tanker trucks or a train of 225, 28,000-gallon tank cars[62].

While there are no exact figures, one estimate suggests that in 2022 there were over 4,000 operational pipelines globally, covering a combined distance of more than 2 million km – enough to circle the Earth 50 times.[63] Over half of these pipelines (51%) are situated in North America where pipelines deliver trillions of cubic feet of natural gas and hundreds of billions of ton/miles of oil every year[64]. The EU is a net importer of both oil and gas, importing around 88% of its crude oil and around 56% of its natural gas consumption from key sources in Russia, Norway, Algeria and Qatar[65]. Being a net importer, the network of oil and gas pipelines in the region, making up around a quarter of the global length of pipelines, are crucial to the energy market.

Pipelines are intrinsically tied to oil and gas supply and demand. From the underground reservoirs from which they are extracted, to the refineries or processing facilities, to the distribution centre and on to the end user, pipelines are part of the entire life cycle. Since oil and gas only exist as resources within certain regions of the world, pipelines also play a critical role in managing price differentials between regions. For example, if there is an oversupply of oil in one region, the price may be lower than in another region where there is a shortage of oil. Pipelines can transport the oil from the oversupplied region to the undersupplied region, thereby reducing the price differential between the two regions.

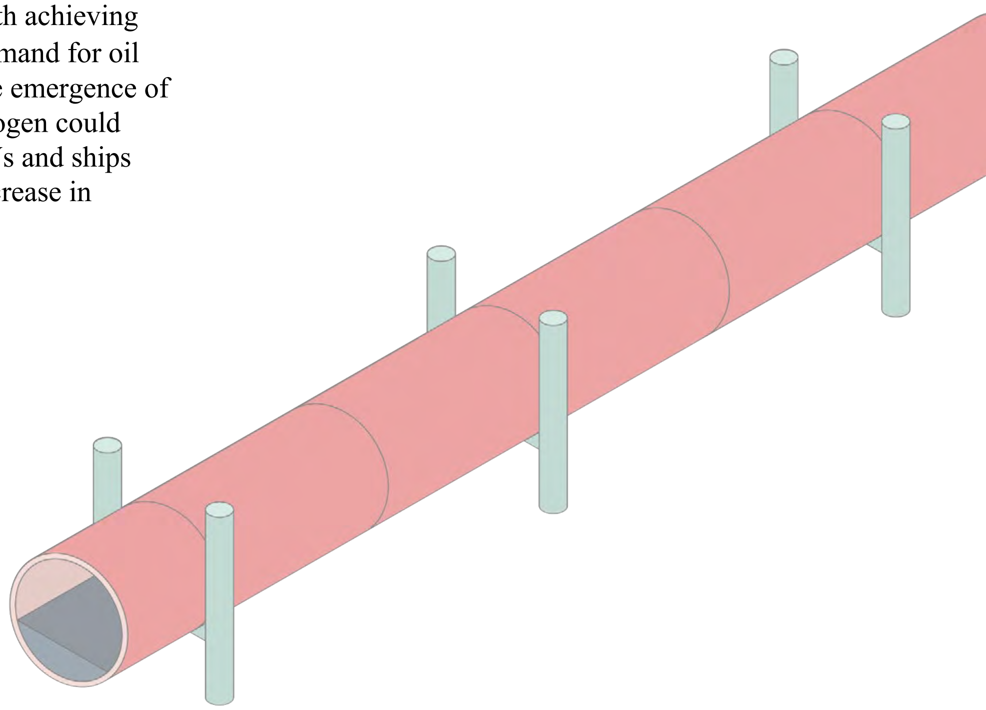
1.5 Pipelines

1.5.1 Opportunities and constraints

While forecasting demand for oil and gas is greatly dependant on what path to net zero is taken, there are no forecasts that suggest that demand for these resources is going away any time soon. The World Energy Outlook from the International Energy Agency (IEA) predicts that oil demand is expected to rise from 97.9 million barrels per day (mb/d) in 2019 to 104.1 mb/d in 2040, an increase of 6.2 mb/d or 6.3%.[67] Natural gas demand is also expected to increase, rising by 1.3% per year on average through 2040.[68]

However, the report also notes that these projections are based on a 'Stated Policies Scenario' where it assumes countries keep to their currently announced targets and intentions for reducing greenhouse gas emissions. If more ambitious climate policies are implemented, such as those consistent with achieving the goals of the Paris Agreement, then demand for oil and gas could start to decline instead. The emergence of new less energy dense fuels such as hydrogen could create new demand for pipelines, as HGVs and ships struggle to accommodate the resulting increase in capacity required to transport these fuels.

Risks associated with reliance on pipelines for access to critical energy sources will need to be managed in a more politically unstable future. In 2022, a natural gas pipeline gave us a clear example of how an important freight infrastructure link can be weaponised during times of political instability when the Nord Stream pipeline was sabotaged. A series of bombings occurred on two pipelines that had supplied the European Union with natural gas from Russia in the wake of tensions resulting from the Russian invasion of Ukraine.



1.6 Understanding the freight system

1.6.1 Unaddressed challenges

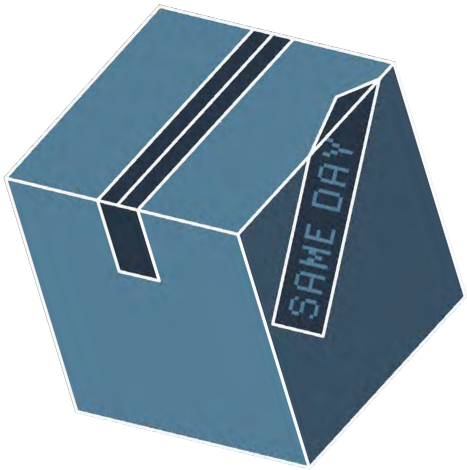
The world around us is rapidly changing. We are at the onset of what is often called the 'fourth industrial revolution', a time characterised by huge leaps in technological innovation representing a fundamental change in the way we live, work, consume, and interact with others. The climate crisis and the need to decarbonise and rethink all aspects of our consumption, industry and production arguably represents the biggest challenge the world has ever faced. Consumer demand is constantly shifting, meaning that private sector retailers and manufacturers have to be agile to respond to the need for different goods. Beyond this, there are political, economic, environmental and social pressures at play and, as a result, a wide range of stakeholders competing on what we consume, where our goods come from and how they should be moved. With demand for freight transport projected to grow at an annual rate of around 3%,[69] it is critical that the future of the industry is carefully considered with a greater degree of strategic planning and investment.

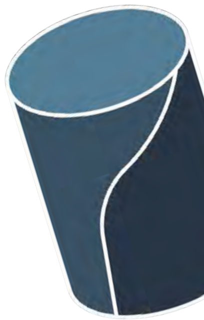
A systemwide perspective is critical to ensure the interests of individual stakeholders for a single mode and across modes are aligned and balanced to optimise the overall network's functionality, efficiency, and resilience, and to limit negative impacts such as congestion, emissions, and unproductive use of land. Systemwide planning and monitoring likely has to be government-led, as it is in the government's main interest to ensure the overall freight network is reliable and functional in the face of disruptions.

The freight system is responsible for giving us all access to the key resources we depend on to support our livelihoods. In assessing future constraints which demand greater resilience, efficiency, and agility, today's freight systems need strategic rethinking in order to reliably maintain core functionality of cities and regions in the face of unexpected events, to enable economic prosperity, and to chart a sustainable and timely path to a net zero world.

2

Future drivers of change





2 Future drivers of change

2.0.1. Overview

The future of goods movement will be driven by what we consume, where goods and services are needed and coming from, and how access to those goods and services is enabled. All of these factors are undergoing major change, which is why it is important to understand how contextual transformations will impact today's freight system. Shifts in terms of the demand for different types of goods, the constraints and pressures on the freight system, and market trends and changing stakeholder expectations and priorities will impact the existing goods movement network both at the global and regional scale. In studying the wider social, technological, economic, environmental, and political trends on the horizon today, we argue that five major shifts will have a core impact on how goods move in the future (right):

Consideration of these five key changes should be integral to forward planning and future freight infrastructure investment and policy. Each of the key disruptions highlighted above encompass a number of different emerging trends that will be influential in the future of freight. These major shifts and the collective uncertainties and changes they pose to the future of freight are described and outlined in this section. The fifth shift, centred on the energy transition, is closely related to the first shift, the need to achieve net-zero emissions and reduce overconsumption and waste. We focus on energy and materials separately due to the direct implications this will have for the goods and volumes which need to be transported in the future.

1

The transition to net zero emissions and the need to transform management of overconsumption and waste

2

The need to prioritise resilience against growing environmental, social, and economic risks

3

The changing nature of global economic power and the role of different nations in consumption and production

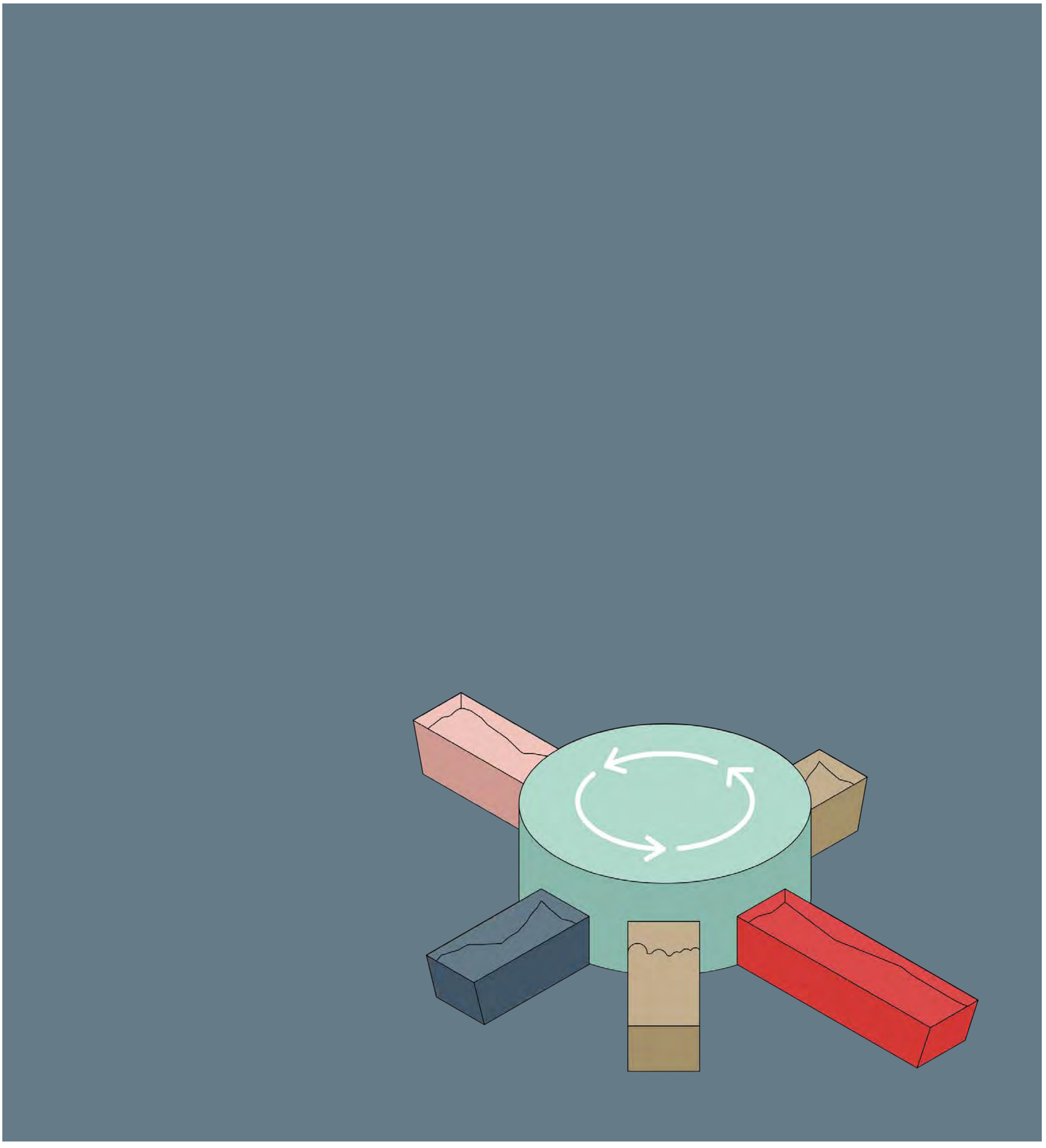
4

New technology and innovation in supply chains, consumer preferences and retail business models

5

The energy and industrial materials transition

2.1 Net zero and managing overconsumption and waste



2.1 Net zero and managing overconsumption and waste

Context

Climate change is having an irreversible impact on the earth, and the need to get to net zero is widely acknowledged by all major countries worldwide. The net zero agenda poses fundamental shifts for the movement of goods. Actions to meet net zero targets will affect how goods move (the infrastructure, systems, and technology), where goods come from and are taken to, and what is transported.

The major changes which will affect the movement of goods due to the need to get to net zero emissions globally include:

The onset of a more circular economy globally

The net zero agenda requires every sector of the global economy – including energy, industry, agriculture, transport, and construction to decarbonise significantly. The idea of a circular economy – a concept that directly rethinks consumption of materials and resources – aims to transition the global economy from a 'take-make-waste' linear model to a model which is inherently regenerative. This is an essential element of achieving net zero given the carbon intensity of extracting and refining raw materials. A shift to net zero will mean prioritising reuse, repair, design and manufacturing practices which maximise product life, and continually recycling materials and products to eliminate waste. The resources and materials which feed into industry and markets, where they come from, and how they are transported are positioned to fundamentally shift as a response to this transformation towards a low-carbon and circular world.

2.1 Net zero and managing overconsumption and waste

Changing consumer preferences and increasing environmental awareness

The urgency around environmental degradation is growing. Individuals are becoming more conscious of their impact on the environment and how their personal choices can influence companies. A survey across 60 countries found that 55% of online consumers consider a company's environmental and social commitments when deciding where to shop and will accept higher prices for sustainable products.[70] Another recent survey showed that 32% of people were willing to pay more for a sustainable product.[71] As part of an effort to better inform consumers who are increasingly conscious of their choices, governments could mandate that all goods come with a carbon impact figure (much like nutritional information on food today). In the absence of government or regulatory action, greater tracking and reporting is still being increasingly implemented by businesses seeking to demonstrate their environmental credentials. Over time, this will have an increasing impact in encouraging consumers (from the individual to entire industries) to select products and make decisions with a smaller carbon impact and for firms to be more conscious of their carbon footprints.

Environmental impact reporting and carbon taxation

A future where environmental impact is measured and associated with higher costs is emerging and arguably an inevitable component of a netzero carbon world. Different forms of environmental taxation are already in place across the world, covering externalities relating to everything from energy to transport, resources to waste and pollution. According to the World Bank, 23% of global greenhouse gas emissions are already covered by a large number of different carbon pricing schemes.[72] However, carbon prices are currently considered too low to have a major impact. A more powerful worldwide carbon tax scheme on imports could have a major impact on where goods are produced, and how they are transported, consumed, and handled at the end of their life. Many environmental economists argue that this is one of the most powerful and effective actions which could be taken to combat greenhouse gas emissions.

2.1 Net zero and managing overconsumption and waste

Implications for Goods Movement

Expectations on how long people are willing to wait for goods and associated costs can change

If people are willing to wait longer for goods this could ease pressure on supply chains or even transform them. A larger proportion of the population may begin to demand locally sourced goods and avoid environmentally damaging goods. For goods whose carbon impact is significantly driven by transport, this could lead to a change the average distances of freight travelled and a strong market preference towards low-carbon transport.

The things we consume and what we need to transport will drastically change

Energy resources, food, waste, construction materials, product components – essentially all goods on the market today, will flow under a different model in a circular future. Volumes may change because consumption will need to be managed to minimise (or eliminate) waste. Materials may be sourced locally (within the boundaries of a single nation), and come from 'central repositories' (which manage recycled materials) rather than extracted from select parts of the earth and distributed globally.

The transport sector must chart a way to meet net zero targets. Freight decarbonisation will be key to a net zero pathway for the sector.[75]

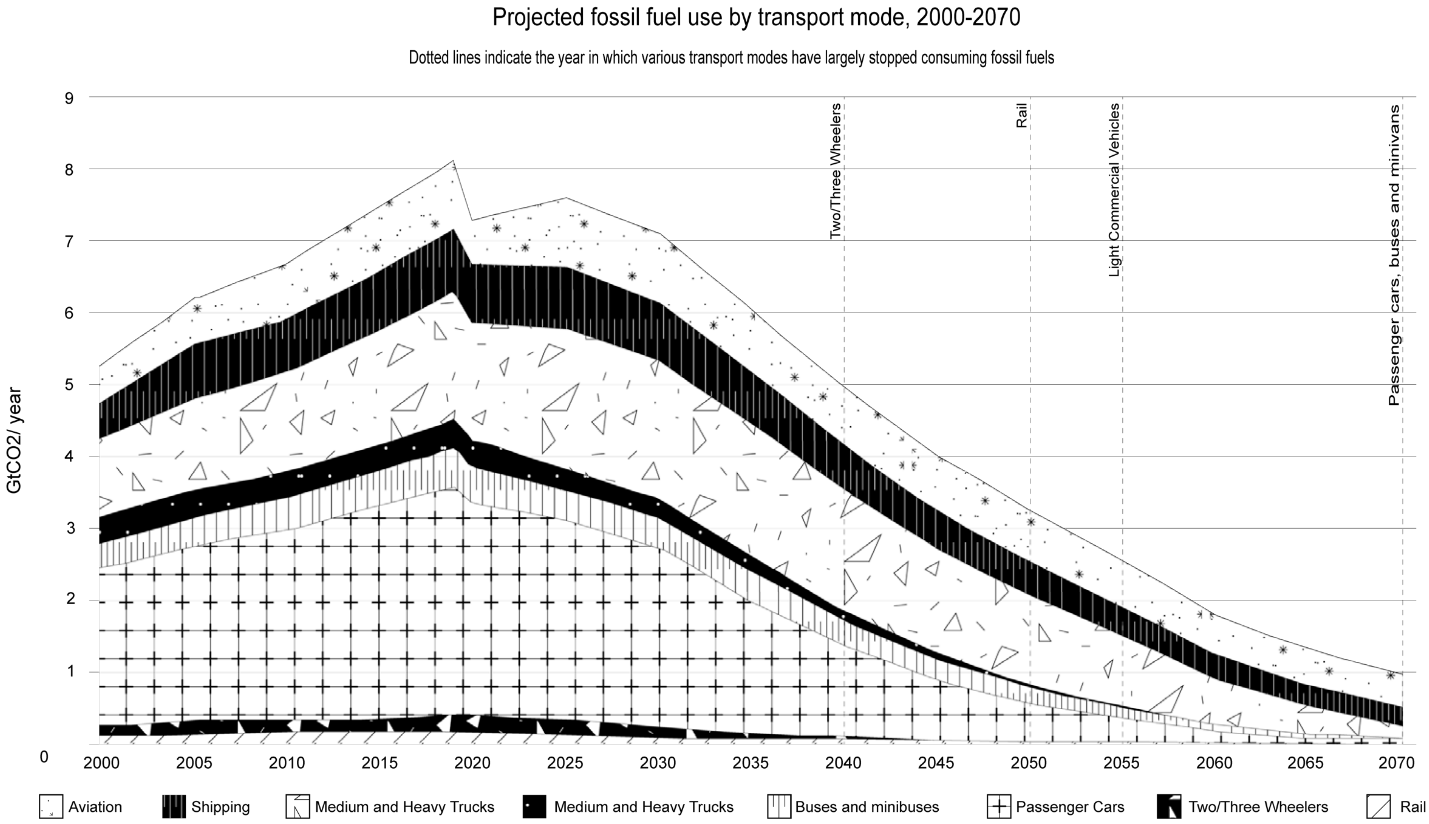


Figure 8
Previous and projected fossil fuel consumption by transport mode, 2000-2070 (International Energy Agency)

2.1 Net zero and managing overconsumption and waste

Implications for Goods Movement

Pressure on decreasing transport related carbon will increase

A powerful carbon pricing scheme could shift the distribution of manufacturing and consumption – potentially affecting where goods flow to and from. Cost advantages have historically led multinational firms to move labour-intensive manufacturing operations to regions of the world with access to cheaper labour to reduce costs. In the US, declining domestic manufacturing activity coincided with increasing shares of US imports of manufactured goods from low-income countries,[73] and foreign material inputs to US industries expanded by almost 50% between 1997 and 2007.[74] It is likely that in the future where transport of a good makes up a significant proportion of environmental impact, businesses will again try to find less damaging forms of transport and/or change routes or locations of industrial activity.

Demand for more discretionary goods which become more expensive as a result of these policies would also fall, reducing the volumes that need to be transported.

2.2 Resilience

2.2 Resilience

Context

The increasing recognition of the need for resilience under unexpected and disruptive circumstances has been brought into focus with the recent COVID-19 pandemic and the Russia-Ukraine War. Climate change is already increasing the observed frequency of extreme weather events and natural disasters. With increasing political, environmental, and economic strains, nations are beginning to prioritise the need for resilient, steady, and secure access to critical goods for the wellbeing of their populations and economies. Key changes to prioritise resilience which will lead to major shifts in the movement of goods include:

Rethinking the race towards supply chain optimisation

Until recently, optimisation of efficiency and cost was the key driver shaping supply chains globally. This was made possible with the diminished barriers to trade, technological innovation, and the rise of Asia as a centre of global production. In recent times, highly disruptive events such as the COVID-19 pandemic, the war in Ukraine, Brexit, or the US-China trade war have all highlighted the importance of building in and prioritising supply chain resilience. Surveys suggest just one lengthy shock can wipe out 30% to 50% of annual earnings for businesses.[76]

Companies are now starting to think about diversifying their sourcing or manufacturing bases, obtaining a greater degree of transparency across their supply chains, and embedding in redundancies – stockpiling, finding identifying alternative pathways for sourcing, processing, and transporting.

2.2 Resilience

Increased frequency of natural disasters and extreme events due to climate change

One of the most destructive results of global climate change is the resulting increase in the frequency and severity of natural disasters. Natural disasters can either be of low intensity and occur frequently, or they can be one-off catastrophic events. Flooding and storms make up the vast majority of global natural disasters which have occurred since 1990. In the US in the 1980s there were on average three natural disasters per year that caused damage of over $1 billion. This number has risen so quickly that in 2021 alone there were 20 such disasters.[77] These events endanger lives and carry huge financial implications and economic losses – reducing investment in critical regions due to the risk to infrastructure and changing the perception of the reliability and vitality of economic centres in high-risk areas in the future.

Photo Credit: Kyle Miller/Wyoming Hotshots/USFS

More protectionism, stronger close-knit trade coalitions, and a little less globalisation

The future world will sit on some balance between localism and globalisation. Strategically important nations may give into rising authoritarianism as a reaction to addressing unmet, overlooked local needs and demands. Identity and outlook of global platforms and alliances may be subject to a higher degree of variation. A rise in international warfare could lead to conflicting countries further blocking trade and the movement of goods across their borders. The war in Ukraine has brought this risk of escalating conflict into the spotlight within the West, but a global scan of political conflict shows that instability is an almost constant state of affairs in the world.[78] The risk of escalated conflict is potentially worsening due to the stresses sharpened by climate change and growing economic inequality. Conflicts are wide ranging and include civil war, criminal violence, sectarian violence, territorial disputes, and transnational terrorism.

2.2 Resilience

Implications for Goods Movement

Priority corridors for trade and goods movement will emerge and look different from those we see today

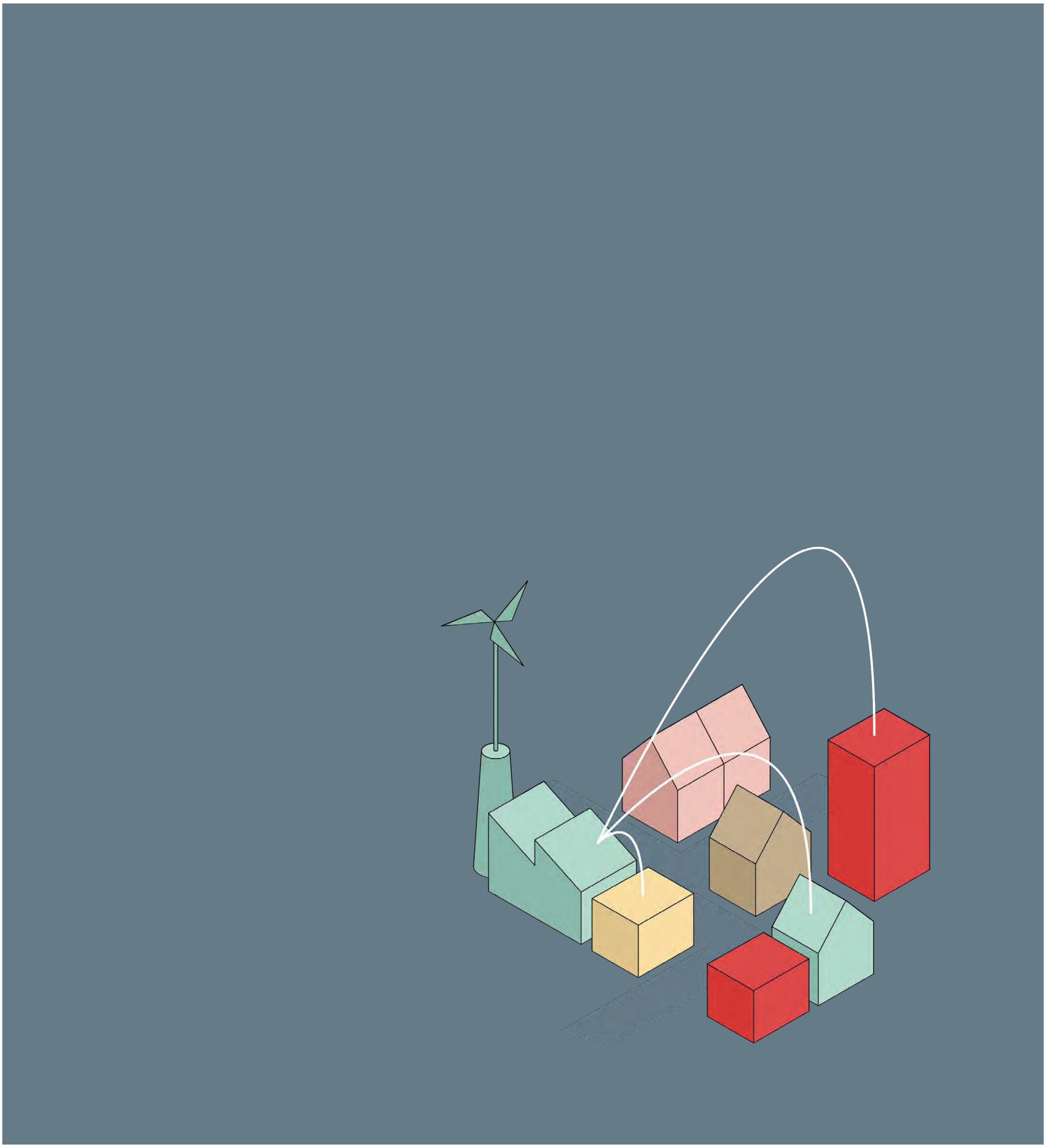
In a world with increased conflict and/or nationalism, countries may look to consolidate production activities more locally or ensure that they trade more exclusively with countries with which they have strong relationships. A higher preference for sourcing services/goods from regions which are closer or perceived to be more economically stable could significantly shift the origin and destination of goods. As an example, US tariffs on Chinese imports resulting from the US-China trade war, coupled with China's retaliation measures in September 2018, targeted almost half of China's bilateral trade with the United States. As a result, around 12% of total US and 8% of total Chinese goods trade was estimated to have been impacted.[79]

The types and volumes of goods requiring transport domestically and internationally may look very different in the future if new local industries begin to absorb activity that was previously administered overseas – implying a rethinking and reassessment of strategic corridors and infrastructure requirements within and across nations. More broadly, strategic goods corridors and supply chains (and reliable alternatives during times of unexpected disruptions) will need to be clearly identified and prioritised for investment. This will ensure key trade routes and access to critical goods are more resilient and reliable in the face of increased risk of conflict and economic disruption.

Redundancy in operational routes, storage for critical goods, and systematic management of risk and resilience for key goods movement corridors will gain greater importance

Increased frequency and likelihood of major disruptions – whether social, economic, or environmental – will create greater pressure in the freight industry to systematically anticipate, manage, and respond to risks to major freight routes which provide access to critical goods. There will be a greater focus on identifying alternative routes and creating redundancies for critical infrastructure to ensure core operations and access to goods in disruptive circumstances. Stockpiling and storing essential goods (where possible) will gain importance to buffer against sudden operational closures or disruptions. The location of storage facilities will need to be planned to ensure trips to and from storage, to processing and to end destinations can be made efficiently and with minimal environmental impact. Addressing system vulnerabilities and volatility may also require a push for greater innovation and the application of technology and artificial intelligence in managing freight networks and to preserve network integrity. As an example, the shortage of HGV drivers in the UK post-pandemic caused major disruption to supply chains and led to fuel shortages and price increases. Such labour shortages and disruptions over the long-term could lead to shifts to autonomous vehicles and operations in the freight and logistics sectors.

2.3 Role of different nations in manufacturing and consumption



2.3 Role of different nations in manufacturing and consumption

Context

The spread of economic and political power globally is changing, alongside lifestyle choices of populations across the world. The global push to net zero emissions, the advancement in technology and data, rising incomes coupled with rapid growth in the East and Global South, will all disrupt and transform the distribution of manufacturing, trade, and consumption across geographic regions.

The rise and power of emerging economies

Emerging economies such as China, Indonesia, Singapore, and more have accounted for almost two-thirds of the world's GDP growth and more than half of new consumption over the past 15 years. The OECD has projected GDP growth to 2060 and the top five countries are all located in either Asia or Africa. India (324%), Indonesia (254%), South Africa (194%), Turkey (172%) and Israel (169%) are forecast to grow the most between 2022 and 2060.[81] While countries like the US, UK, Germany and Japan will remain some the world's largest economies, growth is forecast to slow down. Of the additional 2 billion people who may be added to the global population between 2019 and 2050, 52% could be in countries of Sub-Saharan Africa. Another 25% of global population growth is expected to be concentrated in Central and Southern Asia.[82] Rapid growth, economic and urban development could imply a change in the global roles and relationship between the East, South and the West, particularly in terms of investment, production, and consumption.

2.3 Role of different nations in manufacturing and consumption

Changing distribution of foreign investment

The influence of foreign direct investment (FDI) in the world economy is growing – rising from 22% in the early 2000s to accounting for 35% of global GDP in 2018.[83] While the US is currently the top destination for the world's FDI, there has been a continual shift in the global FDI landscape, with emerging market economies (EMEs) playing a larger role both as a source of and as a destination for investment. EMEs have attracted a growing share of FDI flows, overtaking the EU in 2008, and in 2013 accounting for more than 50% of the world's total inward FDI. UK investment in Africa has risen 61% since 2008 while its investment in Europe has dropped 20% in the same period.[84] In addition to ease of doing business (finance, trade regulation, permitting), experts say FDI is driven by four main factors: (i) markets; (ii) assets; (iii) natural resources; and (iv) efficiency seeking.[85]

In the period between 2003 and 2016, distribution of FDI across sectors has stayed constant – 70% of international mergers and acquisitions (a major form of FDI) were in the services sector, followed by manufacturing (24%) and the primary raw materials/resources sector (6%). In the UK, investment in mining and quarrying has been falling dramatically over the last decade, while investment in engineering and vehicles has seen significant growth.[86]

Making things locally - reshoring

Reshoring is the reverse of offshoring - businesses return production and/or operations to the host country that had previously moved manufacturing and production to a foreign location. Two in five UK-based small businesses are considering a switch to UK manufacturers as rising shipping costs bite into margins and threaten growth, according to a survey of 750 firms by logistics platform ShipBob.[87] Offshoring of manufacturing in the late 20th century was mainly driven by cost economics, with labour being significantly cheaper in developing countries. Now, not only is the wage gap between countries closing, but manufacturing is also not as labour intensive as it once was with factories embracing automation. New technologies like automation and 3D printing are making it possible to set up local micro-factories and negating the need to outsource labour.

The COVID-19 pandemic has been another catalyst for reshoring, with strict lockdowns in China and other Asian countries necessitating a move for some manufacturers back to their home countries. There has also been evidence that increasing nationalistic movements and distrust between countries is leading to reshoring, as exemplified by the US trade war with China.

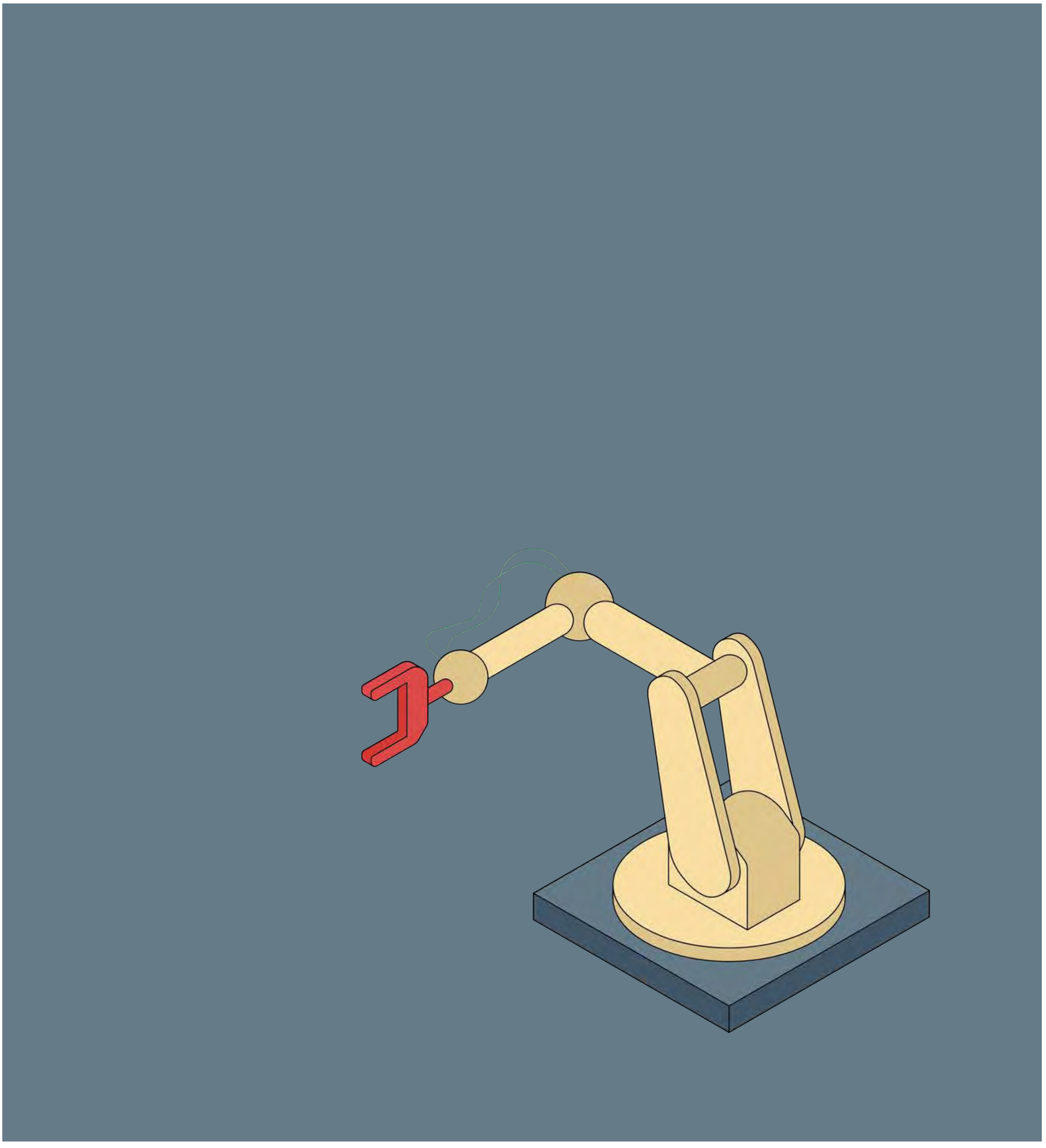
2.3 Role of different nations in manufacturing and consumption

Implications for Goods Movement

Patterns around where goods and services are produced and consumed are set to change from what we observe today.

A shift in where consumption takes place, where resources, labour, and technology are available, and where regulation and pricing is favourable to satisfy demand will reshape the primary movement of goods. The redistribution of production and distribution activities across the globe will change the key corridors across which the flow of goods takes place, giving rise to new major international and regional corridors for freight. Growing parts of the world in the East and South may account for more of the world's consumption and production – potentially making regional corridors more prominent than east to west corridors for trade. Rich countries may shift in the long-term to primarily following circular economy practices – re-using and re-circulating goods and materials already in the market to satisfy demand for consumer products, and therefore only trading long distances internationally for more limited segments of key goods. Studies looking at trade patterns of the future already predict corridors in Africa, Asia, and the Middle East are expected to rise from US $9 trillion in 2021 to US $14.4 trillion by 2030, surpassing global trade growth by nearly 4%.[88] South Asia is anticipated to be the fastest growing region for exports, characterised by robust ties with its neighbouring regions for trade. A recent free trade agreement between India, the UAE and Bangladesh envisions creating more than 100 special economic zones by 2030.[89]

2.4 Technology and changing business and consumption models



2.4 Technology and changing business and consumption models

Context

Technological innovation affecting everything from access to information which shapes decision making, operations, and consumption choices, to the actual devices and vehicles used to transport goods will continue to disrupt the movement of goods.

Increasing automation

The potential onset of artificial intelligence and robotics, combined with an ageing global population, could increase the likelihood of and accelerate the push towards automation. Advanced technology could be particularly transformational in managing risks and ensuring resilience of complex systems and networks such as the movement of goods across long distances. Automation of road or rail transport could significantly reduce operating costs associated with these modes – changing the competitive landscape between modes from a cost perspective. Optimisation enabled through automation of manufacturing and processing facilities could also shift the costs associated with different types of goods production and resulting market demand. The variation of automated operations across different regions could also change the cost competitiveness of production activities.

2.4 Technology and changing business and consumption models

Changing role of e-commerce

E-commerce is on the rise and has already disrupted logistics in major cities - it now accounts for between 16% and 20% of UK commerce by revenue, which is second only to China.[90] Rapid growth of e-commerce is facilitated by online payments becoming more secure, deliveries becoming faster, tailored marketing to consumers to maximise convenience, and a greater share of companies growing their digital presence. Initiatives like Cyber Monday see unprecedented levels of online shopping taking place – $10.8 billion were spent online in the US alone on November 30, 2020.[91] The COVID-19 pandemic has also driven demand for a shopping experience that can be undertaken safely at home, leading many people worldwide to try e-commerce for the first time.

From 'mass production' to 'mass personalisation'

There is speculation that industry is moving from a 'mass production' model – where more generic products suitable to the average consumer are made at high-volumes and mass distributed – towards a 'mass personalisation' model, where products can be personalised to meet individual customer preferences.[92] The continued growth in online purchases and richer consumer data available from digital platforms has given companies insights to tailor products and services to individuals. There is a strong desire for customisation of products, and some research says that businesses which do not incorporate an element of personalisation into their products and services will risk losing customers. A focus on personalisation also shifts consumer expectations around cost and service times. According to recent research, one in five consumers who expressed an interest in personalised products or services were willing to pay a 20% premium, and 48% said they were willing to wait longer for a personalised product or service.[93]

2.4 Technology and changing business and consumption models

Emerging supply chain innovations

A consumer product company's supply chain on average accounts for 80% of greenhouse gases associated with the product.[94] Innovations to increase the transparency and traceability of supply chains are rising as a result of market and regulatory pressure on companies to manage emissions. Development of multiparty systems such as blockchain, distributed ledger, and tokenization, improve companies' ability to track resource use, sourcing, compliance and fraud prevention in reducing the emissions in their supply chains. Additive manufacturing (3D printing), is increasingly being used by firms to develop, customise and produce parts and goods on demand, near their point of consumption, to minimise supply chain lead times and transport emissions.[95] This could see the length of supply chains shorten, as production is decentralised, towards a more onshore/near shore manufacturing model that also supports supply chain resilience. The Internet of Things (IoT) connects independent networks, resources and capabilities between companies to create a system of connected logistics networks. It can be utilised to strengthen warehouse management, fleet tracking, inventory control, and system maintenance. If adopted by industry at scale, and across competitors, it has the potential to generate significant efficiencies in freight and logistics networks.

More utility and less ownership

In a product-as-a-service (PaaS) model, the customer pays for access and use of a product for a period of time (as one would pay to use a given amount of a utility such as energy or water), alongside due maintenance, rather than paying a fixed fee for permanent ownership of the product. This business model has risen in popularity in recent years and continues to gain traction from a sustainability perspective, as it incentivises businesses to design products with a 'whole-life' view and durability in mind. It also makes businesses accountable and better positioned to manage products at the end of their life, as they can reuse parts and components in the design of new products. These products frequently have diagnostic sensors built in and form part of the IoT to flag usage and maintenance requirements. This concept is a key pillar in promoting a circular economy. As an example, the PaaS business model allows Rolls-Royce to increase the service intervals between engine overhauls by around 25% (with up to 95% of a used aero engine being recoverable and recyclable).[96]

2.4 Technology and changing business and consumption models

Implications for Goods Movement

Lower cost and more capacity for freight on the transport network

With increasing digitalisation, many services that people are accustomed to accessing through commercial or public facilities today are increasingly available to them remotely in their homes. This is freeing up capacity on the passenger transport network (roads and public transport), which could theoretically be considered to move goods with an innovative operational model in place. With the onset of truly autonomous vehicles for road and rail, the cost of delivering freight within regions could dramatically decrease.

More policy control over e-commerce

The continued growth of e-commerce will require cities to rethink how goods move within urban regions and between them from major ports and freight hubs. Models which excessively prioritise consumer convenience at the lowest cost possible are likely to see disruption and potentially greater regulation due to the inefficiencies (such as congestion or empty vehicle trips) and the carbon impact they generate on a system-wide level.

Transformation of existing processing and distribution systems

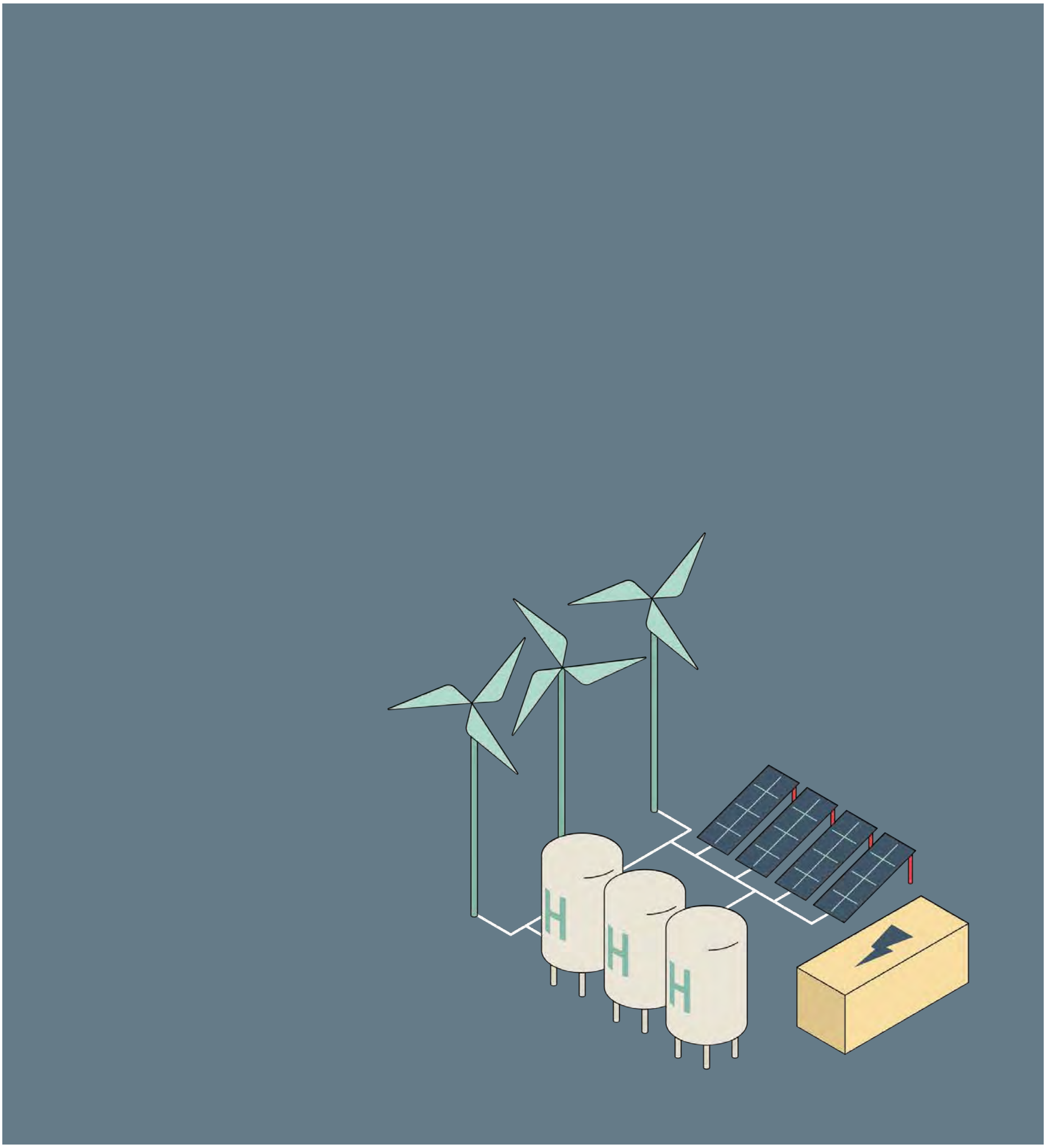
Moving towards mass personalisation implies the need for businesses to rethink operations, manufacturing, marketing, processing and customer service. Bulk distribution systems may require reorientation to enable product specific personalisation and final processing. If customers are willing to wait longer for their customised products, business may reconsider the pressure on maximising speed of delivery and goods transport.

Supply chain innovations paired with a focus on sustainability and consumer demand for transparency could significantly impact which modes are given priority on average, while increasing trip efficiencies by maximising vehicle/fleet loading. It could also encourage greater collaboration in the freight industry to maximise system efficiency in terms of emissions and space utilisation over individual convenience-based just-in-time models.

Changing volumes of consumed products, waste, and turnover

A major uptake and evolution to a PaaS model by major industry players could significantly change the relationship between consumption and production. The increased focus on durability by producers worldwide overtime would mean that growth in the consumption of new products would substantially decrease from the levels seen today. As manufacturers become responsible for the end-of-life stage of products, and focus on re-use, the need for transporting raw materials to processing and distribution facilities would significantly change.

2.5 Energy and industrial materials transition



2.5 Energy and industrial materials transition

Context

Measured in tonne-kilometres (tkm), energy products made up 36% of global seaborne trade[97] in 2021, and with seaborne trade making up 80% of global freight, this represents a significant portion of the global movement of goods. The energy sector is set to see major transformation in the decades ahead. Emissions from energy used in various sectors account for nearly 75% of global greenhouse gas emissions.[98] Alternative clean sources of energy to are fundamental to achieving net zero emissions globally. New low or zero carbon materials to create products and build infrastructure and buildings will also have a major impact on the types of goods which require transporting across the world. However, this is a space of significant uncertainty, rapid innovation, and political volatility. The shape of the energy and materials transition will impact the actual goods and volumes which need to be delivered, how transport systems are powered, key new emerging technologies, and which transport modes become more and less dominant over long-distance routes or to carry heavy goods. The figure below shows how vastly different global CO2 emissions could be in 2050 depending on which future outlook or scenario transpires. Under some of the more ambitious climate scenarios a much cleaner fuel mix is adopted and net zero is achieved, and under some of the more pessimistic climate scenarios net CO2 emissions actually increase from a 2020 baseline.[99]

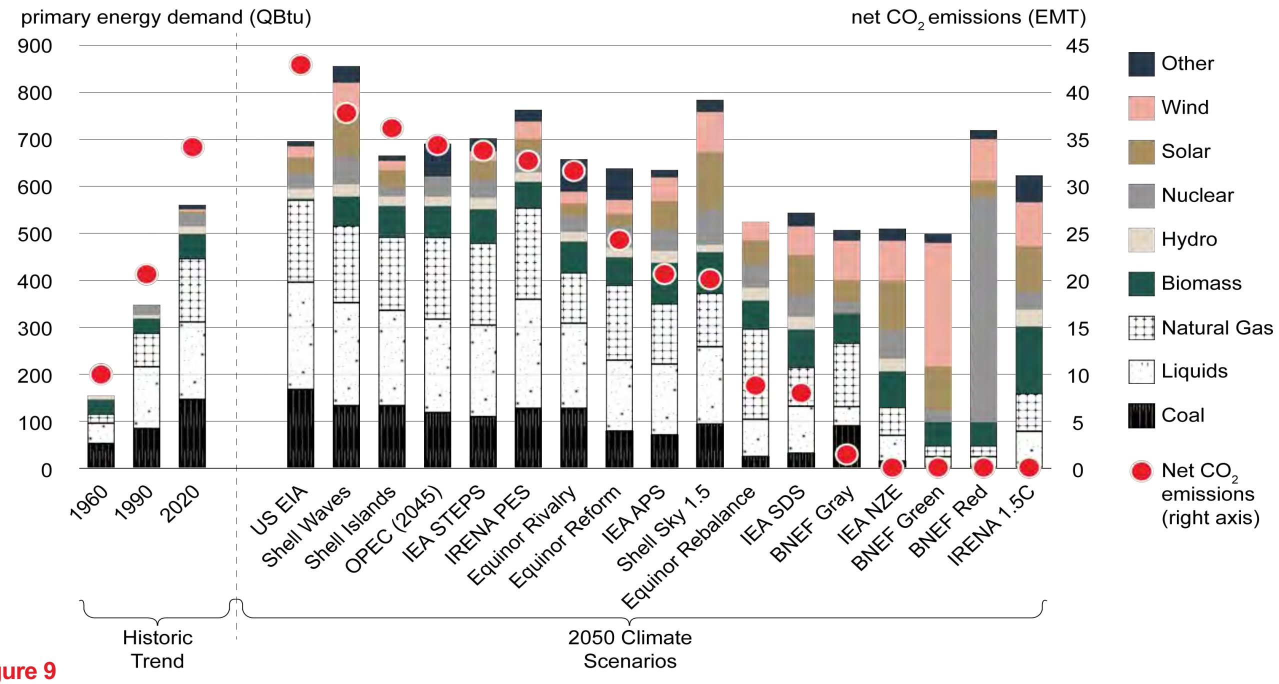


Figure 9

Global Primary Energy Mix and Carbon Dioxide Emissions (Ordered from highest to lowest levels of fossil fuel demand)

2.5 Energy and industrial materials transition

Coal

Many countries still have vast coal reserves and some estimates suggest that in the next 20 years energy consumption could increase by 60% and coal will remain the major source of power generation.[100] Global coal production is still trending upwards despite mining decreasing in Europe and the United States, due to increased activity in Asia, particularly in China, which produced 3,969 Mt of coal in 2021 alone.[101]

Natural Gas

Natural gas accounted for a quarter of global electricity generation in 2021, although its level of use varies significantly between nations. It is beginning to be phased out as a source of domestic energy in mature markets, being replaced with air heat source pumps or other clean sources of heat.

On average, switching from coal to gas reduces emissions by 50% when producing electricity and by 33% when providing heat.[102] Natural gas can also theoretically be used to produce clean hydrogen fuel if coupled with carbon capture and storage (CCS) technology. For these reasons, while it is projected to see some decline, natural gas is still widely seen as a transitionary fuel likely to play a major role in regions of the world still dependent on coal for electricity, even under the net zero transition.

Conflicts and political instability around the globe remain a factor in the natural gas market, with countries seeking to purchase gas from trusted partners to maintain security of supply. Such a shift includes the importing of liquified natural gas (LNG), with countries building new import terminals to increase their import capacity.

2.5 Energy and industrial materials transition

Hydrogen

Demand for hydrogen in transport, industrial heat and power grew by 60% in 2021, while still only comprising a fraction of overall global demand for hydrogen.[103] Most of the increase in hydrogen demand has been spurred by road transport and accelerated deployment of fuel cell heavy duty trucks in China. Public R&D funding for hydrogen rose by 35% in 2021, from the year before, its largest annual increase.[104] Weight and energy density of batteries make hydrogen increasingly important for decarbonisation of long-haul transport, with hydrogen powered trains already in service in Germany and Austria. Significant investment in infrastructure for hydrogen is ongoing and leading to increased usage, parts of natural gas networks have been turned over to hydrogen in areas where it has become dominant.

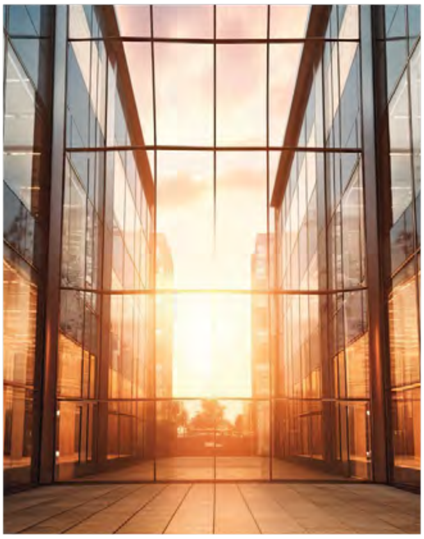
Steel

Steel has an enormous impact on global development through its pivotal role in buildings and infrastructure. In the US, structural steel has a 46% market share in non-residential and multi-storey residential buildings.[105] Most crude steel is produced by reducing iron or using coal and is extremely carbon intensive. Europe was once a net exporter of steel products, but since 2016 it has been a net importer with net imports reaching 3 million tons in 2020.[106] The increasing influence of China and the volatility of raw materials make forward outlooks uncertain for the steel industry in other parts of the world. With the pressure to decarbonise spurring innovation, and changing centres for demand due to accelerating growth in construction in Asia and Africa, the future of the steel industry or the emergence of any unknown breakthrough materials which compete with steel will have major implications for the world of trade and future goods movement.

2.5 Energy and industrial materials transition

Glass

The high temperatures required to melt sand and other materials make the glass industry one of the most energy-intensive industries in the manufacturing sector. Glass remains a key material in packaging, construction, transportation, telecommunication, and electronics. Glass is seen by consumers as a sustainable product meaning it is increasingly favoured over other packaging materials such as plastic. Adoption of circular economy principles means there is increasing pressure on industries to reuse and recycle glass, although net increases in demand for uses like construction and solar panels means demand for new glass continues to grow for the foreseeable future. The five biggest glass exporters are mainland China, Germany, United States of America, France and Hong Kong.[107] These countries collectively generated almost half (48.1%) of overall international sales for glass as a material plus glassware products during 2021.[108] China alone accounts for almost 20% of the current global market share.[109]



Cement

Cement is the second most consumed product globally after potable water and is used in almost every part of construction.[110] It is also, however, one of the biggest contributors to global carbon emissions and is facing an uncertain future in which there is significant pressure on the industry to decarbonise. Cement production is likely to increase in India and other developing countries in Asia and Africa as these regions undertake significant infrastructure development and growth.[111] There are 12 manufacturing and two grinding and blending plants producing cement in the UK and these produce 90% of the cement sold in the UK.[112] The global shortage of sand[113] and the carbon-intensity of cement production, means alternative materials and carbon capture technologies are critical for the future of construction. The cement industry is poised for major disruption in future.

2.5 Energy and industrial materials transition

Critical Rare Earth Materials

Historically key in the production of catalysts and magnets, critical rare earth elements have seen demand surge in recent years following the widespread adoption of mobile devices and other electronic gadgets. Rare earth elements are crucial in the production of EVs and offshore wind turbines. The IEA expects demand for rare earth metals to increase by between three to seven times current levels by 2040.[114] Production and refining of such metals is highly concentrated, with China responsible for 60% of production and 87% of refining globally – raising concerns over the security of supply.[115] To meet growing demand, mining companies have expanded operations with previously untapped resources such as Sub-Saharan Africa.[116] Recycling remains limited, with just 1% of all rare earth elements recycled, but this is expected to increase with a growth in the circular economy, higher future demand, security of supply issues and an expected surge in the amount of spent EV batteries reaching the end of their first life in 2030.[117]

2.5 Energy and industrial materials transition

Implications for Goods Movement

Fluctuating volumes of demand for energy products

With coal production mainly being focused in Asia over the coming decades it is likely that the UK and Europe will continue to see a decline in coal traffic. However, disruption in the global decarbonisation of the energy sector, and concerns over energy security by events such as the war in Ukraine create significant uncertainties around the overall role and global need to transport coal across regions over the next few decades.

Gas is transported by rail or ships where pipelines are at capacity or unavailable. Political instability and conflict between countries makes some fixed infrastructure to transport gas obsolete, such as the Nord Stream 2 Pipeline between Russia and Germany. The increase in demand for LNG imports as a result of the pipeline closure led to a sudden surge in the demand for shipping capacity and infrastructure. Over the long-term it is expected that under a 1.5˚C scenario demand to transport energy products by ship will decrease primarily due to reduced demand for oil and coal.[122]

Reduced reliance on fossil fuels due to increased uptake in hydrogen means that less coal, natural gas, and oil would need to transported in the future. The greater the distance goods must travel via land, air and sea, the more favourable hydrogen becomes as an alternative fuel source against batteries, which are heavier and have lower energy density. Rail freight and HGV transport are most likely to transition to hydrogen in the short term. Hydrogen to fuel aviation and shipping is still in the demonstration/development stages.

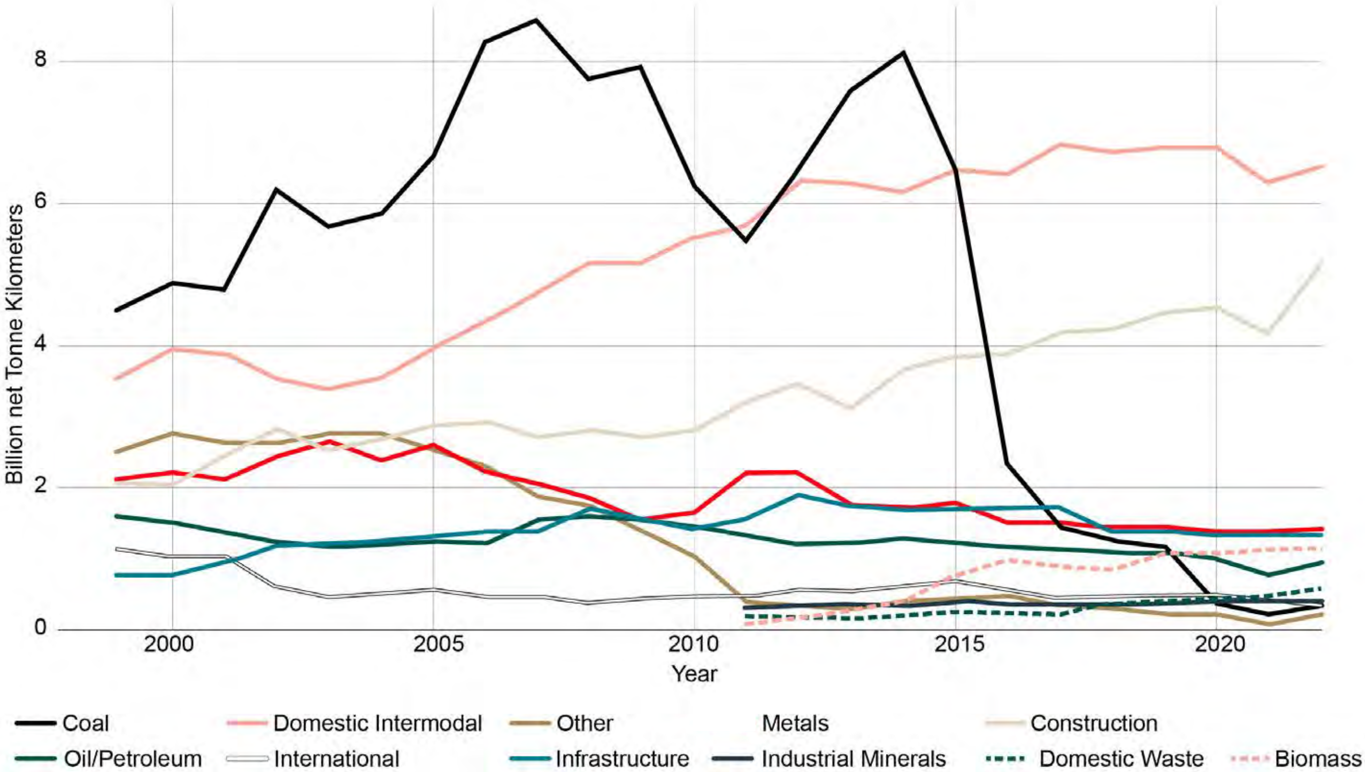


Figure 10
UK National Railways freight moved by commodity, annual from 1999/00 (billion net-tonne kilometres)[118]

2.5 Energy and industrial materials transition

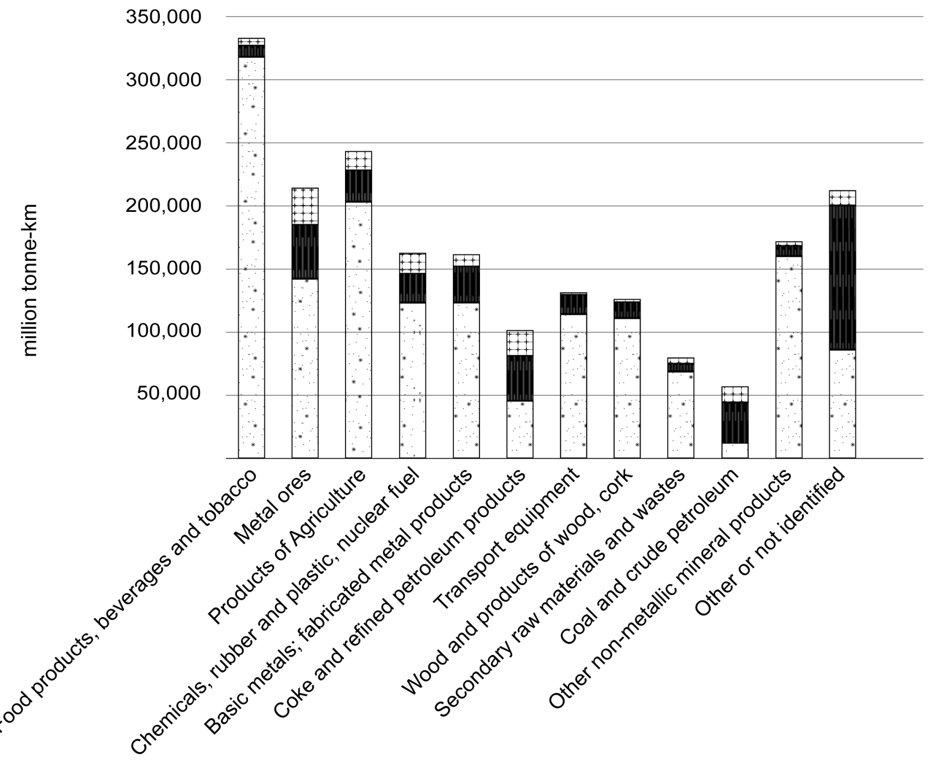


Figure 11
EU Mode Share by Commodity of inland freight (2022)[119]

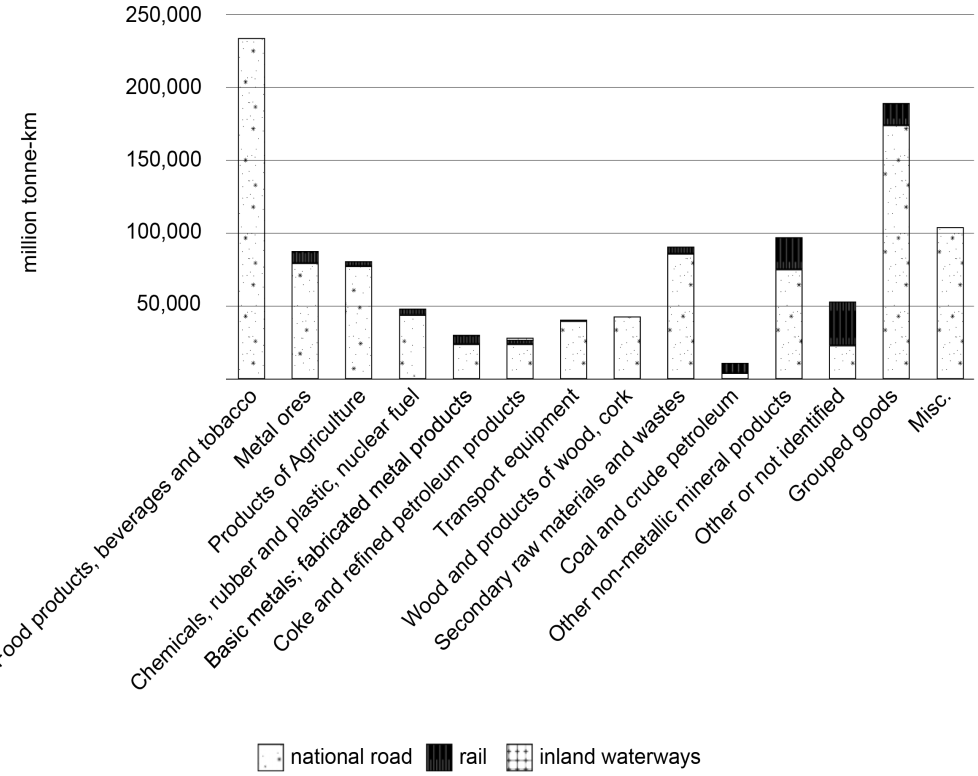


Figure 12
UK Mode Share by Commodity of inland freight (2019)[120]

2.5 Energy and industrial materials transition

Implication for Goods Movement *continued*

New nodes for production and distribution of key materials

The movement of steel requires special handling equipment and systems that are capable of handling extreme weight. More purpose-built terminals and handling equipment will be required to cater for these needs. Net -zero regulations may push steel plants to invest in less carbon-intensive production technologies, or to offshore production in countries with less environmental regulation - impacting the volumes imported over long distances.

Growth in construction and infrastructure development (telecommunication, housing, buildings, transport) in different parts of the world will create new major nodes for demand of glass. Pressure to increase the reuse and recycling of glass in the developed world will create new complex logistical challenges, including gathering of small volumes of glass from dispersed sources in a region to large local recycling or storage and distribution facilities.

Cement is generally a locally sourced and produced material. The scaled production of potential low-carbon alternatives to cement such as Ferrock or Graphene could create new material flows and associated corridors globally, depending on how widely the alternative can be found or generated around the world.

Increased demand as well as expansion of mining facilities for critical rare earth metals could create the need for additional movement of goods. The locations from which these metals originate are limited and emphasise the need to critically secure the corridors through which these goods can travel. An increased push to recycle and reuse the rare metals, as well as security concerns in sourcing these metals from conflicted parts of the world will have implications on the future growth in trade and movement of these materials.

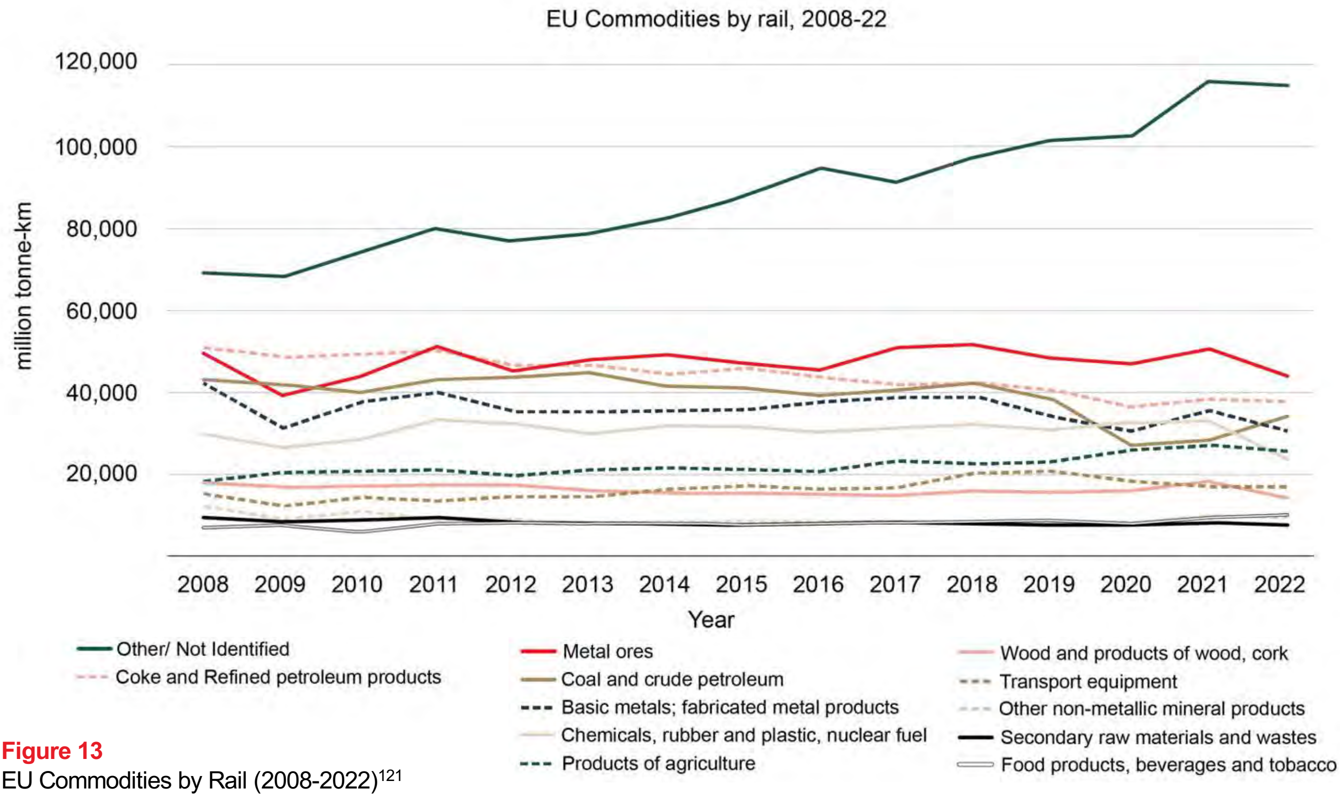


Figure 13
EU Commodities by Rail (2008-2022)[121]

2.5 Energy and industrial materials transition

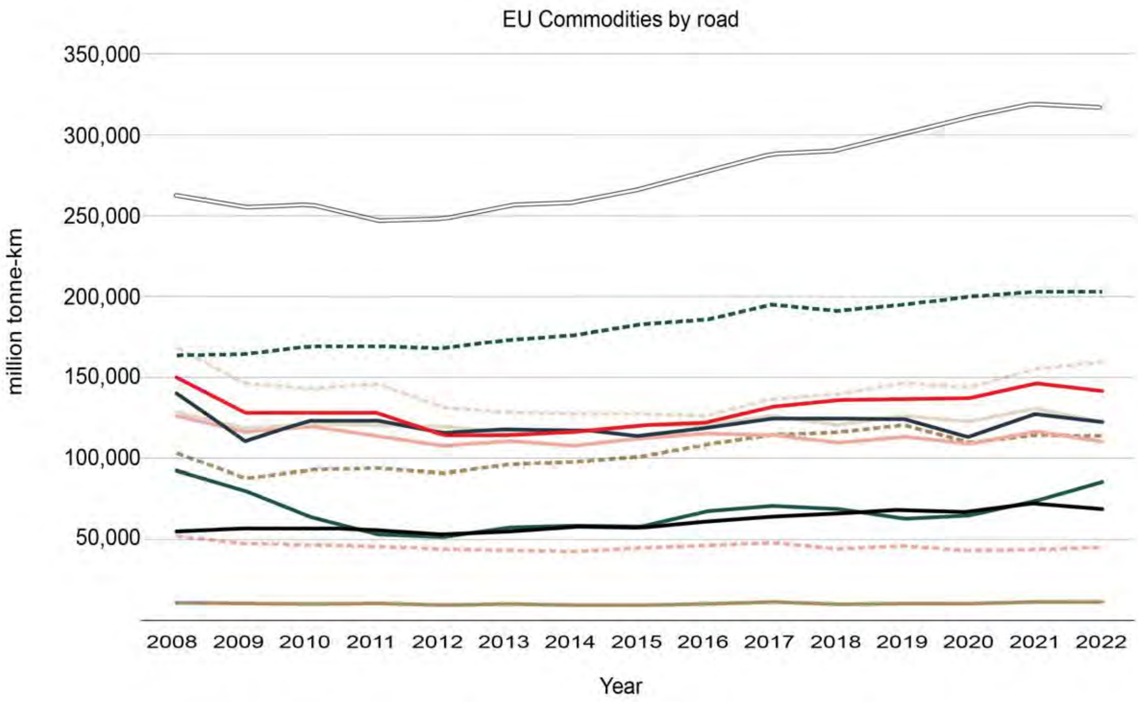
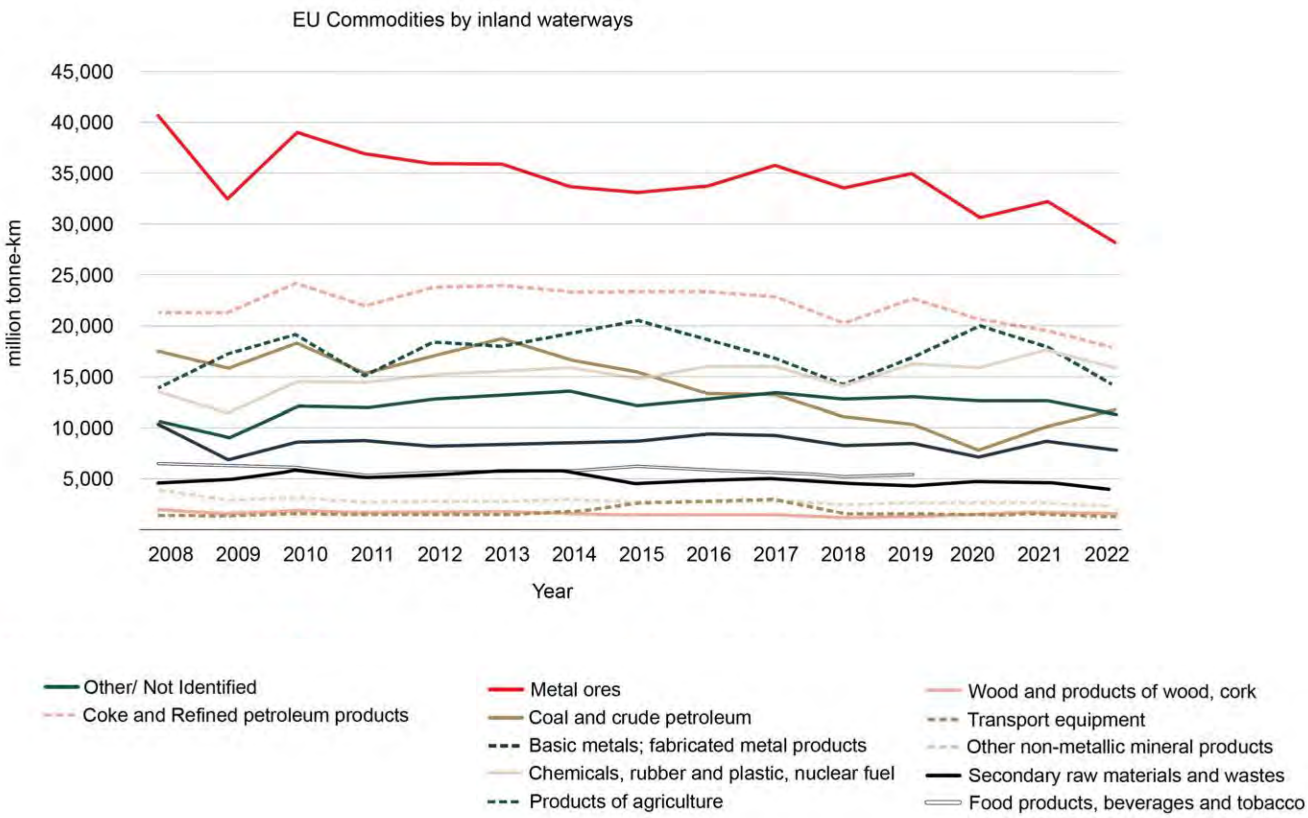
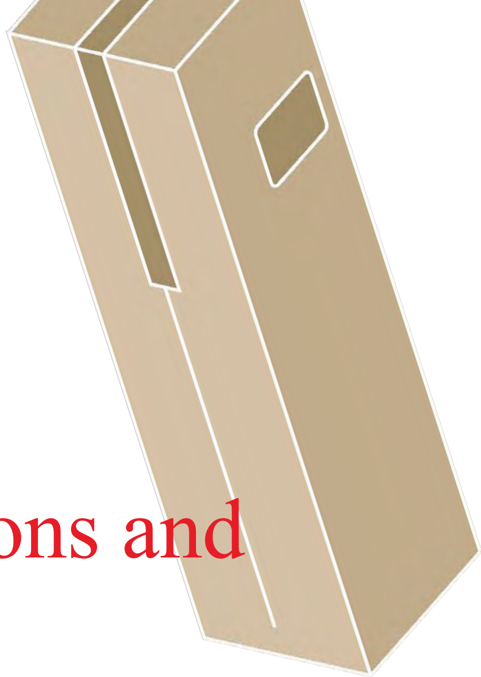


Figure 14
EU Commodities by Road (2008-2022)

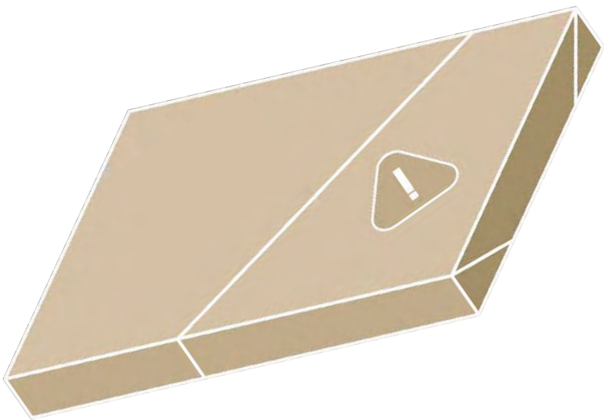


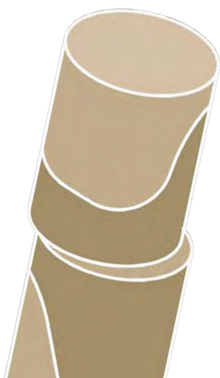
Figu
EU Commodities by Inland Waterways (2008-2022)



3

Future Implications and Opportunities





3.1 Future Implications and Opportunities

Today's global freight system has largely been an outcome of consistent growth in global consumption of resources and products. It is the result of steady trade between a set number of 'producers' of the world's goods (primarily Asia for manufactured goods) and a set number of major consumers (i.e., rich regions of the world such as the US, Europe, and Australia). The world's most traded commodities in terms of volumes are all agricultural, energy, and metal products. These are all resources whose future consumption is directly subject to major transformation due to efforts to tackle climate change and reduce greenhouse gas emissions.

While current and emerging trends still suggest that the speed of transitioning to new forms of energy and materials is slow in the near and medium-term – with current levels of demand likely to continue for many key energy products in particular – a major transition over the longer-term is indisputable if global net zero targets and pressure to address climate change are firm. Around 80% of the world's economy, and 77% of global greenhouse gases, are now covered by a national net zero target[123], and a growing number of major consumer product companies are placing circular economy principles on their sustainability agenda (40% of companies in a study by Kearney[124]). With the evident shifts in the dynamics of world trade and industry, it is critical to consider, explore, and reimagine the future of the system which enables the movements of goods globally.

As described earlier, the freight system in the UK and EU, and to a large but varying extent globally, has been primarily driven and shaped by the private market, and has prioritised consumer choice, convenience and cost-competitiveness – often and increasingly at the expense of systemwide efficiency and resilience. The emergence of sustainability and resource efficiency as key agendas for nations and policymakers at a global level represents a major challenge and oncoming disruption to this incumbent model. Governments and major corporations are moving to reconsider how they price goods, design and use transport, and the associated impact of these production, distribution, and consumption activities as they look to chart a path towards net zero emissions. This means the current freight industry must consider its role in realigning its operations and infrastructure to fit under a new overarching business and policy context.

The perception of optimal freight infrastructure planning, policy and investment decisions varies depending on the relative importance given by governments and the private sector to managing environmental impacts, enabling consumer choice and convenience, and ensuring resilience. Our study of the global trends influencing the future of freight suggests these three competing priorities will be considerable points of tension in weighing trade-offs when making decisions governing the movement of major goods.

3.1 Scenarios to inform long-term decision making and investment in the freight network

To help the reader visualise the possible future conditions which the freight system may need to adapt to, we outline two extreme scenarios. These scenarios help distil the implications of the key drivers of change which we argue are most likely to impact the future movement of goods.

We use the following key drivers to define the contextual parameters for each scenario:

1
Consumption patterns (and how they alter between rich countries and emerging economies)

2
Degree of environmental action and regulation

3
Degree of energy transition

4
The state of international trade

5
The nature of e-commerce

6
The emphasis on resilience (as opposed to prioritising optimisation of operational costs and speed)

7
Technology and innovation

Collectively, these contextual parameters can impact the future freight system by changing:

- Which goods are required to be transported
- The quantities of the different types of goods requiring transport
- Where goods travel to and from (origin, destination and routes)
- How goods travel (mode and speed)

Through the lens of two extreme scenarios of the future world, we explore how these industry-specific factors for freight can be reshaped. These scenarios carry important implications for informing the investment in and development of freight infrastructure today. The shifts these scenarios of the future may entail are vital for decisionmakers to consider in order to challenge the implicit presumption that the future is a continuation of historical trends.

3.1 Scenarios to inform long-term decision making and investment in the freight network

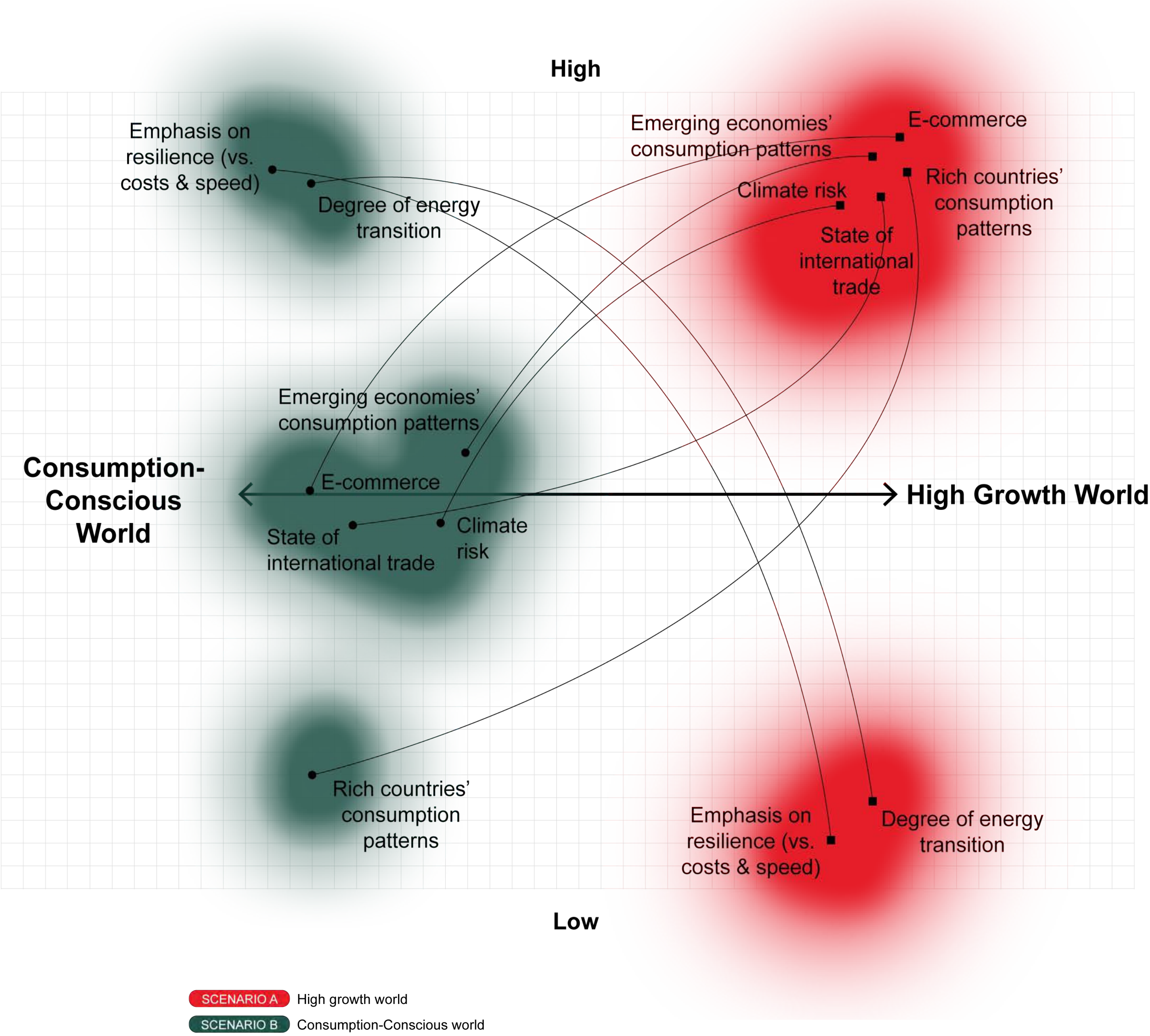
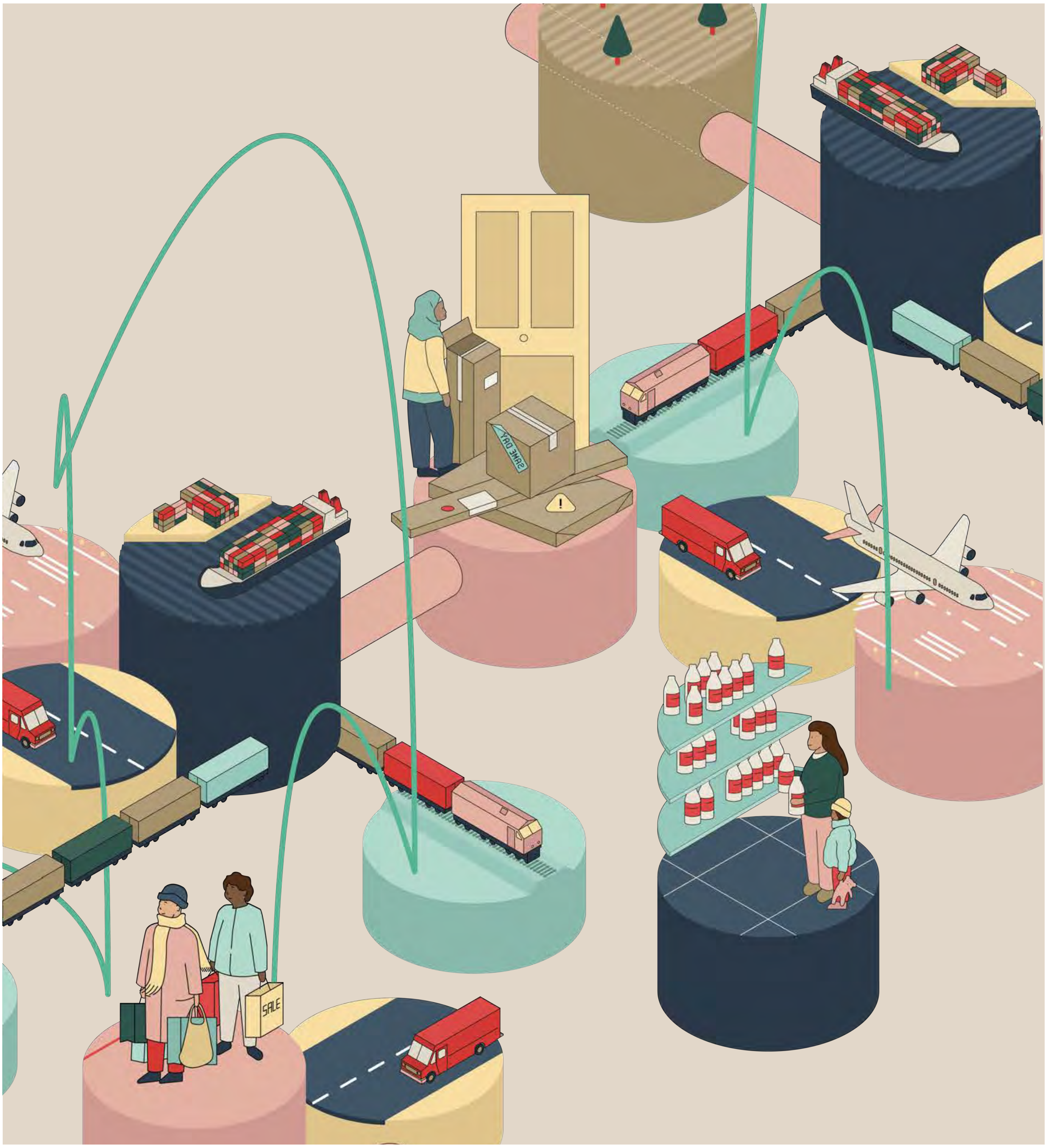


Figure 16
Visual comparison of the High Growth and Consumption-Conscious Scenarios

Scenario A

A High Growth World



3.2 Scenario A: A High Growth World

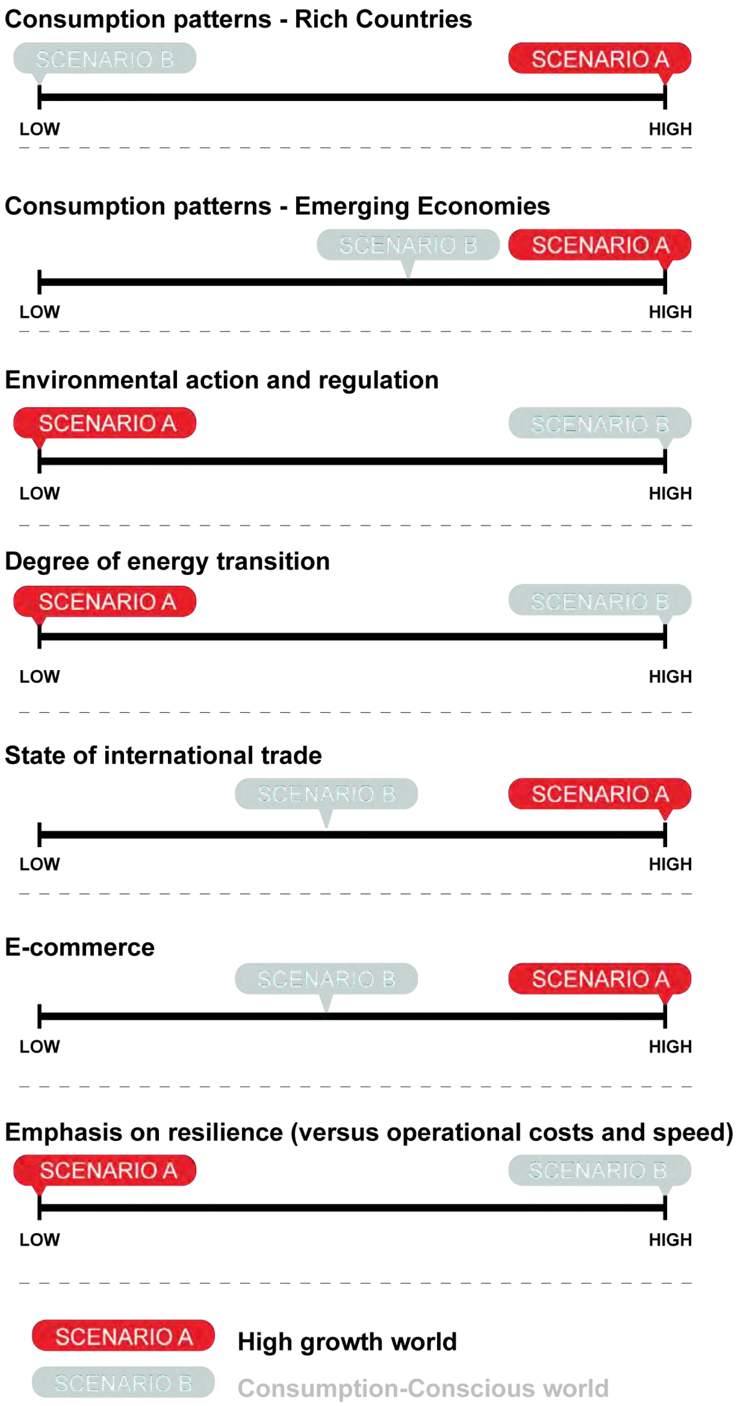
3.2.1. Overview

In a high growth world in 2060, many of the same historical trends which have driven consumption, manufacturing, and trade to date continue to accelerate, largely unchallenged by any new contextual shifts. Rich countries continue towards higher rates of per capita consumption of goods and generation of waste, and global consumption rates for most goods are at unprecedented levels as today's emerging economies now join rich countries with growing incomes and purchasing powers fuelling demand for all types of goods.

Environmental action or regulation governing the use of products, materials, and assets is limited and does not affect the growing demand for new production of goods . Worldwide, the energy transition is limited in scale, and coal and natural gas continue to play a major role in the global energy mix and are traded at increasing volumes, particularly to fuel the significant population and economic growth in Asia and Africa.

Increased deployment of renewable energy and hydrogen in some parts of the world leads to a net increase globally in the need to transport energy products and materials. Food and consumer products sourcing ingredients, raw materials, and sub-components across increasingly complex global supply chains continue to be manufactured and consumed in increasingly high volumes.

Operational costs and speed continue to be drivers of supply chains and goods movements, and any new resilience related interventions are limited to those which do not compromise maximisation in frequency of service and speed of delivery (at increasingly lower costs), upholding ever-increasing consumer choice and convenience, globally.



3.2 Scenario A: High growth world

3.2.1. Overview

As a result of these contextual factors, the freight system in a High Growth World is characterised by an ever-greater emphasis on faster speeds, heightened international trade and interconnectivity, and the need for significant increases in capacity to accommodate fast growing flows of goods across all regions of the world.

How goods travel

Goods travel at ever increasing speeds as the desire to minimise journey times and reach consumers and retailers continues to grow at unprecedented rates. The speed of movement via different freight modes is integral to their competitiveness.

Types of goods and quantities to be transported

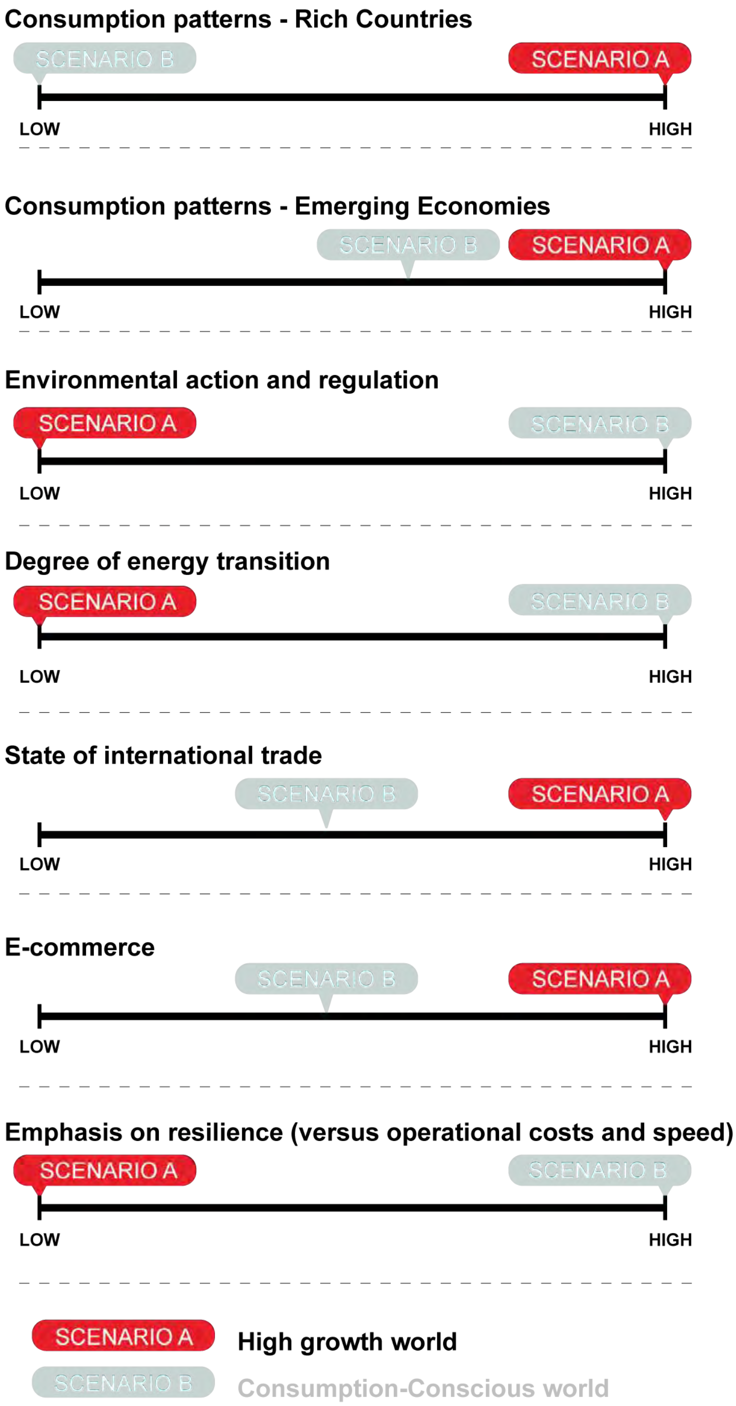
The split in types of goods transported in this High Growth World is the same as that seen today, simply with even higher volumes than previously seen for all types of goods.

Where goods travel to/from

Production and consumption is highly international and all major freight corridors known today experience a major increase in demand to transport goods. Long distance travel increases significantly with high olumes of goods being transported across far flung regions at increased rates.

Quantities / volumes of goods to be transported

All kinds of goods – from clothing to electronics, agricultural to metal and energy products are traded at increasingly higher volumes across regions. Capacity is constantly constrained and the need to expand the network and improve flow is continuously pressing.



3.2 Scenario A: High growth world

3.2.3 Implications for the future freight network

Under simultaneous pressures to accommodate major growth in volumes of goods moved, an even more increasingly complex international trade network with minimal regulation around movement of goods, and an ever-increasing emphasis on speed of movement – the freight network would see a significant increase in risk to its resilience and reliability. Unexpected changes – politically or environmentally – could lead to major disruptions. Access to key goods may be inequitable across regions, as nations with historical precedence leverage incumbent advantages to first access to critical goods in the context of competing demand from different geographic regions. The potential to have enabled limited global warming (in line with the Paris Agreement) is highly uncertain. In the absence of a revolutionary technology providing unlimited clean energy at scale globally the freight network in this High Growth World is likely to experience increased frequency of natural disasters, high degrees of sea level rise, drought, and extreme weather conditions.

1
Due to the intensely high levels of growth in production, trade, and consumption there would be significant congestion issues on the freight and transport network despite continuous attempts to increase and improve capacity.

2
There would be a strong risk of highly volatile operational performance on the freight network as the maximisation of speed, trip distances and global interdependencies, and higher transported volumes compromise resilience against increasing frequency of disruptions posed by climate hazards and/or political instability.

3
To accommodate the increasingly high levels of growth and demand, significant construction works would be in place almost constantly to expand and enhance capacity on all major freight corridors. Construction and investment in the freight network would most likely struggle to keep up with demand for increased freight services. In such a case, there would constantly be bottlenecks and constraints which limit the flow of goods in the system to be less than overall market demand. This would present a scope for using pricing and or other means of regulation to maximise system efficiency and prioritise critical goods or high-paying customers

4
The need to accommodate freight facilities (storage, processing, and transport infrastructure and services) would be challenged by other competing land use and transport priorities in cities and regions, along key travel corridors, and at major intermodal nodes.

Scenario B

A Consumption-Conscious World

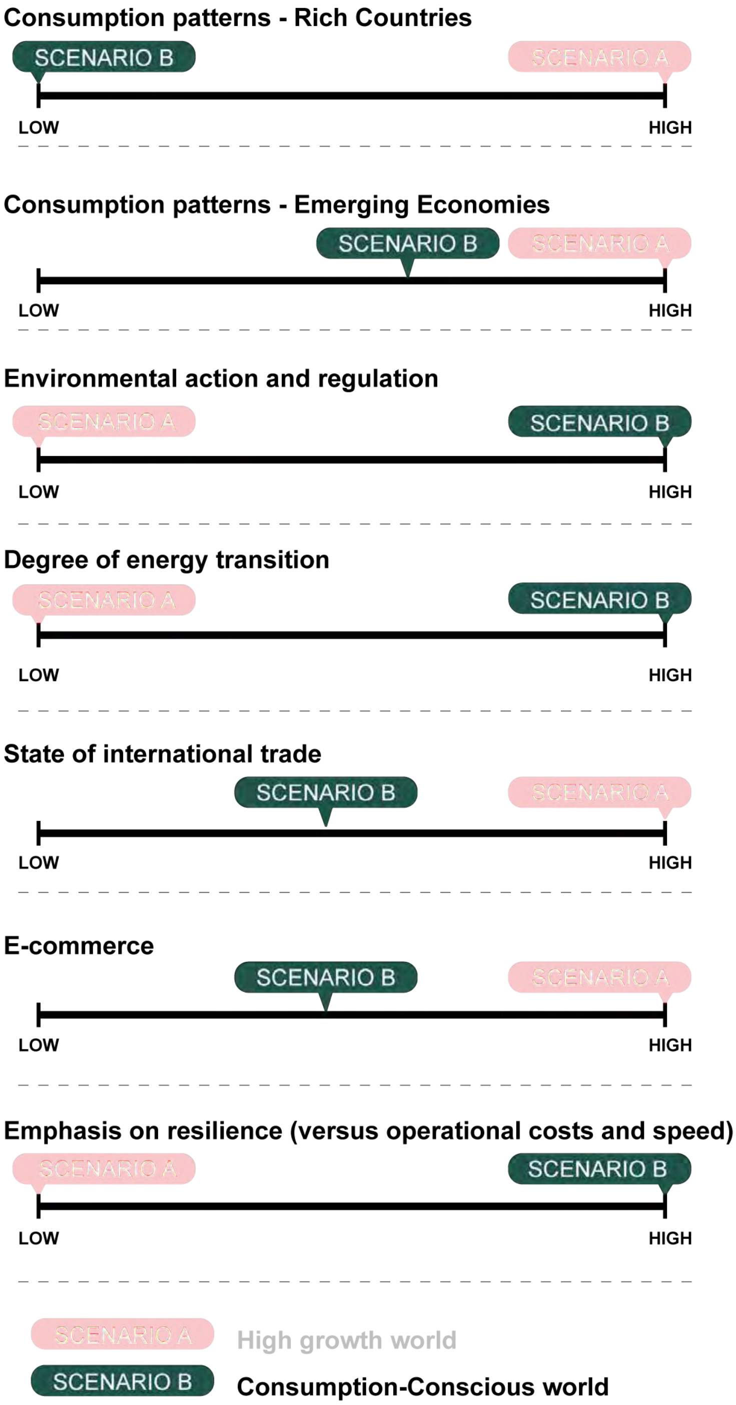
3.3 Scenario B: A Consumption-Conscious World

3.3.1 Overview

In a consumption-conscious world in 2060, the drivers of change which push the world towards sustainability are powerful and dominant. Progress towards net zero emissions through balanced consumption and greater regulation has put the world on track for close to 1.5 degrees of warming. Pricing mechanisms and comprehensive regulation are in place to minimise waste and overproduction of all types of goods, and to accelerate and embed circular economy practices in design, manufacturing, consumption, and end-of-life product and asset management. With dramatic environmental awareness and strategic and effective carbon pricing, there is a major shift in consumer expectations and purchasing behaviour at a large scale, particularly in today's rich countries. Carbon-intensive foreign discretionary, luxury goods attract an ever-shrinking share of the consumer market and consumers place lower emphasis on the high speed of delivery. The energy transition has progressed significantly through mass expansion of renewable energy generation, electrification, and varying use of green fuels worldwide.

With regards to trade and access to critical goods, carbon taxation (driven by environmental action) coupled with global action to prioritise resilience against security risks and political instability, fosters greater reliance in most parts of the world amongst countries of closer geographic proximity and similar political and economic views. Long-distance international movement of goods is reduced as a result, and intraregional and localised movement of goods becomes more dominant.

Existing studies today already show that due to changes in supply chain architectures, de-materialisation and innovations in manufacturing, even as globalisation continues, global trade flows in terms of volumes will not experience the same fast pace of growth in the medium term as has been observed in recent decades.[125]



3.3 Scenario B: A Consumption-Conscious World

3.3.1 Overview

As a result of these major contextual transitions, the freight system in a consumption-conscious world is characterised by an increased emphasis on slower travel, local movement of goods, and agile capacity to accommodate more volatile flows of goods across regions of the world.

How goods travel

With rising awareness and carbon pricing, there is a greater acceptance of slower delivery and constrained access to non-essential goods. Lower overall volume of consumed industrial and agricultural products creates impetus to rethink supply chains and product distribution systems.

Types of goods to be transported

Overall demand for non-essential goods is significantly lower in rich countries than what is seen today as a result of increased consumer awareness, cost increases for generating waste, and government pressure on corporations to improve quality and lifetime of goods. There is a decrease in bulk and high-volume goods due to standardisation of design and production of industrial goods (to enable efficiencies in material use, repair, reuse, etc,), particularly in rich countries. Food waste and transport of non-essential food products are significantly reduced as mainstream consumers and retailers adopt more local and seasonal diets, to relieve pressure on unsustainable use of land and resources in major agricultural exporting countries.

Where goods travel to/from

Materials and goods are recirculated, recycled locally and regionally to a much greater degree, particularly in rich countries. This implies that there is a greater demand on the freight network to transport goods within and between neighbouring regions, rather than between far flung regions and long distances. Long distance movement of goods is more limited to critical, essential, and scarce commodities – e.g., hydrogen production and distribution for nations which cannot meet their energy demands from solar and wind sources, or for transporting captured carbon to adequate storage facilities around the globe as a result of the implementation of Carbon Capture Utilisation and Storage at scale. There is a larger variation in the flow of goods between different corridors worldwide. There is more localisation and recirculation of goods in rich countries. High growth regions such as Asia and Africa continue to rely on new resource extraction and transportation to sustain growth. As these regions are also home to many of the world's agricultural and industrial resources, they are to some degree able to rely primarily on regional movement of goods.

Currently, the Food and Agricultural Organisation of the UN (FAO) estimates that one third of global agricultural and food exports cross at least two borders and that, in developing countries, up to 40% of total food production can be lost before it even reaches the market.[126]

Quantities/Volumes of goods to be transported

The ability to redeploy transport capacity to where it is needed and repurpose infrastructure is increasingly important. Major construction projects to accommodate growth in developing parts of the world and to build infrastructure required to enable the net zero transition will generate periods of high demand to transport materials and products over specific corridors. Simultaneously, due to reduced overconsumption and significantly stricter waste management, coupled with a global energy system that is almost entirely off fossil fuels, there is unused available capacity on the existing freight network and assets.

With over 2 billion tonnes of waste being generating globally each year[127] *even a 10% reduction in waste would negate the need for over 200 million tonnes of goods to be moved to recycling facilities, incinerators and landfills across the world.*

3.3 Scenario B: A Consumption-Conscious World

3.3.2 Implications for the future freight network

Beyond the heightened activity to build new infrastructure to enable the net zero transition and accommodate growth in developing parts of the world, this consumption-conscious scenario suggests the future freight system is unlikely to be characterised by continued growth at the rate seen in previous decades u. Planners and investors should be cautious of over-investment and over-building in new freight capacity that would be difficult to shift/re-purpose 50 years from today. Freight infrastructure and operational planning for the future must question how periods of growth can be sustained, without over-building infrastructure which may be obsolete in the future.

1
With less emphasis on fastest possible delivery or high frequency delivery options, there could be more opportunity for consolidating goods for distribution and delivery and attaining higher load factors on freight vehicles. For example, trips for ‘discretionary goods’ could be limited to certain days of the week or certain times of day to encourage consolidation, reduce congestion, and achieve higher loading factors on transport vehicles.

2
There is a potential for existing long-distance freight networks to have some unutilised capacity in this scenario. Decisionmakers today should subject new proposals to increase global capacity for freight movement to strict assessment of sustained long-term need and utilisation for the life of the proposed asset. If increased demands for transporting goods is limited to specific long-distance corridors (while demand may be declining on other corridors), than new demand would ideally be met by shifting and reallocating existing capacity, rather than through the creation of net new additions.

3
More medium-distance trips for transporting goods suggest the role of rail, road, and inland shipping to transport freight could potentially become more important than long-distance shipping and aviation. Cross-modal strategies to optimise operations and minimise environmental impact would be required, alongside greater coverage, efficiency, and coordination across new and existing international corridors.

4
Modes which can be deployed in a more modular way, where and as needed may be preferable to those which require fixed infrastructure. This should be considered when deciding which modes of transport are used to increase capacity on the freight network along with as assessment of duration of new demand (temporary vs. sustained long-term).

5
Freight infrastructure and buildings should be planned and designed with the idea of enabling future repurposing and flexibility in use. Unused capacity on the freight network could be used to transport people or be re-purposed for other active uses for society. For example, storage and warehousing could be used to create housing, offices, or other social infrastructure.

3.5 Future mode-specific implications

3.5.1 Future mode-specific implications

If the future world is somewhere in between the Consumption-Conscious and High Growth World scenarios outlined above, what should we consider as we plan and invest today for the goods movement system of the future?

An overarching change which needs to be implemented in freight related planning under all scenarios for the future is the need to take an integrated systems-level approach to set targets and plan for the desired role of individual transport modes across key corridors (regional and global). As described earlier, the freight industry is made up of a highly interconnected system of different components, needs, and customers. Mode-specific targets such as, for example policy changes to the 'proportion of freight carried on rail' should only be designated after taking a holistic view of the full freight ecosystem, rather than driven by mode-specific interests which overlook the wider freight system needs and options.

A 'systems-view' – enabled through cross collaboration between industry and government and tracking and sharing of strategic information – to drive decisions and investments for specific technologies, policy mechanisms, and transport modes will be essential to successfully overcome some of the challenges seen globally in recent years (and could grow in the future), due to unexpected disruptions to goods movement.

At the individual mode level, the underlying strengths and suitable roles of different transport modes will still hold true in most cases under both future scenarios outlined above. The key consideration for freight operators will still be about offering reliability, resilience, and cost-effectiveness with high quality access to goods for industry and consumers. The basic strengths of different modes – for example, for ships to travel long distances with heavy goods, or for aeroplanes to provide secure and fast access to critical products – will likely continue to differentiate them and dictate their roles in a changing market.

However, what will happen with a changing context – such as the implementation of high carbon pricing or the availability of low-carbon aviation fuel at scale – is that some transport modes could start to gain a competitive edge for new use cases. This section attempts to highlight some of the key opportunities and considerations that emerge for the different major modes of freight transport as a result of contextual changes we have highlighted as probable. This section also considers and acknowledges the role of emerging and more speculative forms of goods movement technology.

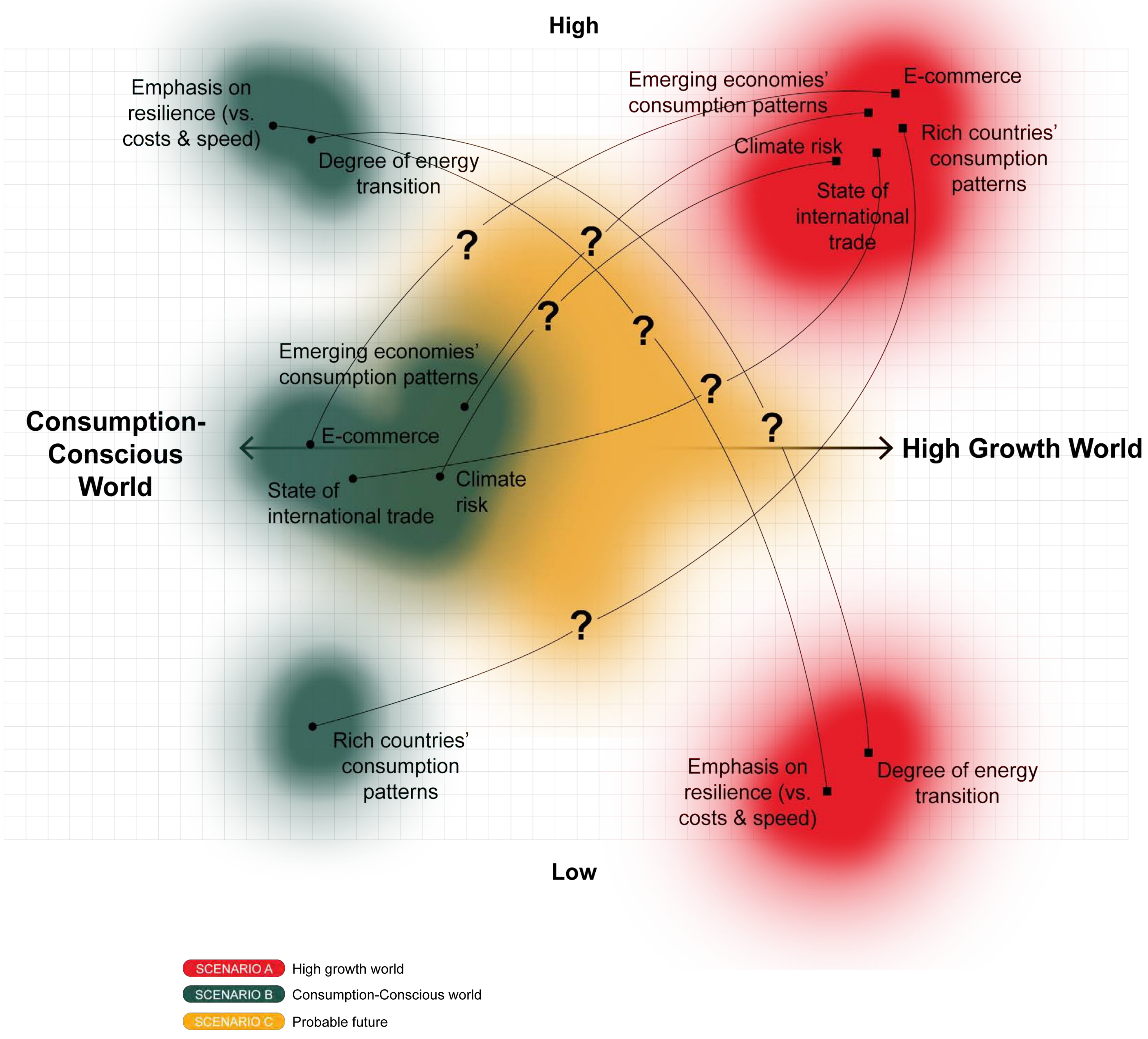
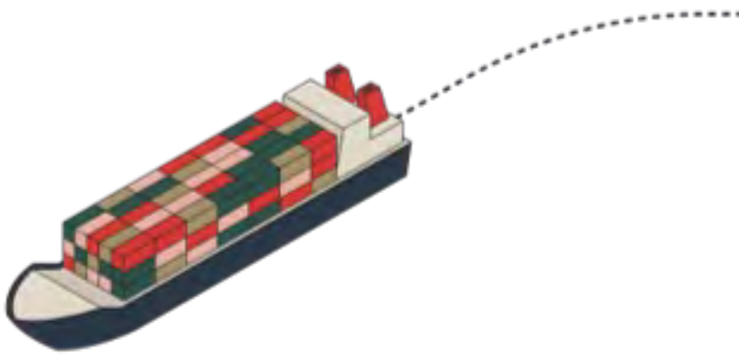


Figure 17
Visual comparison of the High Growth and Consumption-Conscious Scenarios, as well as the Probable Future

3.5.2 What are the prospects for shipping?

In a net zero future where resilience and flexibility are needed to address challenges arising from current and anticipated trends, shipping would have a clear role to play in the movement of goods. Sea shipping is likely to remain the most common way to move large volumes of freight over significant distances between global regions, but there may be a reduction in the volume of demand for sea shipping given the potential future scenarios described earlier. Short sea and inland shipping can be expected to see a relatively higher proportion of freight tonnage (where navigable routes are exist or are viable) as it gains traction in competing with road and rail freight due to both its flexibility in deploying capacity/service as needed, and relatively lower carbon intensity.

In some areas, including the UK and parts of northern Europe, there will be significant growth in shipping traffic to construct, maintain, renew and service offshore power generation and transport hydrogen produced by these facilities.



3.5.2 What are the prospects for shipping?

Key considerations, risks and opportunities for future shipping based on our study are as follows:

1
Shipping decarbonisation

To reach global net zero targets by 2050, shipping would have decarbonised and run on hydrogen or another zero-carbon fuel. Wherever possible, ships should be specified to be easy to adapt for alternative fuels given their long asset life. This will reduce the need to replace fleets prematurely due to changes in preferred fuel sources over the course of the energy transition. The actual nature of the transition to decarbonising shipping is uncertain - shipping is excluded from the Paris Agreement, so it will be necessary for major shipping origins and destinations to structure their own taxes and regulations in as coordinated a manner as possible to avoid inconsistencies. The EU has started to push forward with this by adding shipping to its carbon market (including 50% of emissions from journeys to or from the EU). Other jurisdictions implementing similar measures could give further incentives to shipping companies to accelerate implementation of lower- (and zero-) carbon fuels. The International Maritime Organisation (IMO) is a specialised agency of the UN responsible for regulating shipping and they have set some decarbonisation standards such as the Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII) rating[128] which were implemented on 1st January 2023. The EEXI focuses on improving the technical performance of existing ships, while the CII focuses on improving the operational performance of existing ships. The IMO also has a strategy to reach a net reduction of 70% of carbon per transport (and 50% overall, accounting for an increase in the number of journeys) by 2050.[129]

2
More inland and short sea shipping

Where existing watercourses and canals are navigable or are planned to be retrofitted, or where new routes become available, it can be expected that inland shipping will rise to compete against modes such as road and rail to help meet net zero goals. This is because inland shipping can be very energy efficient in comparison to other modes (particularly road), despite being slower in speed. An increasing focus on sustainable transport over speed and convenience therefore will make inland shipping more attractive for regions seeking to decarbonise. Governments should seek to work with the shipping industry to resolve capacity pinch points where inland shipping has potential to play a greater role in delivering freight capacity.

3
Global variation in demand for bulk shipping

Bulk shipping is the second largest carbon emitter in the global maritime industry. Bulk cargo will still be a feature for countries and regions which are still developing and need raw materials to support population and economic growth. In rich countries, under future scenarios more aligned towards meeting net zero targets, it is likely that transport of bulk cargo (particularly over long distances) will significantly diminish over time – this is especially likely to happen for non-essential consumer goods, agricultural products, and fossil fuels. As an example, China is currently one of the leading countries in the global dry bulk trade. Studies show that the introduction of a carbon tax on dry bulk trade in China could have significant impacts on freight rates, commodity prices, and dry bulk trade patterns. [130] Since shorter shipping distances would have lower emissions per tonne, there would potentially be increased reliance on nearby countries. For example, in the case of China, it may increase trade with India and Australia, for the import of key commodities.

3.5.2 What are the prospects for shipping?

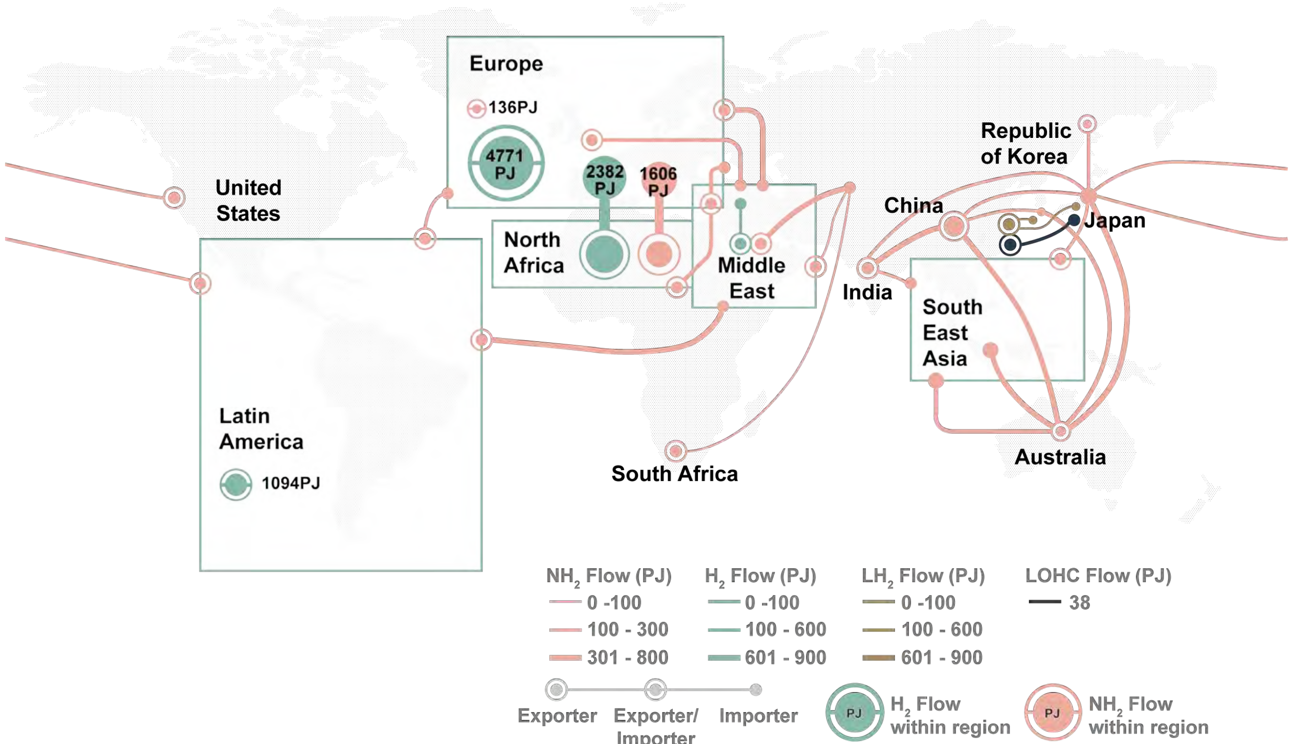


Figure 18
Global hydrogen trade flows under *Optimistic* technology assumptions in 2050[132]

4
Future energy products

One key area of expansion for regions such as the UK and EU will be shipping facilities associated with hydrogen, which is expected to grow in volume sixfold between 2020 and 2050.[131] Hydrogen importers and exporters will need facilities to manage transfer and storage. There may be scope to adapt existing fossil fuels infrastructure in some cases – such as existing gas pipelines converted to transport hydrogen. In any case, shipping, particularly internationally, will have a significant role to play in enabling access to hydrogen at scale, particularly to places which cannot rely on other clean sources of energy such as wind and solar.

5
Resilient and connected ports

Many ports are somewhat removed from major population centres, others will need to be retrofitted and replanned as sea levels rise. As such it will continue to be key to think about how to best connect ports which are situated away from urban areas, to enable efficient delivery of goods to major urban centres or key industry nodes in the most sustainable manner. Bulk-manufacturing and processing centres should be co-located and prioritised to be situated close to ports and/or major intermodal nodes to maximise opportunities for consolidated transport for distribution to population centres. The resilience of ports themselves will need to become a key priority. This will require integrating scenario analysis of physical climate risks into existing planning processes to ensure the promotion of strategic, flexible and resilient businesses and investments.

3.5.2 What are the prospects for shipping?

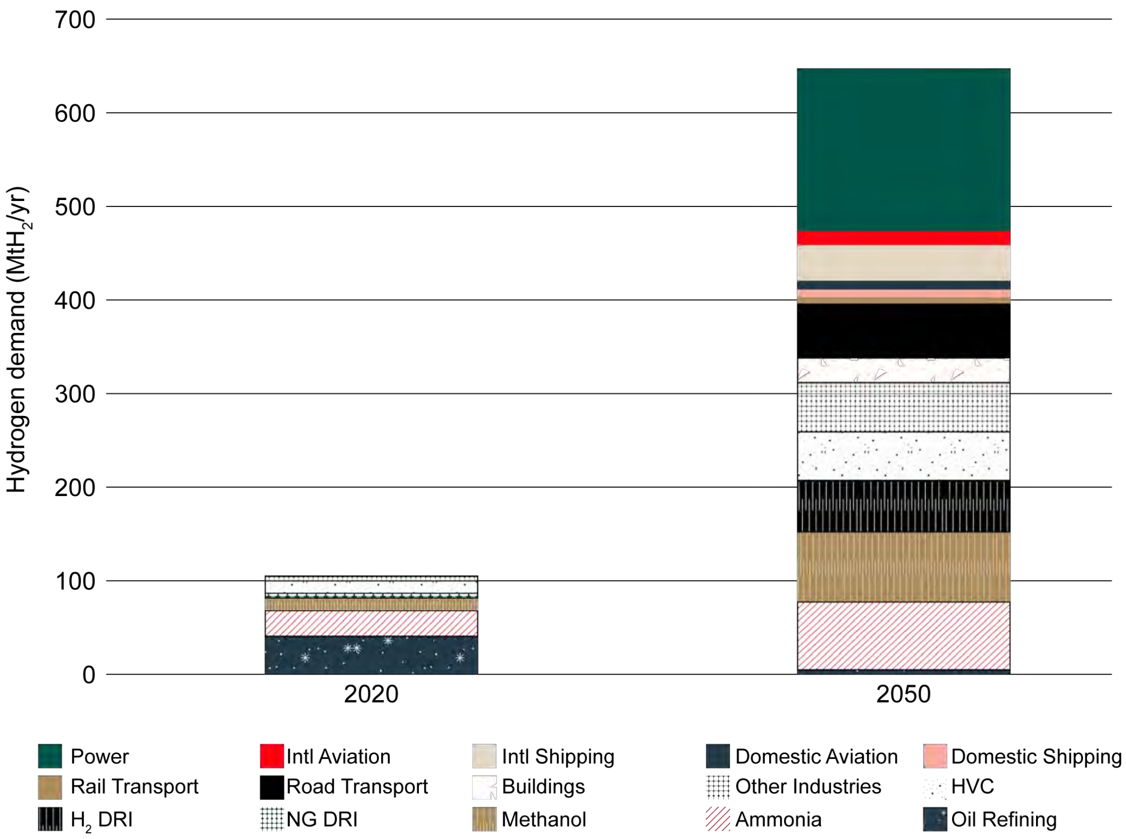
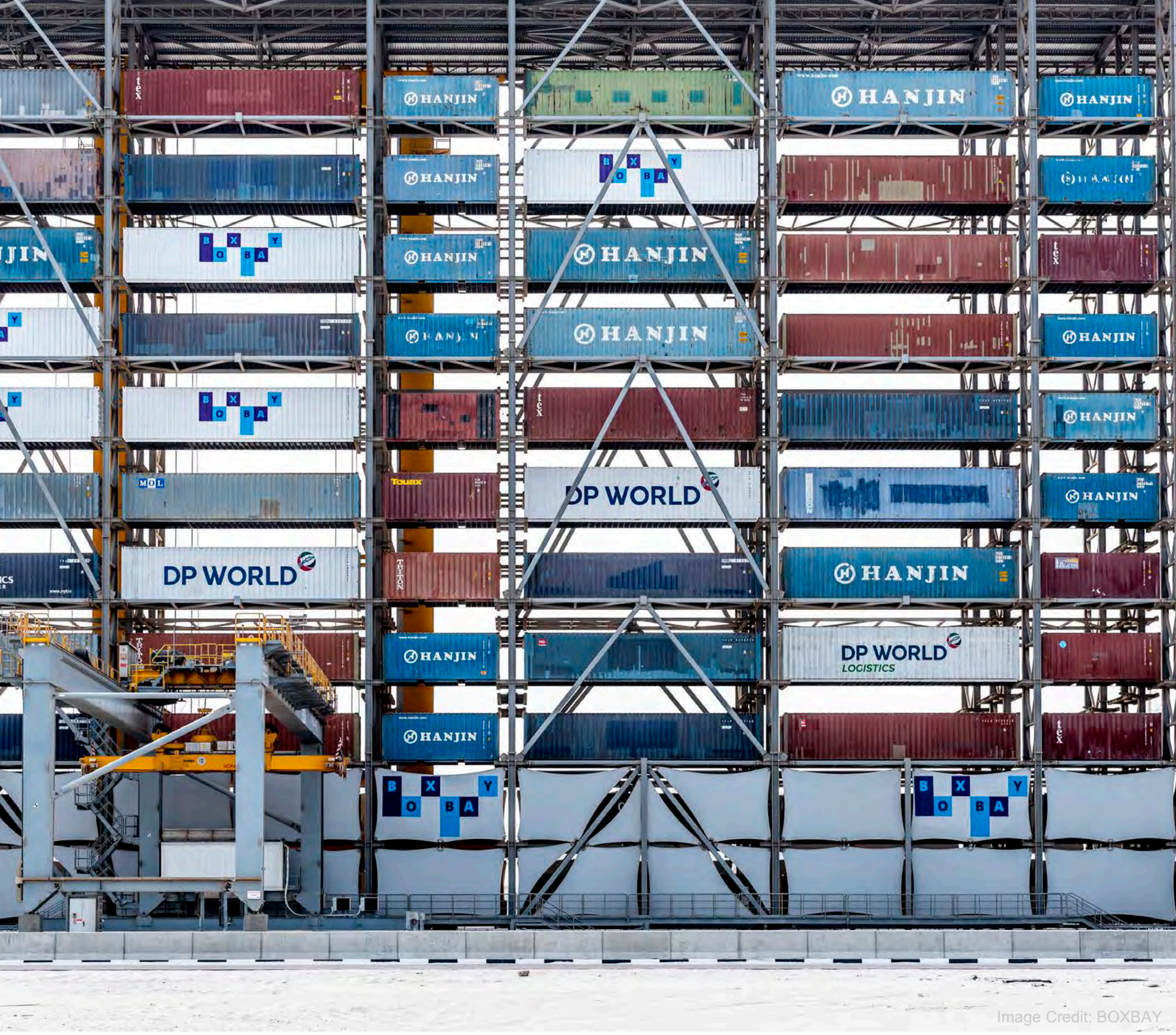


Figure 19
Hydrogen demand by application in 2020 and 2050[133]

6
Repurposing existing infrastructure

As demand for some shipping products changes, and even diminishes in a highly circular economy, countries should plan for how the use of different types of ports, retired ships, and associated facilities could evolve over time and aim to identify opportunities for making use of underutilised assets to generate value. For example, some facilities and port capacity used in the UK today for transporting fossil fuels could be redeployed for construction of offshore wind turbines required to produce electricity and enable green hydrogen production.



Emerging and Speculative Technology: Rethinking space utilisation in ports

Boxbay, Jebel Ali, UAE

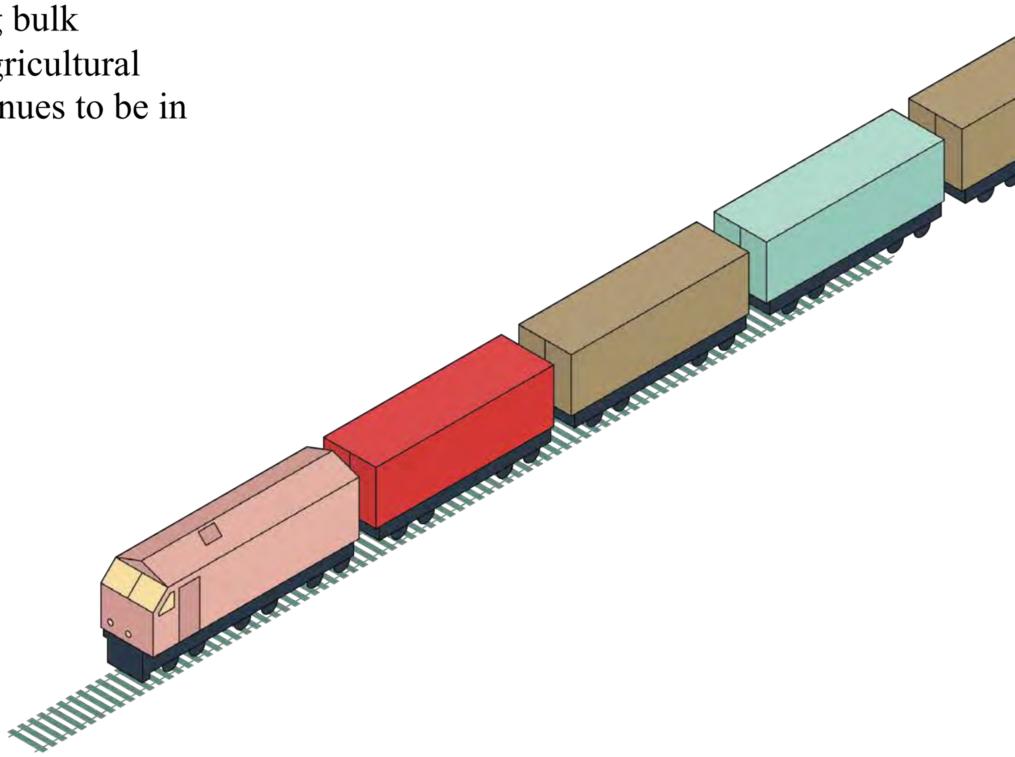
Shippers and port operators are constantly looking for ways to improve efficiency to avoid port congestions. Disruptive technologies such as Boxbay may be part of the solution. Boxbay is a container terminal design concept that aims to optimize space utilisation and operational efficiency at ports by creating an arrangement of shipping containers, stacked in a grid formation, with an automated robotic system for handling and moving the containers.

Its pilot study has been in operation in Jebel Ali in the UAE since 2021 and claims that quayside trans-shipment speeds can be increased by up to 20%.[134] As with most new technologies, the main downside is the significant capital cost but as this technology becomes more mature these costs could prove worthwhile for the operational improvements they promise.

3.5.3 What are the prospects for rail?

The prominence and suitability of rail in the wider freight ecosystem is subject to significant variation under future contextual shifts (i.e., what is transported, how high the volumes are, where goods are coming from and going to), and therefore the role of rail in transporting goods will be highly dependent on coordinated industry, transport, and land use policy and planning. Rail's primary strength in moving large volumes of goods over medium and long distances will continue to be relevant in the face of ongoing shifts. Rail transport will also likely continue being the best option to add major increases in transport capacity on highly congested routes. Rail will continue to play a major role in transporting goods along corridors where freight rail network offer strong service and where demand for transporting bulk commodities, such as staple agricultural products and clean fuels, continues to be in place or experiences growth.

Existing rail freight routes in some parts of the world will also see some reductions in demand, most critically in the case of a decarbonisation and circular economy-oriented world, due to the reduced use of fossil fuels and extracted raw materials such as iron ore. In such cases, planners and developers can repurpose facilities and the location of new industries that may require the transport of heavy goods to places where increasingly underutilised, but functioning rail infrastructure sits.



3.5.3 What are the prospects for rail?

Key considerations, risks and opportunities for future rail based on our study include:

1

Better balancing the prioritisation of freight and passenger rail

Rail freight movement is often driven by the need to transport bulk goods, which differs in origin and destinations from passenger demand for travel. This means that (with the noted exception of 'express freight') some rail infrastructure required for freight facilities can only be justified on the basis of demand for freight transport exclusively, which in many countries is a relatively small market when compared to passenger travel. To ensure adequate rail services exist to transport freight where rail would be most competitive over other modes of transport, governments (or those in charge of planning railway infrastructure) should give freight needs due priority in their long-term plans for railway upgrades and investment. Regulatory frameworks should be put in place to preserve the capacity intended for freight to avoid it being overshadowed by what may ultimately be less critical demands for passenger services.

2

Expanding emphasis on express & mixed passenger/freight rail

Express freight uses either dedicated trains or sections of passenger trains to transport lighter and smaller freight into city centres. This could be retail supplies, food, packages and other similar goods. This has several advantages over sending HGVs and LGVs into major urban centres, including lower environmental impacts. The potential to merge passenger and freight transport onto existing train services should be considered by studying ways to standardise freight capacity on passenger rail service (where possible) and develop systems and methods for processing goods to ensure security to data and items (while encouraging sharing of transport between shippers and suppliers). Standardisation and dedication to express freight services on passenger rail will help give shippers confidence in the long-term viability of this service as a reliable transport option. It can also create a means for rail operators to generate revenue lost from declining ridership due to remote working and digitalisation. Robust sustainable last-mile travel options such as cargo bikes should be considered as part of express rail freight proposals to ensure the transport service offering is integrated up to delivery to the end consumer.

3

New sources of bulk goods in a circular economy

In a circular economy, rail freight will be impacted by a reduction in the use of raw materials. There is likely to be some increase in rail traffic to new major recycling facilities if these are sufficient in scale and specialisation to warrant transport of resources over significant distances. Future industry, waste, and resource circulation strategies and planning should consider rail freight to leverage its efficiency in transporting goods in high volumes between central hubs (e.g., future regional collection and processing centres for different types of materials or waste).

3.5.3 What are the prospects for rail?

4
Ensuring provision of integrated multimodal freight hubs

Intermodal freight hubs that are served by rail and that are well connected to at least one other mode (sea or inland shipping, road) should be developed strategically for countries and regions. Integrated multimodal freight hubs are key to ensuring the optimal utilisation of rail infrastructure, since in most cases rail services will not be able to transport goods for the last mile. Government investment in these hubs is particularly difficult in the UK as multimodal hubs often have a single private sector beneficiary. Resolving conflicts of interest that prevent innovative collaboration between the public and private sector should be a priority for governments and regulators in all places affected by such challenges.

5
Harnessing potential for sustainable freight by rail in high growth markets

Countries and regions of the world experiencing (or that are on the cusp of) major population and economic growth, should consider the role of rail freight as they draw out large-scale infrastructure development plans. Integrated infrastructure to accommodate the movement of goods via rail can help create significant operational efficiencies from a transport perspective, while also embedding environmental considerations from the onset of new anticipated industrial, trade, and consumption activity.

6
Keeping up decarbonisation efforts with other transport modes

As with other modes, decarbonisation of existing rail systems is essential. As set out earlier in this report, rail freight is less carbon intensive than road, and as such is often viewed by governments, the public and others as the environmentally sustainable way to move freight, particularly over land for longer distances. This relative advantage, however, is not set in stone. As an example, most rail freight in the UK is hauled by diesel locomotives, which whilst being less polluting than the equivalent number of HGVs, is not carbon-free. As road vehicles decarbonise, it is critical for rail systems to keep up in adopting and implementing low/zero-carbon operations in order to stay maximally competitive in a market that prioritises carbon reduction.

7
Ensuring compatibility of new systems with freight operations

The equipment required to electrify railway lines can add complexity and cost to the existing infrastructure. Options for designing and upgrading infrastructure as part of decarbonising the existing rail network should be assessed for their compatibility with intermodal operations. For example, ‘first and last mile’ portions of rail journeys may involve the use of cranes to load containers onto wagons, and therefore interfere with standard overhead electrification systems.

8
Preparing for extreme events

Rail infrastructure must be upgraded to make it resilient to major weather events and the other impacts of climate change. Much of the rail infrastructure in places like the UK and the EU is older than the infrastructure associated with other modes of transport. As such it is often not well prepared for the extreme weather events that are expected to occur more frequently in the coming decades as a result of climate change. Strategic development of diversionary routes, as well as the maintenance and upgrading of existing infrastructure is essential to maintain current resilience.

Emerging and Speculative Technology: New form of rail transport

Hyperloop, various locations

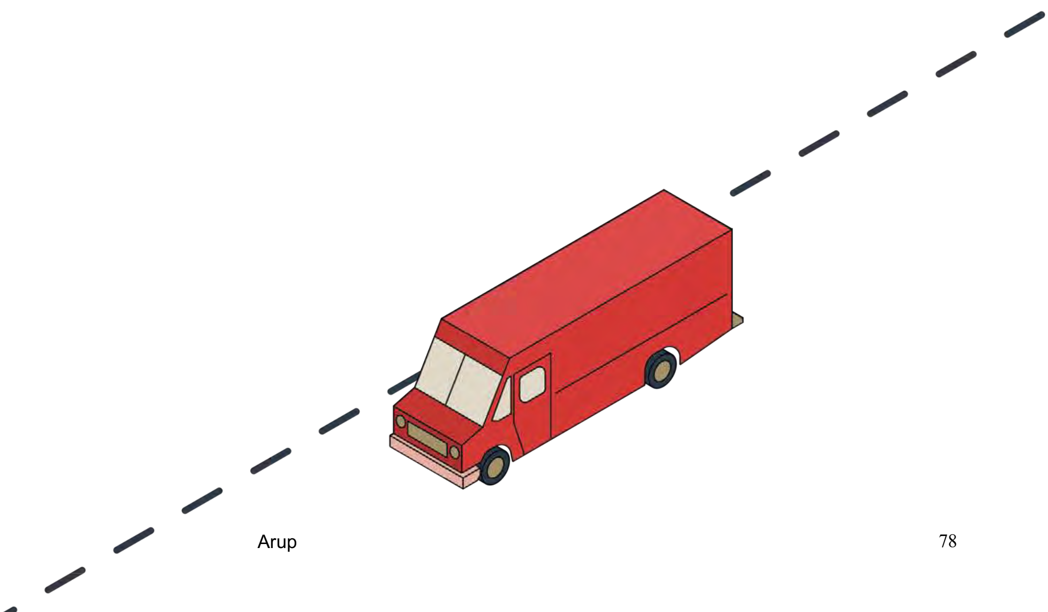
Hyperloop is a proposed mode of transportation that involves using vacuum-sealed tubes or tunnels to transport people or goods at high speeds. It cannot be said that the Hyperloop falls under the category of 'rail', and it is closer to being an evolution of Maglev technology, but in the context of this report it is the closest comparison. The vacuum inside the tubes reduces air resistance, allowing the pods to travel at high speeds, potentially exceeding 600 miles per hour (965 kilometres per hour).

Clearly, the ability to move goods over long distances at almost the speed of sound would be revolutionary and could see land transportation challenging aviation for the movement of high value, time sensitive goods. However, while the Hyperloop is theoretically possible, the engineering challenges surrounding its construction make it quite unfeasible, for now at least.

3.5.4 What are the prospects for road freight (HGVs/LGVs)?

Road transport is and will likely remain a dominant form of freight transport across the world owing to its flexibility, ability to deliver last mile, connectivity arising from existing infrastructure, and the ability to carry smaller loads relatively economically when compared with other modes. Travel patterns between population and employment centres tend to be more stable over time in comparison to the origins and destinations associated with freight. Passenger travel demand has also been relieved to some extent in the post-pandemic world, due to the ability for people to increasingly work remotely a proportion of the time. This arguably makes passenger transport more suitable than freight to be served by fixed route transport modes.

Contrary to the mainstream perspective on 'sustainable freight transport,' (which generally leans towards discouraging road freight) there is a strategic argument centred on identifying corridors where road capacity and the flexibility it offers for transporting goods is more critical for freight than for passenger travel. For such corridors, there should be a greater emphasis on maximising the shift of passenger travel onto rail, buses, and active modes of travel, and using leftover road capacity (as efficiently as possible) for the movement of goods, particularly as road vehicles decarbonise at a faster pace.



3.5.4 What are the prospects for road freight (HGVs/LGVs)?

Key considerations, risks and opportunities for future road transport based on our study are as follows:

1
Offer flexible transport capacity

Road freight is arguably easier to increase and decrease in capacity (re-deploy road freight vehicles to other regions) as demand along corridors shifts. This implies that road freight could be used to serve demand to transport more volatile forms of freight, such as, for example, new types of consumer goods witnessing sharp demand, and more 'temporary' forms of goods movement such as construction material for major project sites, etc., where existing rail infrastructure is not in place or an attractive option. The proliferation of autonomous vehicles and dynamic management of major roads could also increase available capacity on roads over time, reducing the overall need for road expansion to accommodate increased activity.

2
Coordinated policy and implementation for decarbonisation

Road freight transport is highly private-sector-led, but if it is to decarbonise as needed to align with net zero commitments, wider coordination in planning is needed to enable adequate provision of the infrastructure required for hydrogen/EVs. Governments and organisations with major cross-border road freight flows should coordinate to promote common technologies for things like traffic management, autonomous vehicles, and critically, types of fuel. As an example, the UK is currently behind some EU member states in regulation and mechanisms to support hydrogen as an alternative zero-carbon fuel. If implementation of fuelling points for HGVs also lags, this would cause challenges for vehicles traversing the two regions and potentially slow the speed of the planned energy transition.

3
Comprehensive resilience

One of road transport's greatest inherent assets is its resilience. Most countries which are major goods producers or consumers have significant road networks with diversionary routes between major areas of production and consumption. However, recent challenges across nations globally relating to shortage of freight drivers or overflowing customs queues at airports, show that resilience is not just about infrastructure – labour and operational constraints are key to consider and plan for, given the high number of people required to drive the volume of trucks needed for a trading economy. Investment in and development of autonomous vehicles may reduce this dependency, and governments can facilitate the resilience benefits of new technology by progressing and expediting trials and regulatory reforms so that new solutions can be deployed with minimal delay.

4
New competitive landscape

The average length of HGV haul in the UK is currently 108km[135], and road freight is expected to continue to play a prominent role in moving goods over such distances. However, inland and short sea shipping and rail will also increasingly compete with road freight over medium distanced trips (where capacity and infrastructure for these modes is available) on the basis of having lower carbon intensity, and as their operators adopt new operating models to attract shippers.

5
Sharing information and deploying technology

Alongside rapid decarbonisation of road vehicles, road freight can align well with the global vision for sustainability and net zero if the sector is able to capitalise on innovative digital platforms and maximise vehicle sharing and information across shippers to increase vehicle load factors and minimise empty trips. A 50% increase in the load of a high-tonnage vehicle increases energy efficiency by approximately 37%.[136]

6
Support facilities and intermodal urban hubs

Road freight network planning should more consistently include provision of facilities such as logistics transfer hubs, particularly in or near urban areas to allow for transfer from HGVs to LGVs, cargo bikes, and other forms of more flexible and agile urban transport modes to avoid the impacts of large vehicles in urban centres.

Emerging and Speculative Technology: Underground freight networks

Boring Company, various locations, USA

One way that road freight could be disrupted in the coming years is by reimagining not what the mode looks like but rather what the infrastructure itself looks like. Underground freight transport has been subject to numerous studies over the years due to its potential to ease congestion, improve traffic safety, reduce pollution and make better use of public space.

Projects to build such tunnels remain in their infancy, but high profile attempts, such as Elon Musk's 'Boring Company' (now valued at $5.7 billion) could see it come to fruition. The main stumbling block for this as a means of transporting goods is the enormous capital costs compared with using existing road infrastructure.

3.5.5 What are the prospects for aviation?

The aviation industry's ability to connect the world at the speed, comfort, and affordability attained to date is undeniably attractive for the world's economy, collaboration, and for the accessibility it offers to both remote places and goods. Due to aviation's focus on light but high value goods, its economic role is far more significant than the volumes it carries would suggest. In a world oriented around sustainability and consumption consciousness, the role for aviation in the movement of goods over the coming decades is likely to continue to be limited to time sensitive, critical goods, and, if anything, in lower quantities on average than previously seen. In a more high-growth future world, potentially with some breakthrough in sustainable aviation fuels at scale, the quantities of freight transported via air could expand to some degree – but given that the cost of travel via air is likely to remain higher than other modes, air freight in the future will most likely continue to be limited to high value and time sensitive goods.

It is worth noting that aviation here refers to the transport of goods by aeroplanes (whether or not these are fully dedicated freight services) but other airborne concepts have the potential to play a role in the movement of goods.

3.5.5 What are the prospects for aviation?

Key considerations, risks and opportunities for future aviation based on our study are as follows:

1
Prioritising innovation towards net zero aviation
Net zero aviation relies on significant and uncertain technological advances such as zero carbon aviation fuel and/or transformational improvements to battery technology. Innovation in decarbonising aviation should be prioritised by decision makers. A framework including taxes or charges for continued use of carbon intensive fuel or aircraft should be put in place to encourage sustainable aviation – either through demand management (shifting people and goods onto other modes where they are more environmentally friendly) or through tangible impetus for the industry to invest in innovative solutions to decarbonise its operations.

2
Reassessing demand for air freight in a low consumption world
Like all other modes, aviation will need to adapt to serving fluctuating demand (growth in some parts of the world and plateauing or even decline in others). Policymakers in locations with growing demand for air freight will need to decide how air travel aligns with wider environmental objectives, and weigh the benefits of air services against the impact both in terms of emissions arising from the flights themselves, but also the environmental impact of any required infrastructure.

Emerging and Speculative Technology: VTOL aircraft

Worldwide

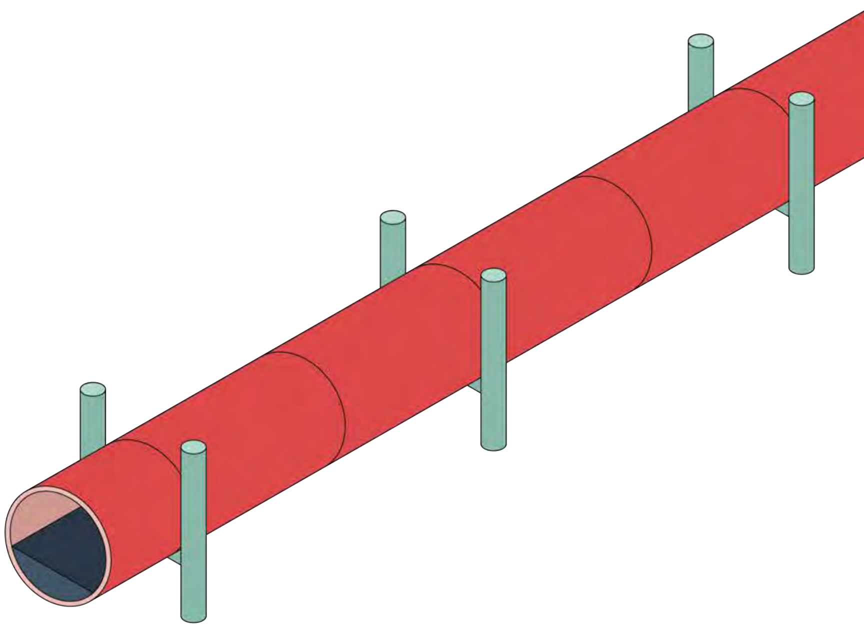
Vertical take-off and landing VTOL aircraft have the potential to move goods in the future due to their ability to take off and land in areas where there is limited space for runways, such as in urban areas. VTOLs come in many shapes and sizes from small drones, to helicopters, all the way up to dirigibles and do not require very much (if any) fixed infrastructure making them potentially very useful for delivering goods to densely populated areas where ground transportation may be slow or congested or to very remote areas that are disconnected from infrastructure networks.

While traditional helicopters are technically VTOL aircraft, they are currently too expensive to be a feasible way of moving goods. However, the rollout of smaller VTOLs for the movement of goods and people should make the cost significantly less. Several companies are currently developing VTOL aircraft for the transport of goods, such as Wingcopter, Volansi, and Bell. These aircraft are typically designed to carry small packages or payloads over short distances, but there is potential for larger VTOL aircraft to be developed in the future for longer-range cargo transport.

3.5.6 What are the prospects for pipelines?

Pipelines offer a safe and efficient way to transport certain liquids and gases without the use of vehicles, but they lack the flexibility of other modes which can carry liquids, gases and other forms of freight. As pipelines are almost solely used in the fossil fuels industry their role will need to evolve significantly if they are to remain in common use in a net zero scenario. The future of pipelines is therefore highly dependent on the future of hydrogen. Pipelines can be used to transport hydrogen and other clean fuels where volumes are significant.

This will remove the need for large numbers of vehicles to transport these fuels, freeing up capacity within those more flexible transport modes for other uses.



3.5.6 What are the prospects for pipelines?

Key considerations, risks and opportunities for future pipelines based on our study are as follows:

1
Coherent planning for repurposing existing pipelines

Some hydrogen flows will be similar to those of fossil fuels, meaning that pipelines which are seeing declining utilisation can potentially be converted to transport hydrogen cleanly and efficiently, maximising the utilisation of a fixed asset that was financially (and in some cases environmentally) costly to deliver. This may need multinational cooperation where pipelines cross borders and serve multiple countries, especially where there is some remaining fossil fuel usage and an agreement is needed to switch over.

2
Guard against overreliance on key conduits

In a future with less political and climate stability, the use of pipelines can run the risk of dependency on particular providers and infrastructure that can be easily disrupted. This would pose a key risk, irrespective of whether a pipeline is repurposed to carry clean fuels.

3
Assess environmental cost of new pipelines

Like other fixed infrastructure, the construction of pipelines can have a significant environmental cost which is more tangible than (for example) the impact of transporting the flow via rail using existing infrastructure. The construction of new pipelines for clean fuels should therefore be considered with this trade off in mind.

Moving Forward

As set out in this report, ongoing and anticipated major trends will drive transformation in the world economy in ways that are very different from the last century which has generally been a case of more of everything: extraction, production, consumption, disposal - often in an unsustainable manner. Alongside technological developments, growth has been facilitated by increasingly complex supply chains and ever greater movement of goods across a constantly evolving web of flows. The benefits this has brought are undeniable, but the negative impacts are increasingly being realised and felt.

In the context of these trends and the driving imperative to move towards a more sustainable model for using the world's resources, this report has explained the ways in which the movement of goods must change to fulfil its ongoing vital role within the world economy. This includes:

1
Adaptation to serve more sustainable and circular patterns of consumption,

2
Increased resilience of supply chains for critical goods,

3
Decarbonisation of all modes of goods movement and adoption of other new technologies to increase efficiency,

4
Holistic planning of major flows to incorporate environmental impacts,

5
Careful planning of future infrastructure, including (re)use of existing assets.

Overlooking some of the major shifts which could shape the future demands on freight, and continuing the business-as-usual patterns for delivering freight services would likely risk giving way to a period characterised by increased impacts of climate change, disruption to supply chains, misdirected spending on critical infrastructure which lacks resilience to external shocks, and diminishing security of supply of critical goods for consumers. This will impede the world's ability to implement other vital measures by creating diversion in other efforts and investments which deal with crises, and make it more difficult to deliver other major infrastructure change such as that required for the energy transition.

The currently complex and fragmented nature of the global freight industry means that it is not set up to respond to these unprecedented types of change in a coordinated manner. Some changes can be made by market forces, but the findings of this report are that in many critical areas, a cross-modal and cross-border approach to develop national and regional strategies which inform freight planning and investment would significantly strengthen the future goods movement network. Greater coordination is required between and across industries and governments to provide the freight industry with a framework in which it can effectively manage and react to change. Key areas where this coordination is most needed are regulation, and in particular, the development of incentives to encourage adoption of lower and zero-carbon technologies, planning, funding and financing of necessary infrastructure changes, and the rollout of industrial polices which fully consider the benefits of simpler supply chains.

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About Arup

Dedicated to sustainable development, Arup is a collective of designers, consultants, and experts working globally. Founded to be humane and excellent, we collaborate with our clients and partners using imagination, technology, and rigour to shape a better world.

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