06

Impact Series

Oil in 3D: the demand outlook to 2050

Barclays investigates the world's continued reliance on oil in the next few decades, and considers consumption in three potential scenarios

BARCLAYS

Foreword

Welcome to the sixth report in our Impact Series, in which the Barclays Research team turns the spotlight on the potential paths for global demand for oil in the decades out to 2050.

May 7, 2019

The energy industry is essential to almost all economic and human activity, and lies at the heart of both important opportunities and challenges faced by the world today. The sector provides power, transport, heating and supports industry and livelihoods in just about all communities, globally. However, it is also one of the key sources of carbon-related emissions.

Climate change represents one of the greatest challenges faced today and the scientific community has set out the changes society, including the participation of government, civil society and business, must make to help combat it. The Intergovernmental Panel on Climate Change (IPCC) has identified the need to limit temperature increases to less than 2°C above pre-industrial levels, but has identified that efforts to limit increases to 1.5°C would help further reduce impact and mitigate risks. The success, or otherwise, of these efforts is set to have a material impact on the evolution of how much energy we use in the future, and how that energy is produced.

The global energy sector is already changing rapidly: it is embracing new technology, data-driven efficiency solutions, and is increasingly reliant on renewable energy. Alternatives to oil do exist in many sectors, but not yet at the scale demanded by growing populations and economies across a complex global energy system.

This report explores how the energy landscape could evolve over the coming decades, and specifically, how much oil – currently the largest source of energy – the world might consume by 2050, in three different scenarios.

Advances in renewable energy, technological innovation, and strict low-carbon policies will play a critically important role over the next 30 years, but oil is likely to remain a significant part of the energy mix over this timeline.

We hope you find our analysis enlightening and thought-provoking.

Jeffrey Meli
Global Head of Research

Introduction: More energy needed, but in a lower carbon way

The need to provide sufficient, affordable, reliable, low-carbon energy to a growing population is one of the world's most pressing challenges.

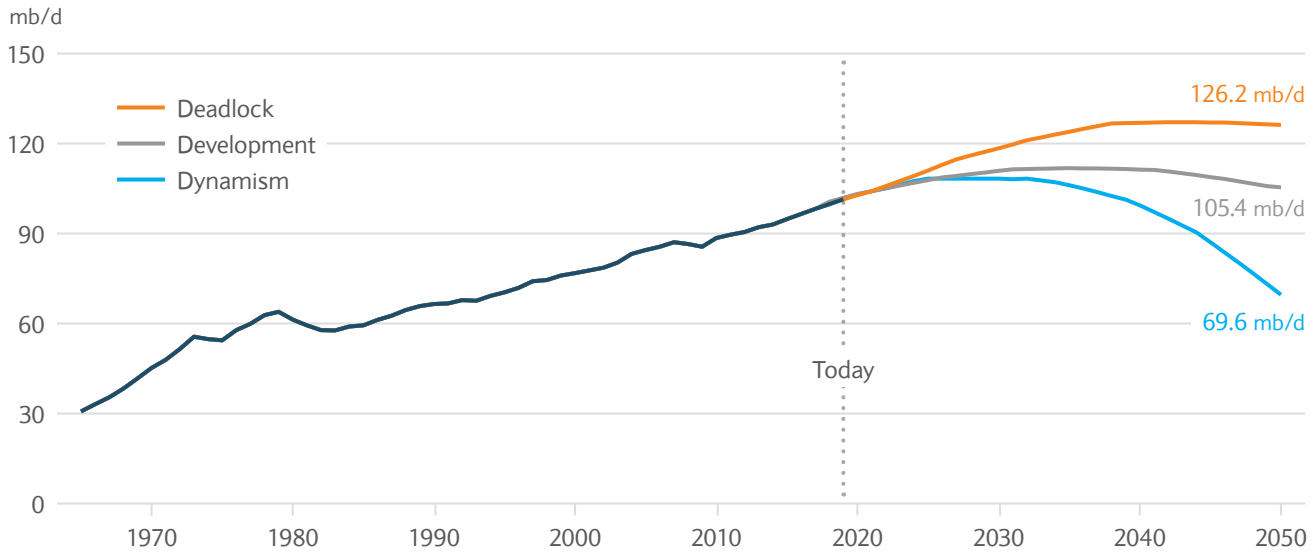
Ambitions of achieving carbon emissions that limit global warming initially to 2 degrees Celsius, and ultimately to 1.5 degrees above pre-industrial levels, have come into sharp focus with governments and investors alike. Our analysis shows that the global energy system is not yet on the pathway to achieving the pledge to limit the increase in global temperatures to 2 degrees this century, let alone the revised target of 1.5 degrees. Immediate action on all areas including carbon pricing, energy efficiency, greater use of renewables, and electrification will be needed, requiring not only stricter policy enforcement but also a rapid change in consumer habits, with a significantly reduced reliance on fossil fuels such as oil, coal, and gas also a necessity.

Close to 70% of global greenhouse gas emissions are generated by the energy industry.[1] Oil still makes up the largest part of the global energy mix and for that reason this *Impact Series* report investigates how demand for oil is likely to evolve over the next few decades, what it could mean for the overall energy mix and for global emission-reduction ambitions — set out by world leaders at the Paris Conference of the Parties (COP21) in 2015 — to limit global warming to 1.5 degrees. To frame this analysis, we create three broad scenarios of consumption, driven by policy regulation and consumer behaviour. We call these three scenarios, our '3Ds', Dynamism, Deadlock, and Development. In this note, our sector analysts also look in detail at the main drivers of oil demand across several key industries – autos, trucks, aviation and maritime, petrochemicals, and power – and how they might play out between now and 2050.

Oil demand has increased by 30% over the past 20 years, and the next 20 years are likely to prove crucial, with reliance on oil expected to peak between 2030 and 2035 if countries stick to their current low-carbon pledges, although that peak could come as soon as 2025 if the world was to increase its focus on reducing emissions. Based on current policies the more likely outcome is that oil demand stagnates out to 2050, as increased use of petrochemicals offsets the electrification of transport.

FIGURE 1

Potential evolution of oil demand 1965-2050 in our '3D' scenarios



Source: BP Statistical Review for historic data. All other data and forward looking estimates are sourced Barclays Research

1 Total: Integrating Climate Into Our Strategy (September 2018)

Key findings of this report

Our research analyses future demand for oil in three potential scenarios. Our main conclusions are as follows:

- Renewables are the most rapidly growing part of the energy mix, under all scenarios
- Oil consumption is likely to peak between 2030 and 2035, with a long plateau period thereafter
- In a world in which controlling emissions is given a primary focus, this peak could come earlier, as soon as 2025
- Depending on the scenario, oil demand could range between 70 million barrels per day (mb/d) to close to 130 mb/d by 2050
- This compares to current demand of nearly 100 mb/d
- Petrochemical demand is expected to increase under all three scenarios
- Oil is expected to remain a large part of the energy mix, even under our low emissions scenario

Key drivers behind energy demand – now and in the future

A growing, wealthier global population will ultimately have higher energy requirements. How that energy is provided will be determined by choices made by governments, corporates, and consumers alike

We base our report on the following assumptions:

- Growing population: 9 billion people worldwide by 2040 and 9.7bn by 2050, compared to 7.5bn today
- Increases in GDP per capita: Base line growth of 1.7% per annum, ranging from 1.5% to 2.2% in our deadlock and dynamism scenarios, respectively
- GDP growth: Combination implies total base line GDP growth of 2.6% pa, ranging from 2.4% to 3.1%
- 1 billion people without access to electricity in 2018 heading towards <200 million by 2050.

We expect these factors to be offset by increased energy efficiency through regulation, policy and technology. Energy demand has increased by an average of 1.7% per year in the past decade, compared to average GDP growth of 2.6% per year – essentially 65% of the rate of GDP growth and we expect this ratio to fall to 50% in our central scenario

The future of energy in 3Ds

Although there is a vast array of possible outcomes for future oil demand, this report looks at potential outcomes through three scenarios, which we call our '3Ds': Dynamism, Development, and Deadlock.

We make several assumptions about global efforts to reduce carbon emissions over the next few decades through technologies and climate policies. Our assumptions do not take into account the potential impact of other variables on energy demand, such as the effects of short-term price spikes, black-swan (an occurrence beyond that which we could reasonably be expected to predict) economic or geopolitical events, or step-changes in energy (for example, nuclear fusion), material, or transportation technologies.

Prices and policies are set to vary markedly in each scenario and our underlying price assumptions are similar to those presented in the International Energy Agency's (IEA) World Energy Outlook.[2]

The three scenarios we use are:

Dynamism

Our best-case scenario for carbon emissions is characterised by aggressive policies and technology uptake combined with rapid electrification. It reflects a concerted effort to limit global warming to below 2 degrees this century, with 1.5 degrees the ultimate goal, in line with pledges made by signatories of the Paris Climate Accords.

This model assumes that industries and countries prioritise long-term investments in efficiency, technology, and low-carbon alternatives rather than short-term gains. It assumes widespread adoption of energy-efficient technologies, an aggressive transition to electric and hybrid vehicle engines, and greater uptake of low-carbon alternatives in infrastructure, buildings, and industrial materials. These assumptions are underpinned by a decrease in petrochemical products as plastics recycling and the use of alternative base materials increase.

These forecasts could prove to be conservative if radical (and as yet unknown) new technologies and processes speed up the transition to low-carbon energy even further. It also could prove conservative if, in a reversal of today's nationalistic tendencies, governments adopt more aggressive policies on carbon targets, vehicle standards, and plastic use. Breakthroughs in jet-fuel efficiency and alternative aeroplane technologies could also accelerate the transition to a low-carbon economy. Lastly, our Dynamism scenario also assumes significant carbon capture and storage from 2040 onwards.

2 World Energy Outlook 2018 – International Energy Agency

Development

This is our "business-as-usual" scenario, and reflects current emissions policies. Our modelling assumes that industries and countries continue to tighten environmental policies more rapidly than currently. It foresees an increase in energy efficiency and progress towards a low-carbon economy, but not enough to deliver the "two-degree" pledge. Cars, infrastructure, and industrial materials are expected to use less oil, but this will be countered by growth in demand for petrochemical products, truck transport, and airlines.

This outlook assumes a return to more centrist government policies, with economic and environmental policies prioritising economic development, job growth, and national security, without an over-emphasis on environmental regulations and efficiency. It further assumes that the European Union continues to lead the transition to low-carbon energy and electric vehicles by 2050; that Asian countries speed up low-carbon adoption (but not at the expense of economic growth); and that the US uptake of renewable energy and the shift from coal to natural gas for power generation continue.

Technological development and uptake continues in the Development scenario, while the adoption of step-change environmental strategies, such as the Green New Deal in the US, could impact hydrocarbon production. Slower economic growth is the main risk from an energy transition standpoint in this scenario.

Deadlock

In our worst-case scenario for emissions, the world still experiences modest economic growth, but is held back by trade wars, little technological adoption, and a lack of political will to prioritise low-carbon policies. In this scenario, we expect a reversal of current trends towards more sustainable economies in favour of near-term, low-cost transportation and industrial solutions. It also assumes a limited focus on low-carbon policies.

These assumptions could be negated if energy efficiency trends continue, economic growth slows and international environmental activism picks up. Due to the pace of technological development and the heightened focus on environmental issues by companies and individuals, we think there is limited upside risk in our Deadlock scenario, with more scope for the energy transition as decarbonisation increases.

Key assumptions

Dynamism

GDP growth: Slower initial growth, accelerating to 3.1% per year.

Energy intensity: The energy-GDP growth ratio falls from 65% today to 30% by 2050.

Electrification: Electricity as a proportion of primary energy demand to rise from 17% currently to 35%.

Renewables assumptions: By 2050 renewables make up close to 40% of the energy mix.

Carbon capture and storage: Large-scale carbon capture and storage in excess of 10 million tonnes is required from 2045.

Development

GDP growth: In line with historic average at 2.6%.

Energy Intensity: The energy-GDP growth ratio falls to 50%.

Electrification: Electricity reaches 25% of the energy mix by 2050.

Renewables assumptions: Renewables as a proportion of the energy mix grow from close to 5% currently to 30% by 2050.

Carbon capture and storage: Storage capability of less than 5 million tonnes by 2050.

Deadlock

GDP growth: Lower than historic averages at 2.4% pa.

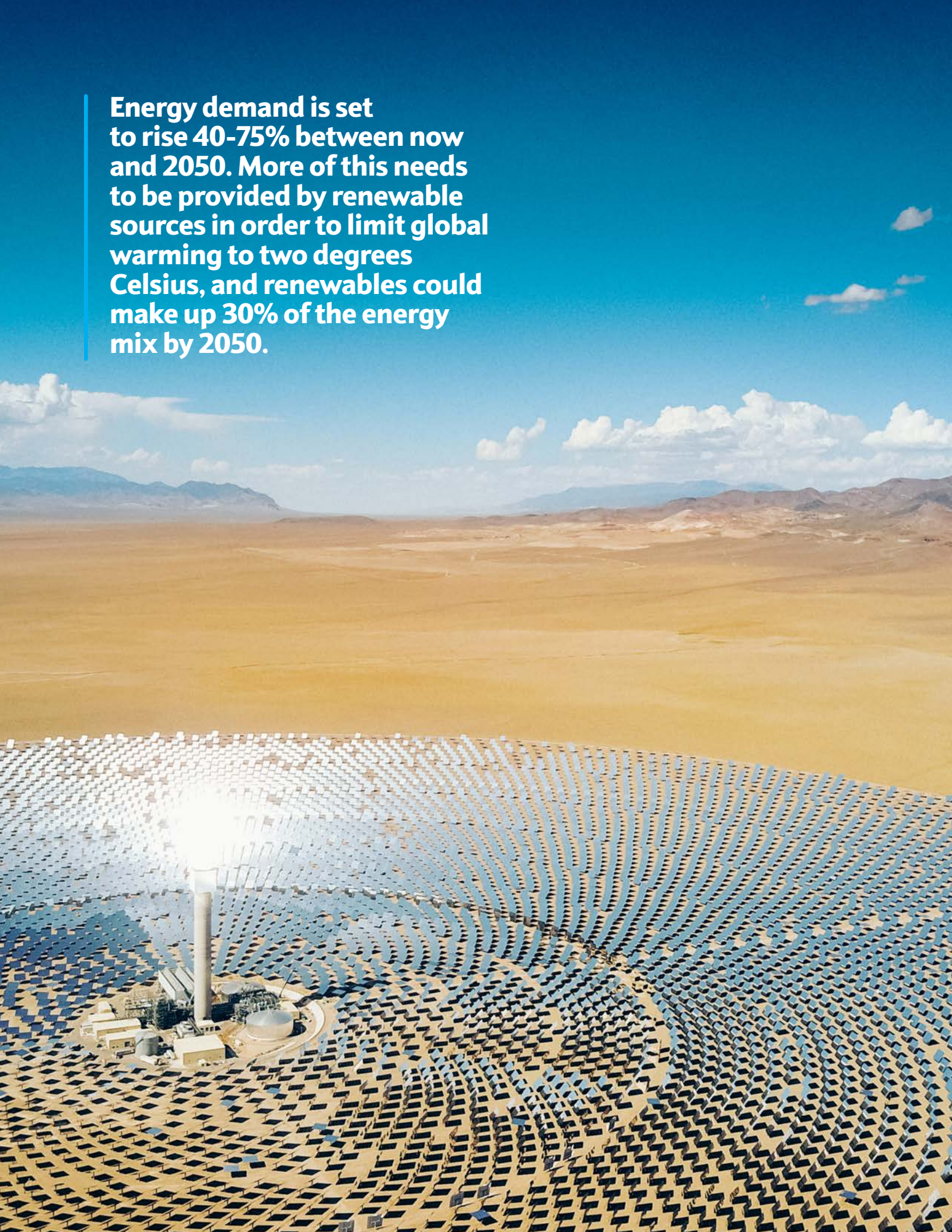
Energy intensity: The energy-GDP growth ratio falls slightly to 60%.

Electrification: Electricity reaches 20% of the energy mix by 2050.

Renewables assumptions: Renewables grow from close to 5% of the energy mix currently to over 15% of the total mix by 2050.

Carbon capture and storage: Not significant

Energy demand is set to rise 40-75% between now and 2050. More of this needs to be provided by renewable sources in order to limit global warming to two degrees Celsius, and renewables could make up 30% of the energy mix by 2050.



More energy, different pathways

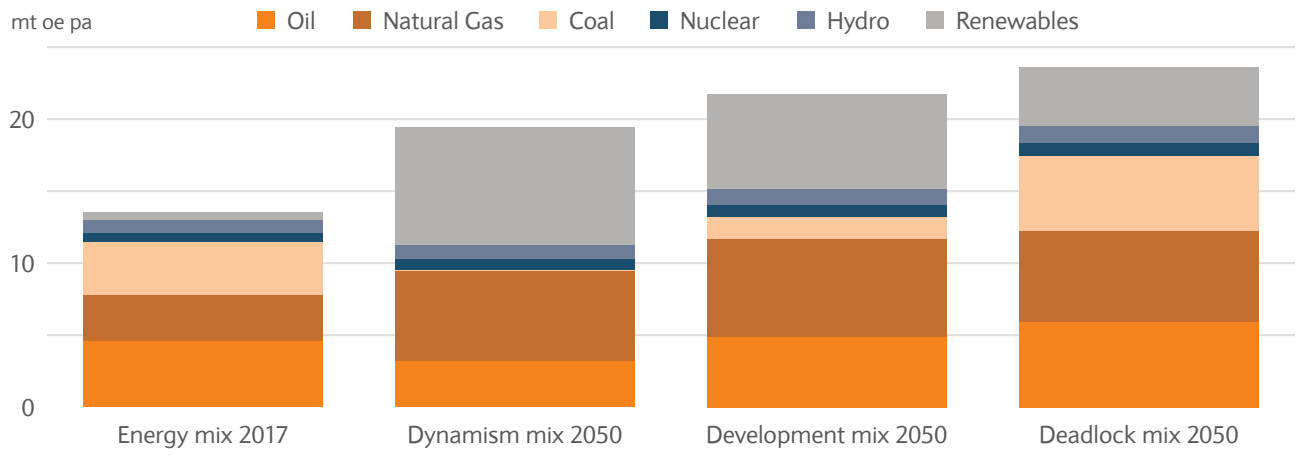
These scenarios are just three of a wide spectrum of possibilities about how energy demand could evolve over the next 30 years. The chart below compares the outcome for absolute energy demand and the mix in the 3D scenarios. Energy demand rises in each outcome by between 40% and 75%, but the reality remains that total oil and natural gas demand will be higher in absolute terms than today. Natural gas and renewables will gain most market share. This is consistent with the outlook from most large cap energy companies, whose strategies are changing to reflect this.

Energy demand and the impact on the climate

The global challenge is how to meet these energy requirements in a low-carbon manner. We have designed our Dynamism scenario to be within the carbon budget necessary to limit global warming by 2 degrees Celsius, in which carbon capture and storage technology is deployed on a large scale basis from 2040 onwards. In our Development and Deadlock scenarios societal changes are too slow to keep carbon emissions within the desired range. We show the cumulative emissions compared to estimates of carbon budgets to keep warming at both 1.5 degrees and 2 degrees below.

FIGURE 2

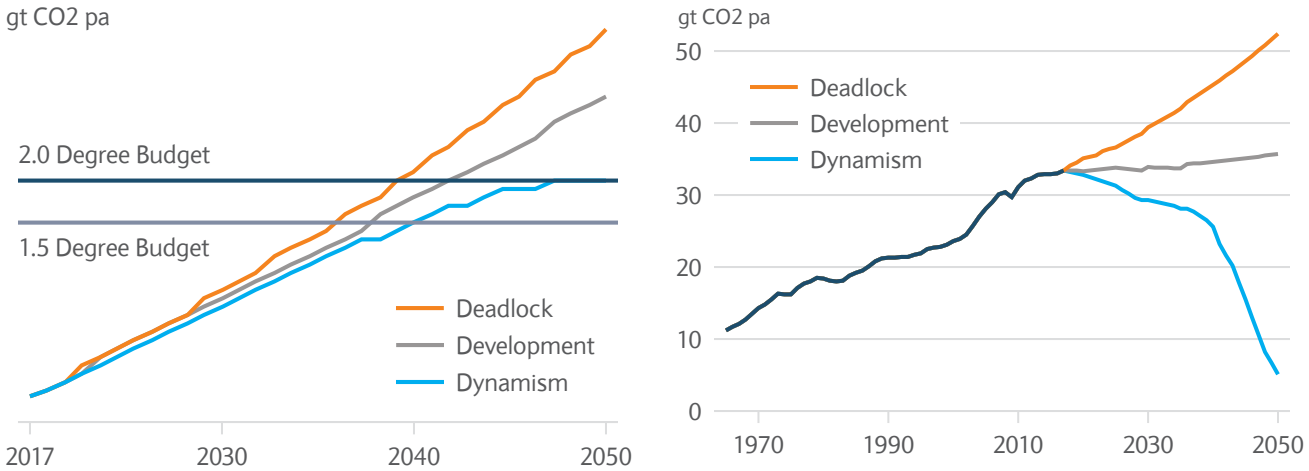
Energy mix by type, and across our 3D scenarios, 2050



Source: BP Statistical Review for historic data, Barclays Research estimates for 2050, mt oe pa refers to million tonnes of oil equivalent per annum

FIGURE 3

Cumulative CO2 emissions vs. carbon budget and per year budgets



Source: BP Statistical Review for historic energy related CO2 emissions. UN IPCC [3] used as a basis for carbon budget estimates. All other data and forward-looking estimates are sourced Barclays Research.

3 IPCC Special Report: Global Warming of 1.5 degrees C

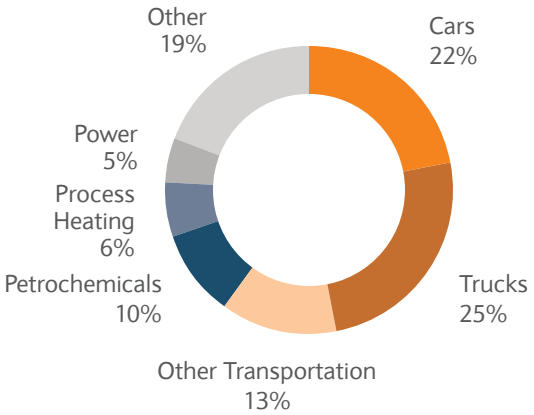
Which sector will have the greatest demand for oil by 2050?

The world in 2050 will undoubtedly look very different to today, particularly if the IPCC ambitions are to be met. However, oil is highly likely to continue to play a substantial role in the energy mix and how the current largest source of world energy evolves will be important to government, corporate, and investor decisions.

We outline the current demand for oil by sector in figure 4. In figure 5 we show how we see this demand mix out to 2050 across our 3Ds.

FIGURE 4

Current global oil demand by sector – 2017



Source: Barclays Research. 'Other' refers to buildings, agriculture, transformation and other non-energy use, mainly bitumen and lubricants

Our key takeaways from this analysis are:

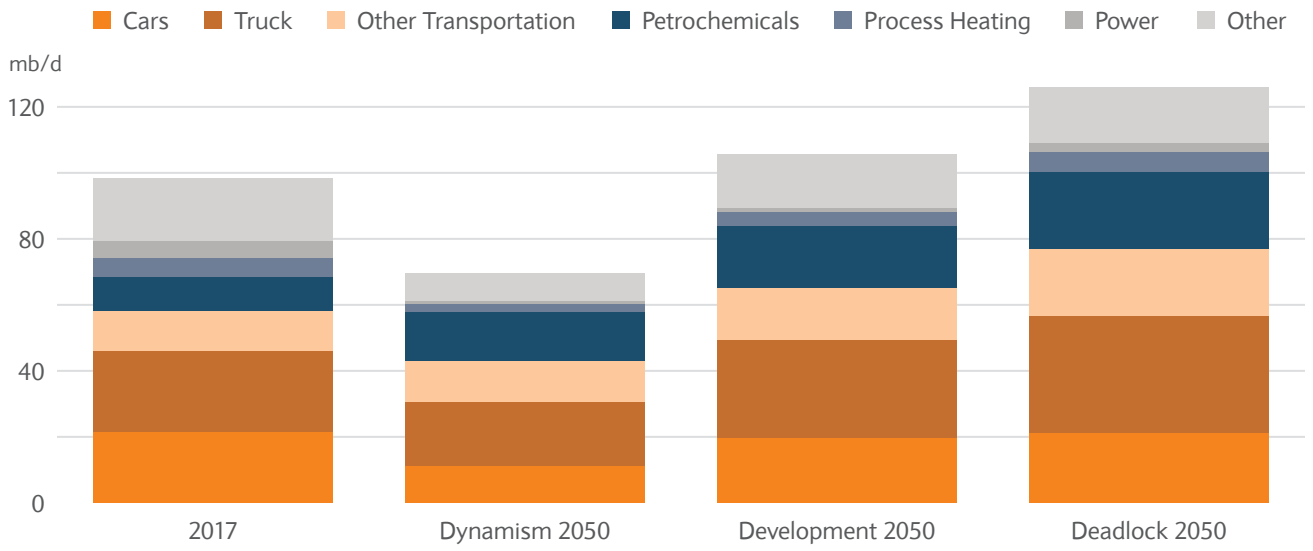
- In our Dynamism scenario oil demand could fall by more than 30% between 2017-2050, peaking as early as 2025.
- In our Development scenario oil demand plateaus between 2030-2045, with 2050 volumes almost unchanged from today's levels.
- In our Deadlock scenario demand could grow by more than 25% from today's levels, to over 125 million barrels per day in 2050.

From a sectoral demand perspective, the four key trends we identify are:

- **Petrochemicals will be the fastest source of growth.** Under each of our scenarios petrochemicals would represent the second-largest sector in terms of oil demand. In our Dynamism scenario, petrochemicals account for 23% of oil consumption in 2050, up from around 10% today. With this will come a greater need for recycling and reduced use of single-use plastic.
- **The importance of passenger cars for oil demand is likely to decrease under all three of our scenarios.** Passenger cars constitute just 17% of oil demand by 2050 in our Dynamism case, down from around 22% today. The biggest driver of this change is not the rise of electric vehicles, but an improved efficiency of the internal combustion engine.
- **It remains highly unlikely that a large-scale replacement for jet fuel will emerge any time soon.** This means that the Other Transportation (Aviation and Maritime) sector will make up a larger portion of oil's demand mix, particularly in our Dynamism scenario, which sees oil demand for Cars drop off substantially. Improvements in bio-jet help, but cannot contain materially higher passenger demand.
- **Strong growth in the global trucking fleet** is likely to increase oil demand from this division, despite potentially aggressive efficiency gains and the adoption of electric vehicles.

FIGURE 5

What oil demand could look like in 2050

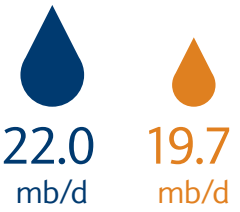


Source: IEA World Energy Outlook, BP Statistical Review for historic data, Barclays Research estimates for 2050

We predict that these four consumption trends will dominate

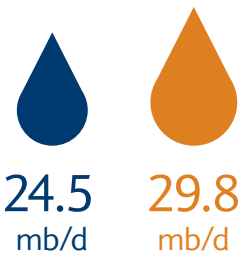
Current **2050E**

Mb/d = million barrels per day



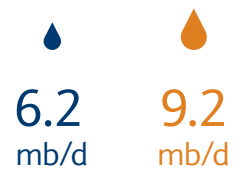
Passenger cars will need less oil.

There will be more cars on the road, but with greater fuel efficiency and increased uptake of electric vehicles.



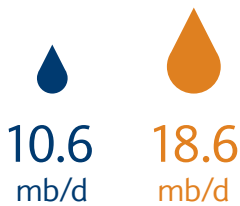
The global trucking fleet will increase, tied to global economic growth.

Despite potential efficiency gains and adoption of electric vehicles over time, 97% of the current trucking fleet is still powered by gasoline and diesel.



It remains highly unlikely that a large-scale replacement for jet fuel will emerge any time soon.

As the demand for air travel grows, the Aviation sector will place greater demand on oil supplies.



Petrochemicals will continue to grow.

As the base for all plastics and much else, the demand for petrochemicals has increased over 50% in the last 10 years. As the world economy and the global population continue to grow, this sector is expected to overtake transportation in the 2020s or 2030s as the biggest contributor to oil consumption.

Source: Barclays Research

Is a supply-demand imbalance coming?

The growth in electric vehicles, momentum for increased plastics recycling, as well as interest in other initiatives and policies are all positive steps towards a more sustainable future.

Yet our analysis shows that oil and gas will remain a material part of the energy mix in any scenario out to 2050: the future of supply is therefore as critical to the outlook as demand. This situation will create both opportunities and challenges for the incumbent oil and gas producers.

In contrast to other natural resources, oil and gas (oil in particular) has what is termed a "natural decline rate". As resources are produced from each field the pressure drops and each year the same field produces less and less volume.

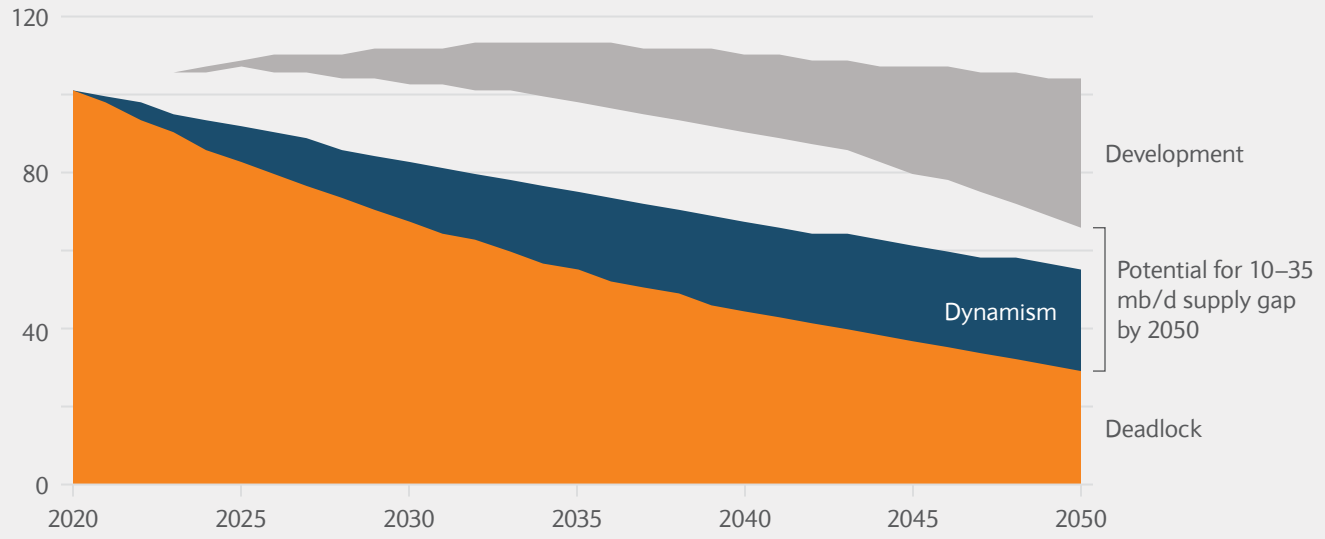
As such, if investment were to cease today the existing stock could deplete to produce only 20mb/d by 2050. As seen in figure 6, even under our current Dynamism scenario (which sees oil demand fall by more than 30% by 2050), without ongoing investment we expect there will simply not be enough supply to satisfy demand.

Uncertainty over the long-run demand levels has the potential to cause meaningful price volatility. Our own analysis shows that to avoid a price spike, investment in oil and gas production is still needed, even in our Dynamism scenario, in order to replace the volumes lost to natural decline. As such, it is reasonable to expect the industry to continue to explore and show material investment.

In the following section we investigate in more detail the demand for oil by sector: Cars, Trucks, Petrochemicals, Other Transportation, and Power.

FIGURE 6

Oil supply and demand forecast based on Barclays long-term scenarios



Source: Barclays Research

Sector Outlook: Cars

Current oil consumption:
22 million barrels per day

Likely consumption by 2050:
20 million barrels per day

How will the evolution in the Cars sector impact oil demand?

Today there are close to 1 billion cars on the world's roads, consuming about 22 million barrels of oil per day, compared with total global oil demand of 98 million barrels per day. Passenger cars therefore account for c.22% of total demand – the second-largest individual sector after Trucking.

Many factors determine how much oil these vehicles will demand in the coming decades, but in our view the three most important are:

- The absolute number of cars on the road
- Fuel efficiency of internal combustion engines
- Take up of electric vehicles (EVs)

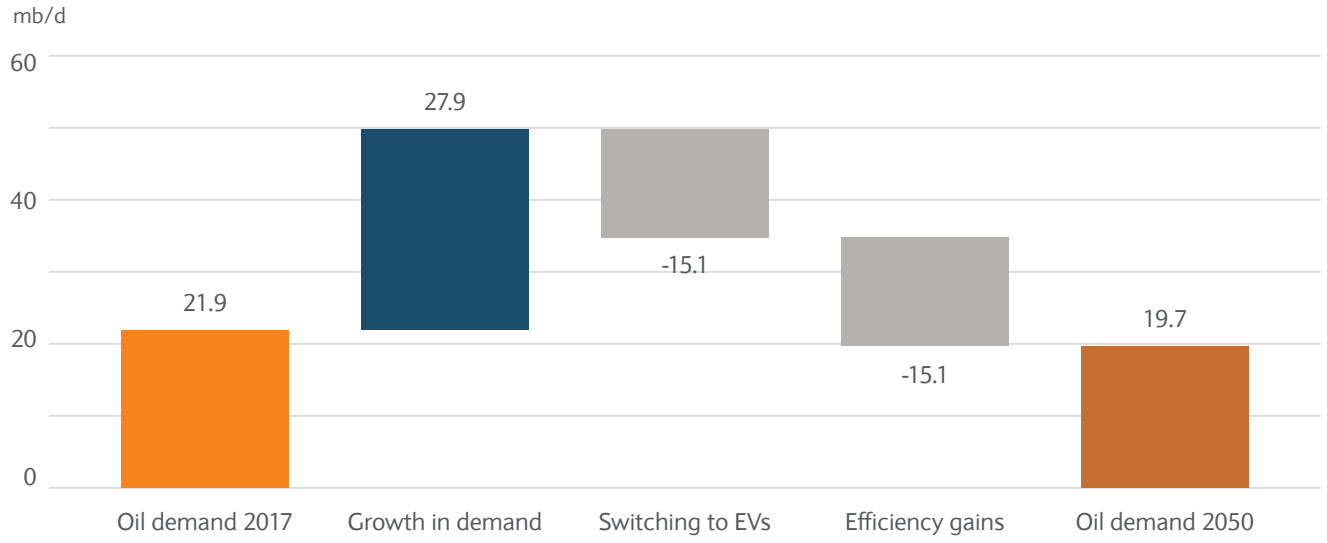
More cars on the road…

Taking into account population growth, an increase in vehicle registrations per person (particularly in Asia, Oceania, and the Middle East), and the scrappage rate of cars, we project that the total number of passenger cars on the road will grow from 980 million in 2016 to 2.3 billion by 2050. Growth is set to come entirely from non-Organisation for Economic Co-operation and Development (non-OECD) regions, with Asia expected to show the strongest momentum; car sales in the OECD markets should broadly flatten and potentially decline over the period as transport as a service becomes more prevalent.

In our scenario analyses we have kept assumptions about vehicle ownership and scrappage rates at our base case levels.

FIGURE 7

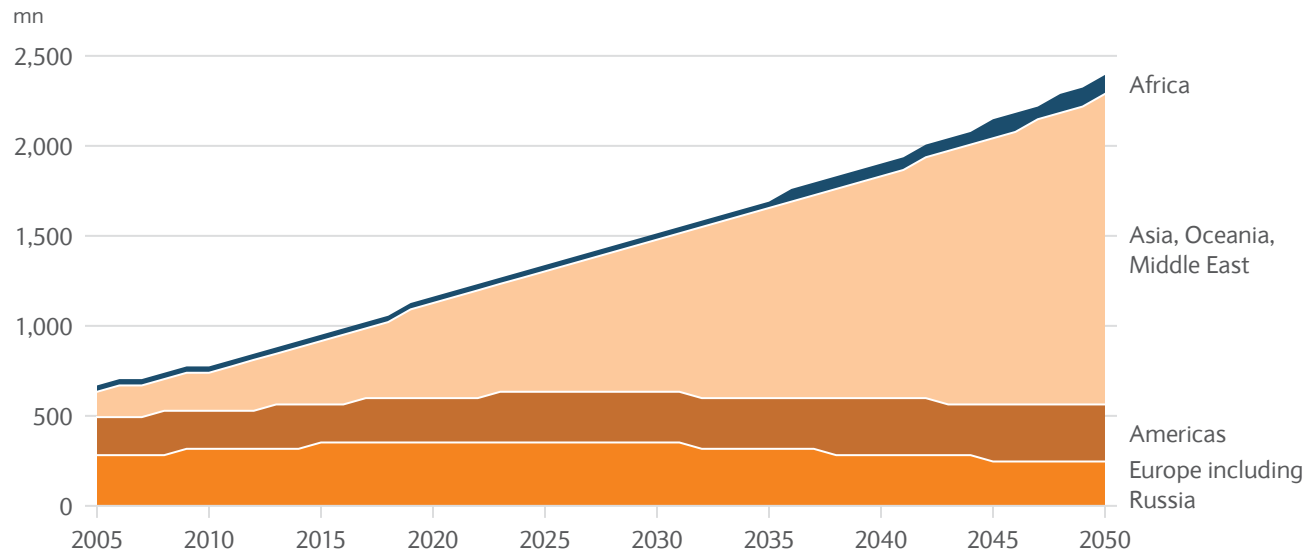
Fuel efficiency gains have as much impact as EV uptake (Development scenario)



Source: IEA World Energy Outlook, BP Statistical Review for historic data, Barclays Research estimates for 2050

FIGURE 8

Barclays estimates the number of all cars, including ICE and EVs, to reach 2.3 billion by 2050



Source: International Organisation of Motor Vehicle Manufacturers for historic data. Barclays Research estimates for forward projections.

And more of those are electric…

The type of car that is being purchased is also changing and the number of EVs is growing rapidly, accounting for a growing proportion of new sales. Exactly how quickly market share for EVs is set to evolve is subject to both consumer preference and regulation, but by 2020 we should see the start of mass-market battery EV adoption.

There were just over 1.2 million EVs on the road in 2015 and for our base case we expect this to grow to 160m vehicles by 2030 and to more than 1.2 billion by 2050, representing 51% EV penetration from around 1% today. Our 2030 forecast is above the 100m agreed after COP21. Longer term, we expect EV penetration to accelerate during the 2030s and 2040s, coinciding with a surge in autos delivered in Asia.

We forecast Battery Electric Vehicle (BEV) adoption to be 20% in 2025 in Europe, rising to 40% by 2030, 70% in 2040 and 80% in 2050. In the US, however, we are less optimistic about BEV penetration. The country has less stringent fuel efficiency regulations, which means that carmakers are likely to concentrate on smaller high-efficiency combustion engines or the High Efficiency Powertrain (HEP) rather than BEVs.

By contrast, we expect China to lead the way in pushing for higher BEV penetration through tougher CO2 regulations, better infrastructure, and possibly further incentive schemes. Our assumptions for each of our scenarios in terms of the fleet is as follows:

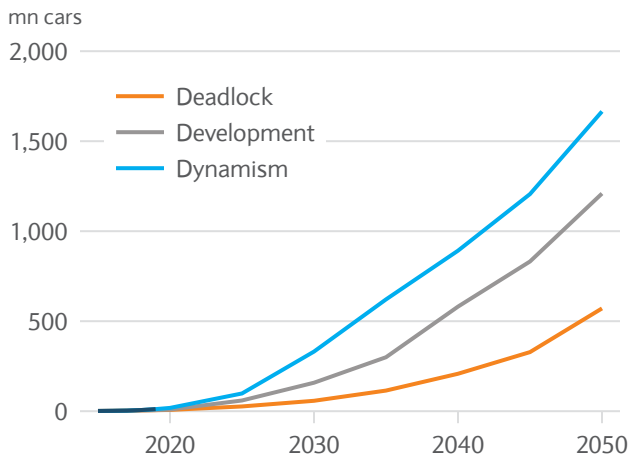
- Deadlock – average global EV penetration of 30% by 2050
- Development – average global EV penetration of 51% by 2050
- Dynamism – average global EV penetration of close to 75% by 2050

Demand impact starts to grow

As the proportion of EVs in the sales mix rises, and starts to impact the overall number of vehicles in the market, the cumulative impact of EVs on oil demand starts to accelerate on our numbers from the middle of the next decade. In our development case the impact is c15.1mb/d, although this rises to close to 19mb/d in our Dynamism scenario. The data shown below assumes a scenario of all else being equal with regard to scrappage rates and efficiency assumptions.

FIGURE 9

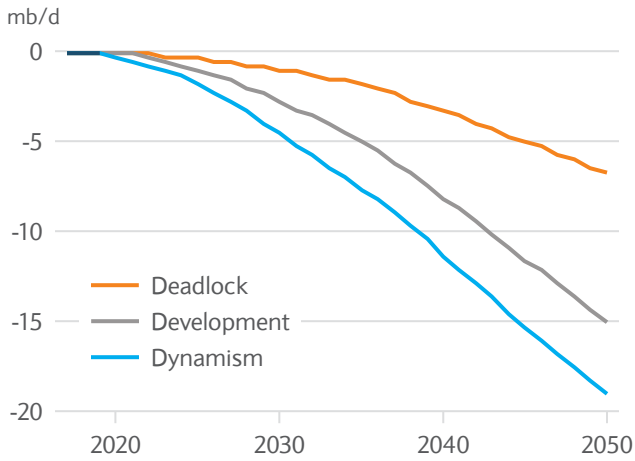
Number of EVs in different scenarios



Source: Barclays Research

FIGURE 10

EV impact on oil demand to 2050, mb/d



Source: Barclays Research

Fuel efficiency could have a bigger impact

We see significant potential to improve the efficiency of traditional fuel engines. Throughout our analysis it has been evident that improvements in fuel efficiency are likely to have a greater impact nearer term on oil demand than EVs. By 2050, we expect fuel efficiency gains to offset oil demand from cars by 17.1-35.5 mb/d, as shown in Figure 11.

We assume current fuel efficiency for the average car in the US as 25 miles per gallon (mpg) (9.4 litre per kilometre) and 33mpg (7.1l/km) in the rest of the world and that the average miles driven per year stands at 10,000. The three scenarios which we use to assess the impact of increased fuel efficiency on demand are:

- Deadlock – a 1% pa improvement in efficiency globally.
- Development – a 2% pa improvement in efficiency in the US and 1% pa in the RoW.
- Dynamism – a 3% pa improvement in efficiency in the US and 2% pa in the RoW.

It is worth highlighting that average fuel efficiency has improved by 13% over the past decade, based on data provided by the IEA (2005-2015)[4] and as such both the Development and Dynamism scenarios are a step change. It is possible that as auto manufacturers focus their efforts on developing the electric drive-train, improvements in the traditional diesel and gasoline drive-trains start to stagnate, which could make it challenging for the fuel efficiency gains we outline below to be realised.

Putting it all together

Our three scenarios see oil demand from cars ranging from 11.2mb/d to 21.3 mb/d by 2050, versus around 22 mb/d today, as shown in Figure 12. In addition to the absolute number of cars on the road, our most critical modelling assumptions for these forecasts include efficiency gains and EV penetration rates.

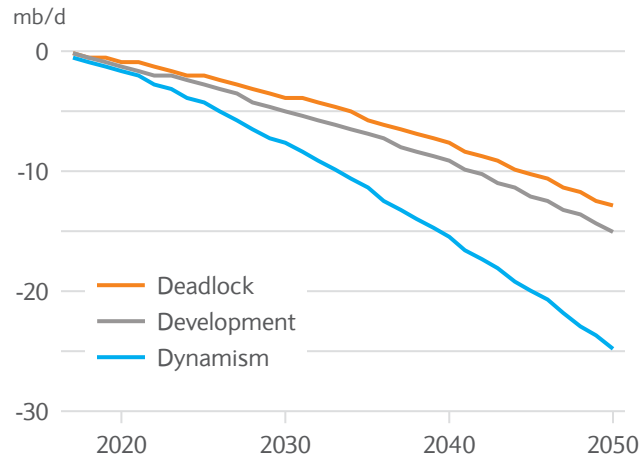
Cars in summary

In reality, the trends we discuss in this section – growing number of cars, growth in EVs and improved fuel efficiency — are all occurring at the same time. All scenarios point to oil demand from cars subsiding in absolute terms and as a percentage.

Taken together, our analysis shows that fuel efficiency gains have a far greater impact on oil demand than EVs over the period to 2050. Putting this into further context, oil demand from passenger cars represents 22% of total demand today and we continue to see growth from other sectors, and its share of oil demand, falling to 12-20% by 2050.

FIGURE 11

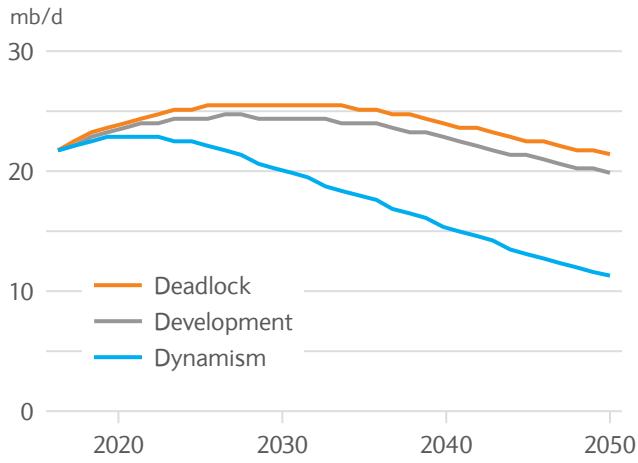
Energy efficiency impact on oil demand to 2050 (mb/d)



Source: Barclays Research

FIGURE 12

Oil demand under different fuel efficiency and EV penetration scenarios (mb/d)



Source: Barclays Research

4 International Energy Agency: Fuel economy of cars and vans

Sector Outlook: Trucking

Current oil consumption:
24.5 million barrels per day

Likely consumption by 2050:
30 million barrels per day

Freight to drive oil consumption

Trucking and road freight transportation is now the largest oil-consuming sector, comprising 25% of overall oil demand, or about 24.5 mb/d. Road freight transport at 84% of overall consumption also represents the lion's share of diesel demand, or 14 mb/d. We estimate consumption of oil to range between 17.8mb/d in our Dynamism scenario and 35.3 mb/d in Deadlock by 2050, and expect our Development scenario of 30 mb/d to be the most likely outturn.

Virtually the entire trucking fleet (97%) is powered by gasoline and diesel, with compressed natural gas, liquid petroleum gas and hybrids making up the rest. There are few electric-powered trucks on the road today.

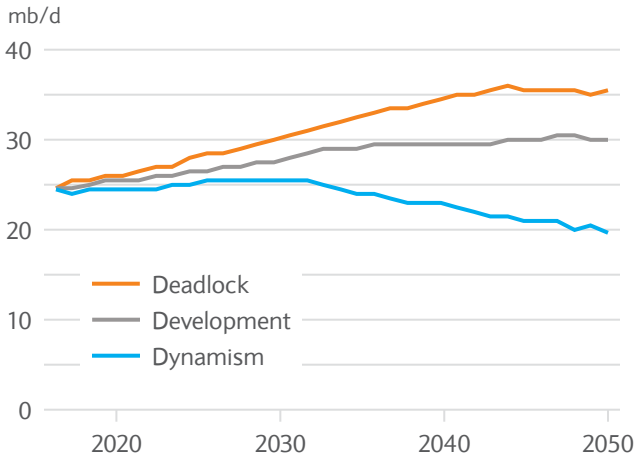
Despite efficiency improvements, and logistical and technological improvements, the global freight fleet is set to increase substantially under all of our scenarios, barring an unexpected and prolonged economic shock.

Although there are many drivers of oil demand for freight trucking, the most important in our view are:

- Global economic growth, which is closely correlated with ground freight activity
- Technological fuel efficiency adoption by freight trucking manufacturers
- Government policies targeting emissions reductions including increased rail transportation
- Artificial intelligence and improvements in logistics processes and techniques could reduce oil demand

FIGURE 13

Trucking demand for oil – 2017 to 2050E (mb/d)



Source: Barclays Research

With 25% of oil demand coming from trucks, efficiency improvements in this sector have the potential to make a material impact on demand expectations

Backdrop for Trucking

Types of trucks: The majority of trucks worldwide are light commercial vehicles (LCVs) – at 117 million they make up more than 70% of the fleet mix, or over 130 million trucks, according to the IEA. Over 40% of LCVs are in located the US and Europe, with 15% in China, and 4% in India. Heavy-freight trucks (HFTs) are forecast to experience the largest growth, and LCVs the least, although LCVs are expected to remain the dominant truck on the road, with more than 200 million vehicles globally by 2050. Medium-freight trucks (MFTs) are forecast to experience steady growth under our baseline Development case.

The biggest regional truckers: The US consumes the largest amount of oil for trucking at roughly 3.3 mb/d – this represents 20% of global ground freight oil demand, according to the IEA.[5] HFTs almost exclusively consume diesel. As a result of the US's large HFT fleet, nearly 75% of the overall fleet runs on diesel. The EU has the largest absolute number of HFTs which gives it a higher diesel mix, as essentially all 2.1 mb/d of oil consumption in the region is diesel. However, the public backlash targeting diesel in EU cities due to health and climate concerns could drive change. China has similar demand levels to the EU, but the majority of trucks are powered by gasoline, which could slow a transition to alternative fuels.

Diesel continue to dominate in HFTs

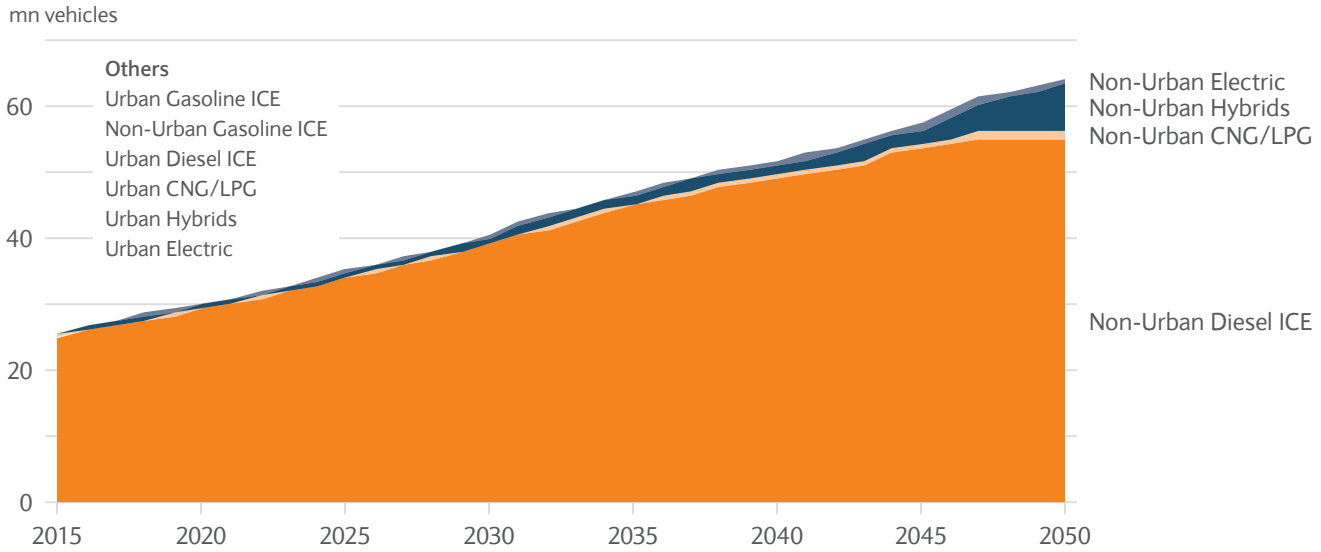
Roughly 65% of road freight activity is performed using heavy-freight trucks, which consumes about half of the oil demand in road freight transportation.

The vast majority of the HFTs are powered by diesel engines, implying that the growth in their numbers over the following decades will increase the demand for oil. We expect that only some of the HFT growth will come from alternative energy vehicles, such as hybrids.

The MFT fleet is expected to undergo moderate growth, with gasoline and diesel vehicles generally flat over 2050, as modest continued growth over the next decade is offset by a levelling off of hydrocarbon-fuelled vehicles over the following decade.

FIGURE 14

Heavy-freight trucks (HFTS) by fuel type – 2015E to 2050E (millions of vehicles)



Source: IEA, Barclays Research estimates. Urban refers to vehicles that make the majority of travel within urban areas. Non-Urban make the majority of journeys outside of urban areas.

5 International Energy Agency: Future of Trucks

Hybrid expansion in the early 2030s

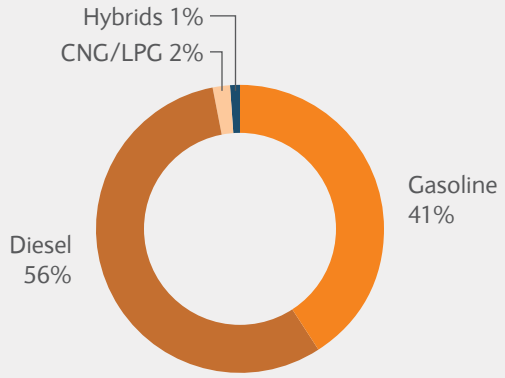
Regulators are increasingly looking to rein in carbon emissions from freight transportation, which should lead to an increase in hybrid and EVs, as well as the adoption of higher renewable fuel standards.

Under our baseline Development scenario, we see hybrid trucks starting to take modest market share in the early 2030s, which accelerates somewhat into the 2040s – largely at the expense of diesel and gasoline trucks.

We expect electric engines to remain a small portion of the global trucking fleet, but to pick up some share by 2050, making up less than 5% of the worldwide fleet. Even under our more aggressive Dynamism scenario, electric engines are expected to power only the smallest portion of the global trucking fleet, with hybrids surpassing gasoline and rivalling diesel as the largest engine by fuel type.

FIGURE15

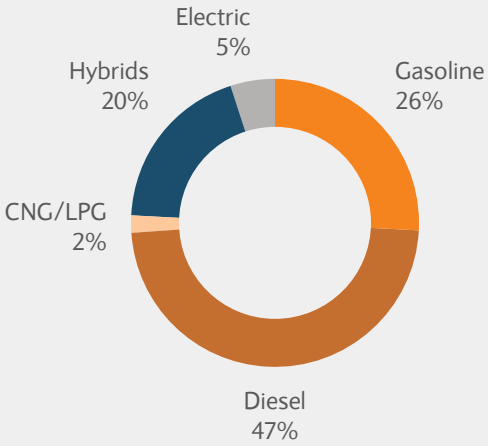
Estimate of Current Fleet Mix



Source: Barclays Research

FIGURE 16

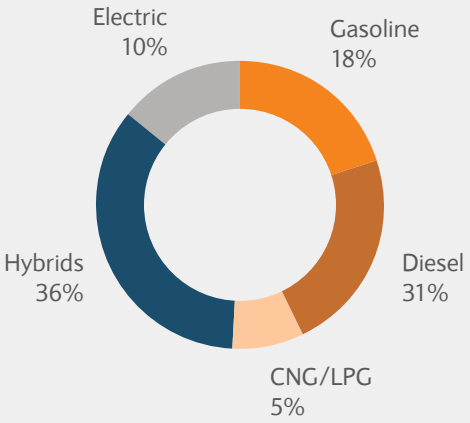
Development Scenario – 2050E



Source: Barclays Research

FIGURE 17

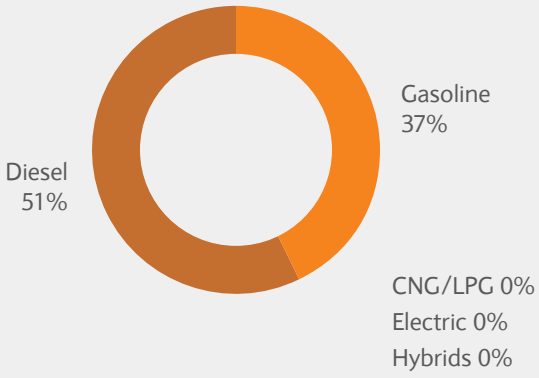
Dynamism Scenario – 2050E



Source: Barclays Research

FIGURE 18

Deadlock Scenario – 2050E



Source: Barclays Research

Corporate sustainability goals could drive a rapid deployment of hybrid engine trucks.

Trucking: Demand for oil in our 3Ds

Our scenarios consider oil prices, political support for climate-friendly initiatives, and technological improvements. They take into account changes to the types of engines used globally, rather than changes in trucking activity. Our underlying assumptions remain: moderate economic expansion and population growth, and continued trends related to transportation and trade. Our scenario outlooks result in wide-ranging outcomes leading out to 2050.

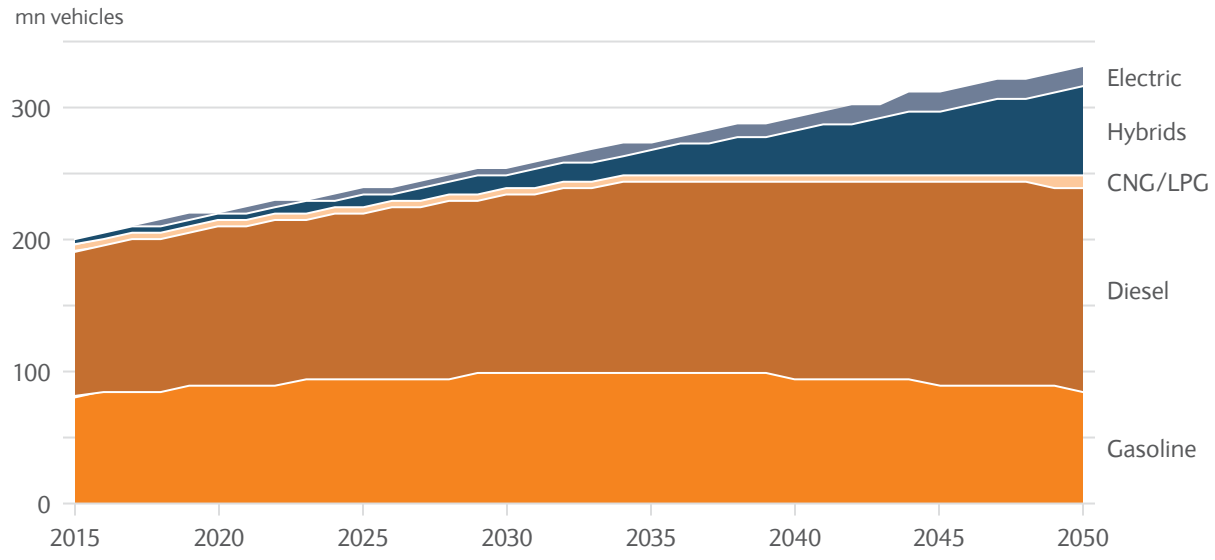
Development: Our baseline scenario assumes that there will be roughly 330 million trucks on the road globally by 2050, up from 200 million in 2015. In 2050 we think the global trucking fleet will continue to be powered by diesel and gasoline (74%). However, we forecast substantial market share expansion for hybrids (19%), and for some penetration of electric engines in the trucking fleet. Gasoline and diesel LCVs should experience flat to modest growth.

Dynamism: This scenario assumes a technological tipping point for hybrids coupled with high oil prices and political support over the next decade. This should encourage strong hybrid adoption in the mid-2030s, with electric also making meaningful progress. Our Dynamism case assumes gasoline and diesel powered trucks maintain collective leadership (50%), but has hybrid fuelled trucks surpassing diesel trucks. We think this could be conservative in a situation where there is strong political support, a prolonged period of high oil prices, and technological improvements.

Deadlock: Under our Deadlock scenario, diesel and gasoline powered trucks continue to dominate the road (88%), with only small advances in alternative trucking engines. We estimate hybrid engines only capture 7% of market share, with stable oil prices, limited political initiatives, and further alternative fuel technological improvements taking hold.

FIGURE 19

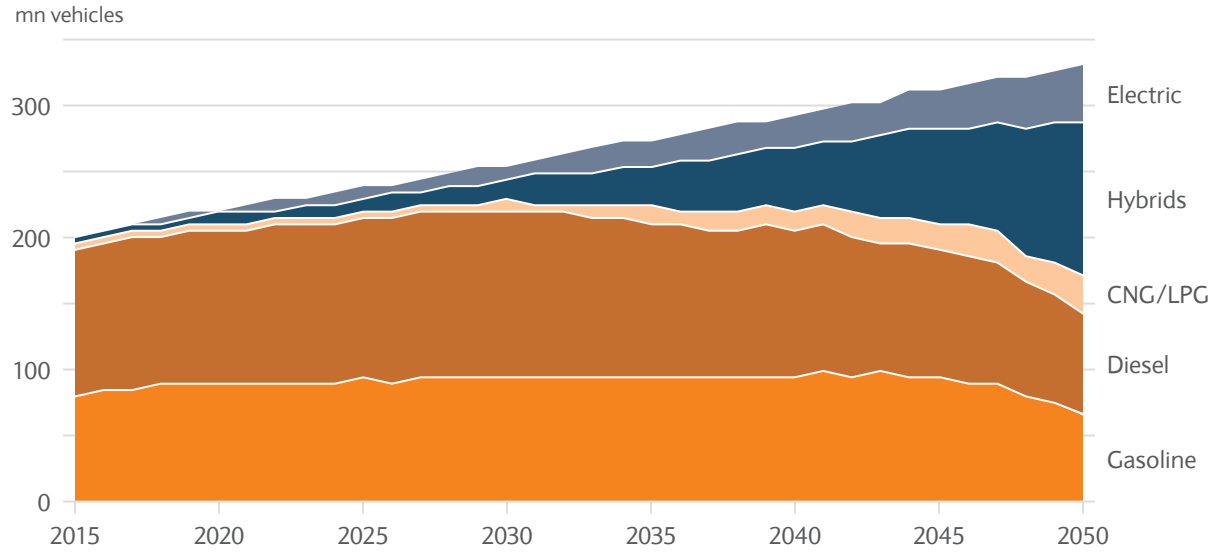
Development scenario – 2015E to 2050E (millions of vehicles)



Source: IEA, Barclays Research

FIGURE 20

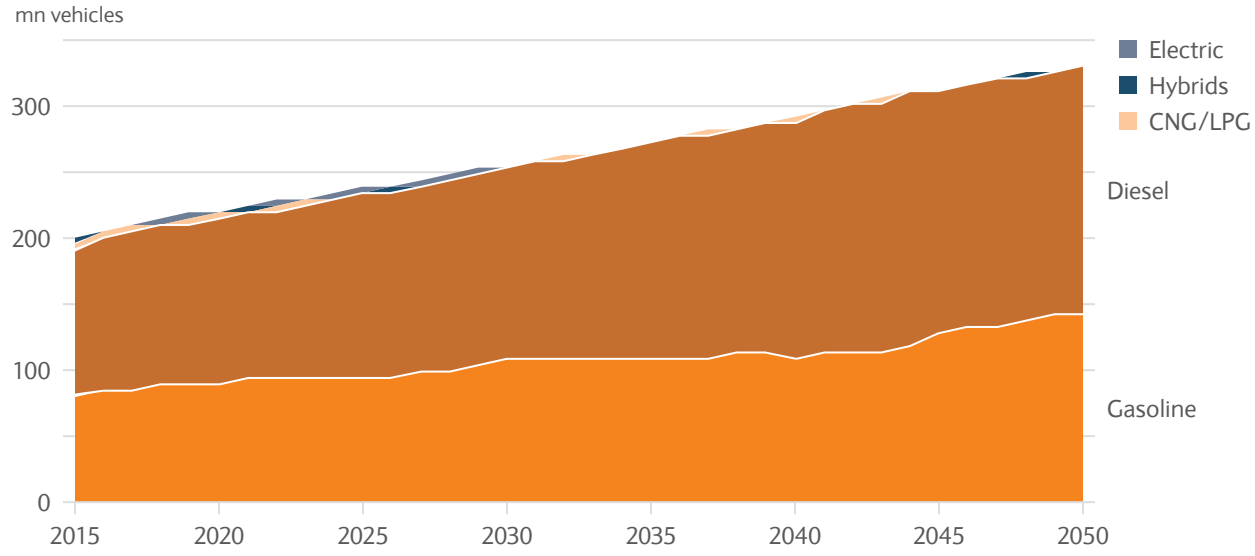
Dynamism scenario – 2015E to 2050E (millions of vehicles)



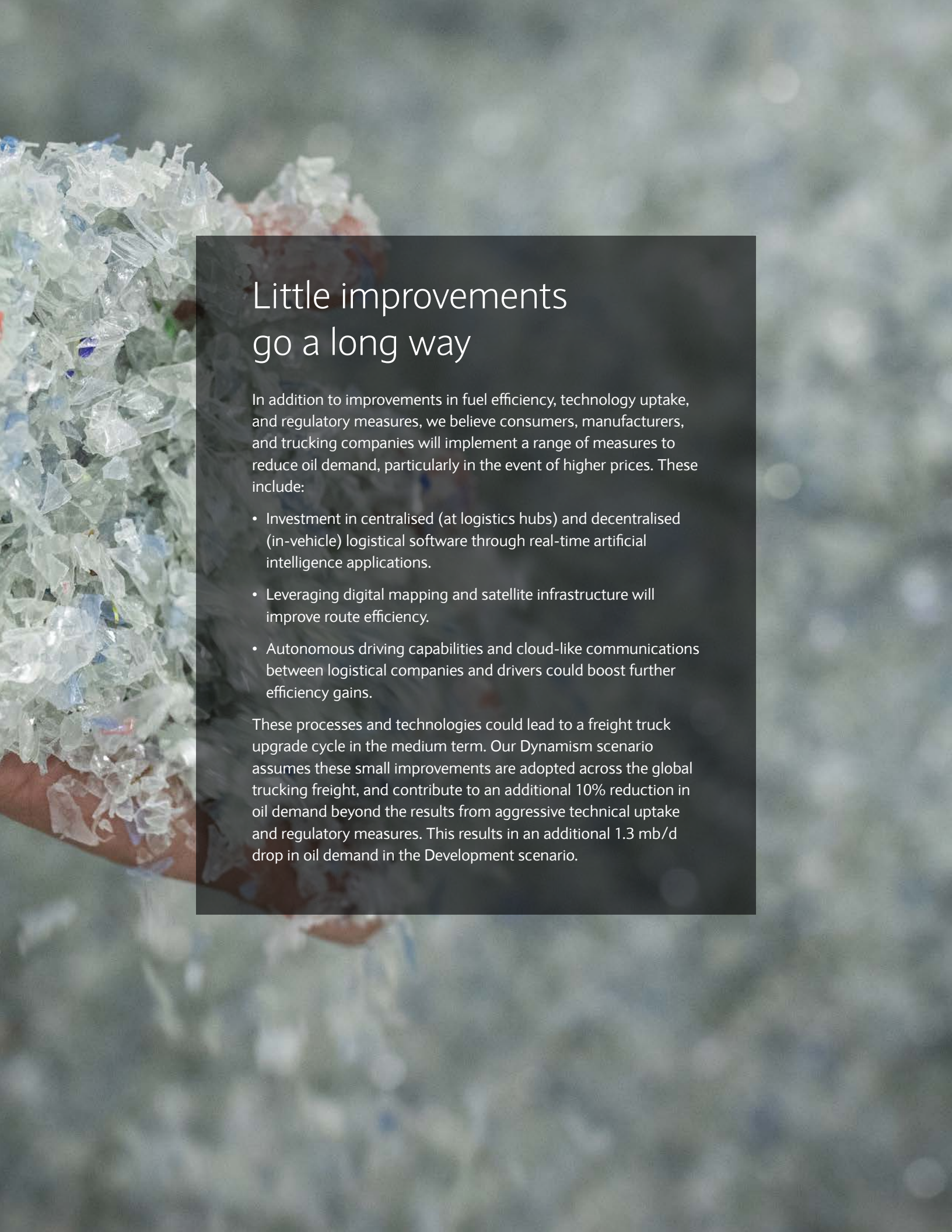
Source: IEA, Barclays Research

FIGURE 21

Deadlock scenario – 2015E to 2050E (millions of vehicles)



Source: IEA, Barclays Research



Little improvements go a long way

In addition to improvements in fuel efficiency, technology uptake, and regulatory measures, we believe consumers, manufacturers, and trucking companies will implement a range of measures to reduce oil demand, particularly in the event of higher prices. These include:

- Investment in centralised (at logistics hubs) and decentralised (in-vehicle) logistical software through real-time artificial intelligence applications.
- Leveraging digital mapping and satellite infrastructure will improve route efficiency.
- Autonomous driving capabilities and cloud-like communications between logistical companies and drivers could boost further efficiency gains.

These processes and technologies could lead to a freight truck upgrade cycle in the medium term. Our Dynamism scenario assumes these small improvements are adopted across the global trucking freight, and contribute to an additional 10% reduction in oil demand beyond the results from aggressive technical uptake and regulatory measures. This results in an additional 1.3 mb/d drop in oil demand in the Development scenario.

Sector Outlook: Petrochemicals

Current oil consumption:
10.6 million barrels per day

Likely consumption by 2050:
18.6 million barrels per day
Full single use plastics ban could reduce this to 13 million barrels per day

A growing sector with high oil demand

Products derived from petrochemicals are a key part of everyday life. Plastics, fertilisers, foams, glues, pharmaceuticals, washing powder, and textiles all originate from petrochemicals, which are a by-product mostly of oil and gas.

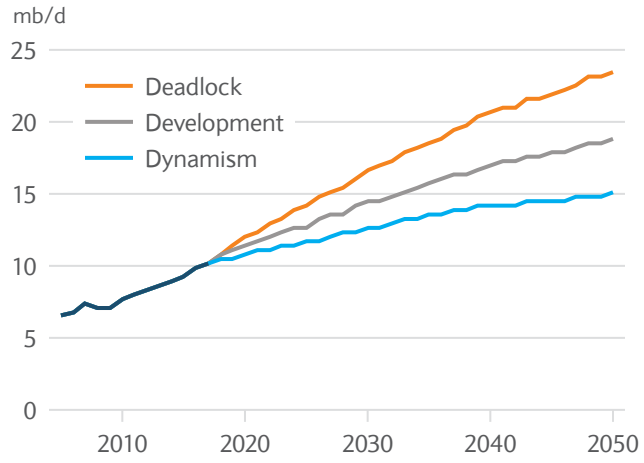
Demand for petrochemicals has increased by more than 50% over the past 10 years and we expect the sector to remain a large user of oil in the next few decades – potentially overtaking cars in the 2020s or 2030s. Currently using about 10.6 million barrels per day, we expect the industry to require between 14.9 mb/d and 23.4 mb/d by 2050.

Is the thirst for petrochemicals unquenchable?

In 2016, petrochemical production reached 470 million tonnes from 600 million tonnesof capacity.[6] By 2050, we expect this to grow to over 1 billion tonnes in our base-case Development scenario, 1.2 billion tonnes in Deadlock, and around 800 million tonnes in Dynamism.

FIGURE 22

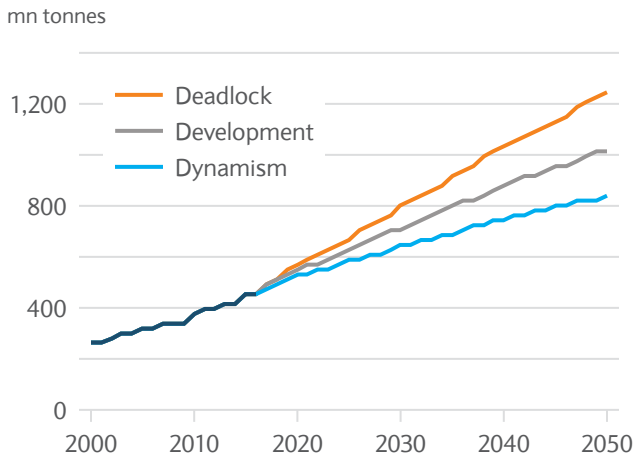
3D Scenarios: the demand on oil from petrochemicals – 2005 to 2050E (mb/d)



Source: IEA, Shell, BP, Barclays Research estimates

FIGURE 23

Global petrochemicals production scenario analysis – 2000 to 2050E (million tonnes)



Source: IEA, Shell, BP, Barclays Research

6 Based on data from IEA: The Future of Petrochemicals alongside data from BP, Shell & Total

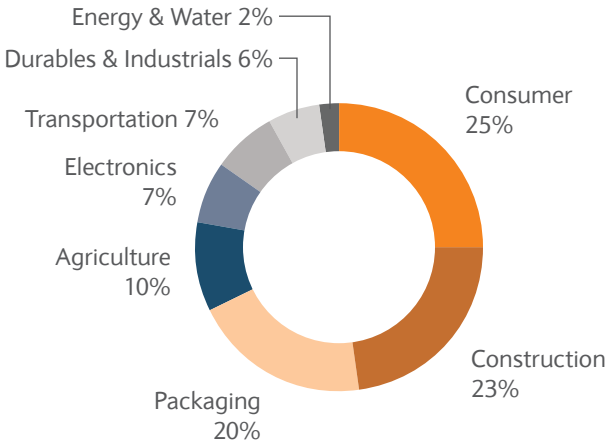
This substantial demand for chemicals in consumer goods, construction and the packaging industries will be determined by several factors. Population and global GDP growth, urbanisation and increased trade all require more petrochemical production, and this will be boosted by growing demand for consumer goods as living standards in emerging markets rise.

On the supply side, the oil and gas renaissance in the US has improved the competitiveness of the domestic industrial and chemical industries, which will also increase production. Much of this demand is likely to be met from non-oil sources that can bypass the refining system. However, we still expect petrochemical consumption from oil based products to constitute 20% of global oil demand by 2050, up from around 10% today.

The two factors that can counter this growth are plastics recycling and finding alternatives to chemical products.

FIGURE 24

Share of chemicals volumes by end product, 2015



Source: Royal Dutch Shell, Barclays Research

Where are petrochemicals produced?

The US, China, and the Middle East make up the lion's share of petrochemical capacity and production, followed by Russia, India, and Southeast Asia. Energy reform and privatisation could drive growth in Latin America as well.

US: More than 65% of North American primary petrochemicals are derived from crude oil.[7] However, low gas prices are incentivising US refiners to produce petrochemicals from natural gas instead, and we think this will continue in the medium term. Shale drilling in the US has also driven significant growth in natural gas liquids (NGL) production. This has rejuvenated investment in basic materials and industrials in the US. We estimate North American petrochemical production will grow 235% by 2050 to over 240 million tonnes, up from 72 tonnes in 2016.

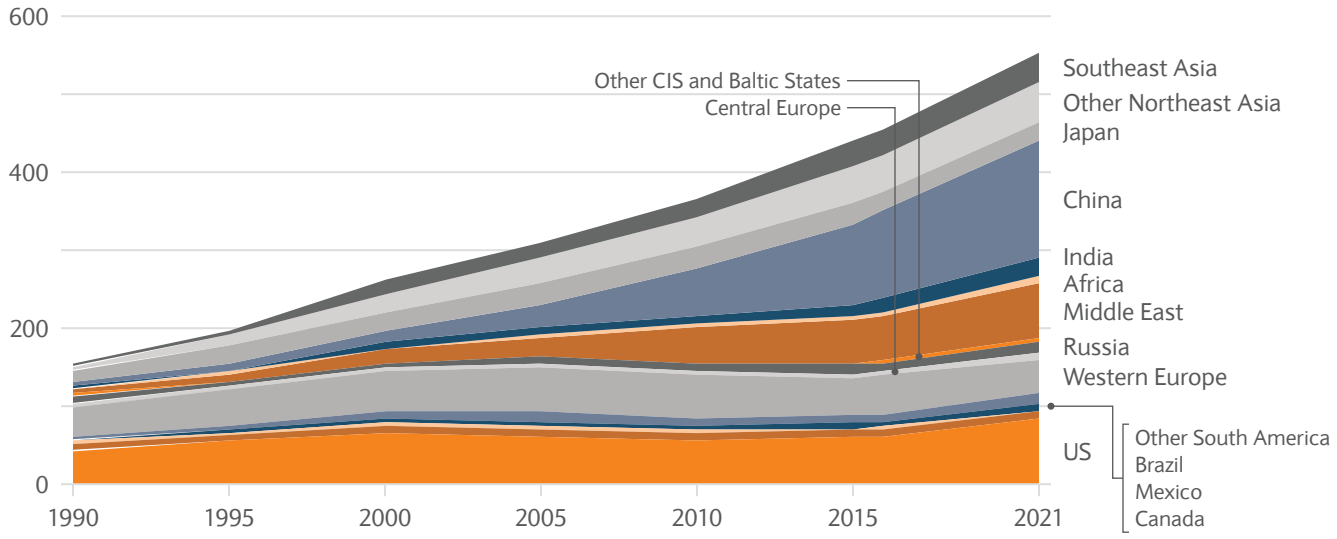
China: In 2016, China used roughly 4.8 billion barrels of crude oil for petrochemical production, with between 88% and 93% of the seven basic petrochemicals derived from petroleum.[8] The country's recent focus on the environment should slow petrochemical production, but it is expected to remain one of the fastest growing investors in petrochemicals. Driven by demand for products such as plastics, pipes, and coating materials, we forecast petrochemical production to grow 22% to 72.5 million tonnes by 2021.

India: The country used 1.7 billion barrels of crude oil to produce petrochemicals[9] in 2016. Indian petrochemical consumption is expected to increase 6.7% by 2021, and its capacity is expected to stand at 23.2 million tons in 2021, up 32% from 2016 levels.[10] We expect India to build petrochemical capacity in the coming years due to meet domestic demand and eventually export, with domestic oil demand estimated to reach 500 million tonnes by 2040; however, its current refining capacity stands at 230-250 million tonnes.[11]

Middle East: Middle Eastern[12] refineries are largely dependent on naphtha, a crude oil byproduct, for petrochemicals. The region used 3.9 million barrels of oil as petrochemical feedstock in 2016. It also produced a substantial amount of ethane from natural gas liquids, and ethane is expected to make up 45% of Middle East petrochemicals by 2021.

FIGURE 25

Petrochemical production by region – 1990 to 2021



Source: IHS, Petrochemical Industry Outlook, 13 April, 2017, Barclays Research

7 IHS Chemical, "Petrochemical Industry Overview, Chemical Economics Handbook", 13 April 2017

8 IHS Chemical, "Petrochemical Industry Overview, Chemical Economics Handbook", 13 April 2017

9 IHS Chemical, "Petrochemical Industry Overview, Chemical Economics Handbook", 13 April 2017

10 IHS Chemical, "Petrochemical Industry Overview, Chemical Economics Handbook", 13 April 2017

11 "Indian Petrochemical Industry – The Growth Continues": http://www.worldofchemicals.com/media/indian-petrochemical-industry-the-growth-continues/442.html

12 Middle East includes Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE

The war on single-use plastics

Between the mid-1960s and 2016, global plastics production had grown more than twenty-fold to 335 million tonnes due to its convenience, flexibility and durability.

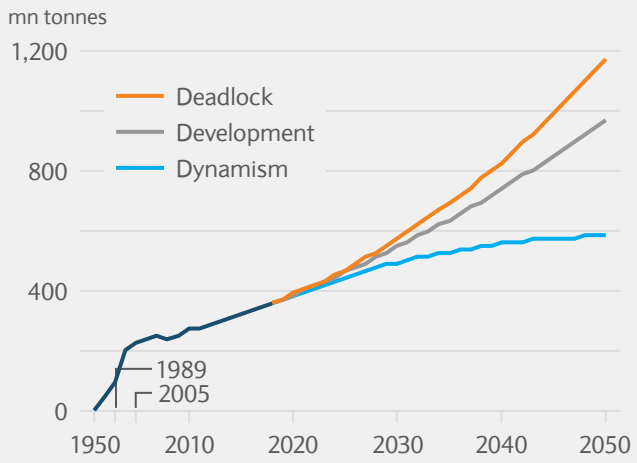
Despite increasing demand, the global "war on single-use plastics" is gaining pace, triggered by increased media attention and public awareness of problems that single-use plastic can cause when not disposed of properly. The extent of pollution in the oceans, particularly from water bottles, is becoming increasingly clear, with the EU highlighting that plastic makes up 80-85% of the total number of marine litter items, measured through beach counts. This has led to several countries and cities taking measures to curtail single-use plastic products.[13]

About 40% of plastics end up in landfills, while 30% escapes collection systems, according to the Ellen MacArthur Foundation.[14] Further, the majority of recycled single-use plastics degrades in quality, which means that water bottles cannot be recycled into more water bottles, and instead are converted into textiles or carpets that are non-recyclable. This illustrates the challenge increased recycling faces in exerting a meaningful impact on plastics production.

Single-use plastics currently make up between 3-3.5mb/d of oil demand on our estimates and we expect this to grow to 5.5-6mb/d over 2040-2050. As such, a complete ban on single-use plastics would lead to a demand reduction of 5% relative to our base-case forecast. Our dynamism case assumes 75% recycling, but not a complete global ban on single use plastics.

FIGURE 26

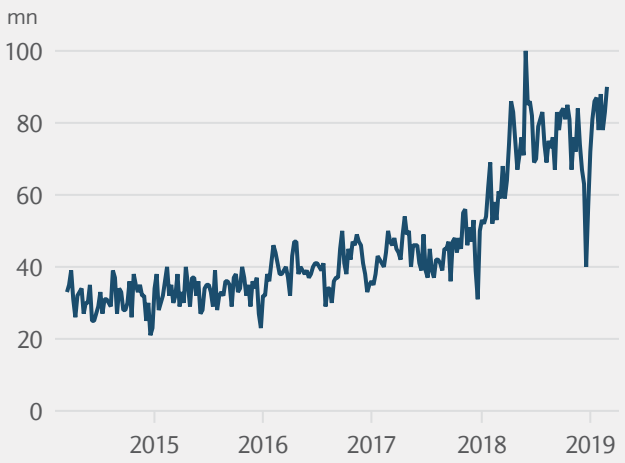
Global Growth in Plastics Production – 1950 to 2014



Source: Plastics Europe, Barclays Research

FIGURE 27

The use of the search term "plastic waste" on Google has surged since end-2017



Source: Google Trends. Barclays Research. Scale shows volume as % of peak hits in timescale

13 European Commission: Directive of the European Parliament and of the Council

14 Ellen Macarthur Foundation: New Plastics Economy

FIGURE 28

Plastic initiatives: Recent efforts to stop the use of single-use plastics across the world include

Initiative	Regulator / Country (Introduction)
Ban on plastic straws	Seattle (2018), Taiwan (2019), Scotland (2019)
Ban on plastic bags	Kenya (2017, punished with prison), Australia (2018), Montreal (2018)
Ban on microbeads	UK (2018), Taiwan (2018), Canada (2018)
Total ban on Styrofoam-like EPS	Zimbabwe (2017)
Ban of 10 single-use plastic items	European Union (2021, proposed May 2018)
End of all single-use plastics	Indian State Maharashta (2018), India (2022), EU/UK (2030), Taiwan (2030)
Requirement to collect 90% of single-use plastic drinks bottles	European Union (2025, proposed May 2018)
Minimum of 50% of all plastic packaging waste to be recycled	European Union (2025, proposed May 2018)

Source: Barclays Research, IEA

FIGURE 29

Plastic initiatives – recent efforts by corporates to reduce plastic consumption

Company	Initiative
Coca Cola	Pledge to collect and recycle the equivalent of all its packaging by 2030 Aims to make bottles out of on average 50% recycled content
McDonald's	Switch to paper straws in the UK/Ireland beginning in September 2018
Iceland	Eliminating plastic packaging from own-brand products by end of 2023
Evian	Promise to make all bottles from recyclable plastic by 2025
Unilever	Goal to make the plastic it uses recyclable/re-usable by 2025
Adidas	Plan to stop using virgin polyester for all shoes and clothing by 2024
UK Plastics Pact	Multiple UK Supermarkets and Retailers pledging to strip unnecessary plastic from their shelves by 2025
Starbucks	Planning to phase out straws from its stores by 2020
Sustainable Packaging Coalition	Companies committed to working towards 100% reusable, recyclable or compostable packaging by 2025 (including Pepsi, Wal-Mart, Nestlé)

Source: Barclays Research, IEA, Company Data

Plastics in our 3D scenarios

Despite the war on plastics, we expect production to continue growing robustly for the foreseeable future.

Development: In our base-case scenario we forecast plastic production to rise from 350 million tonnes today to about 1.3 billion tonnes by 2050, assuming 4.5% annual growth in production through to 2020, slowing to 3.75%, and a recycling rate increasing to 50% by 2050, up from 15% today. We calculate that this would reduce oil consumption by c.4mb/d if today's trends continue.

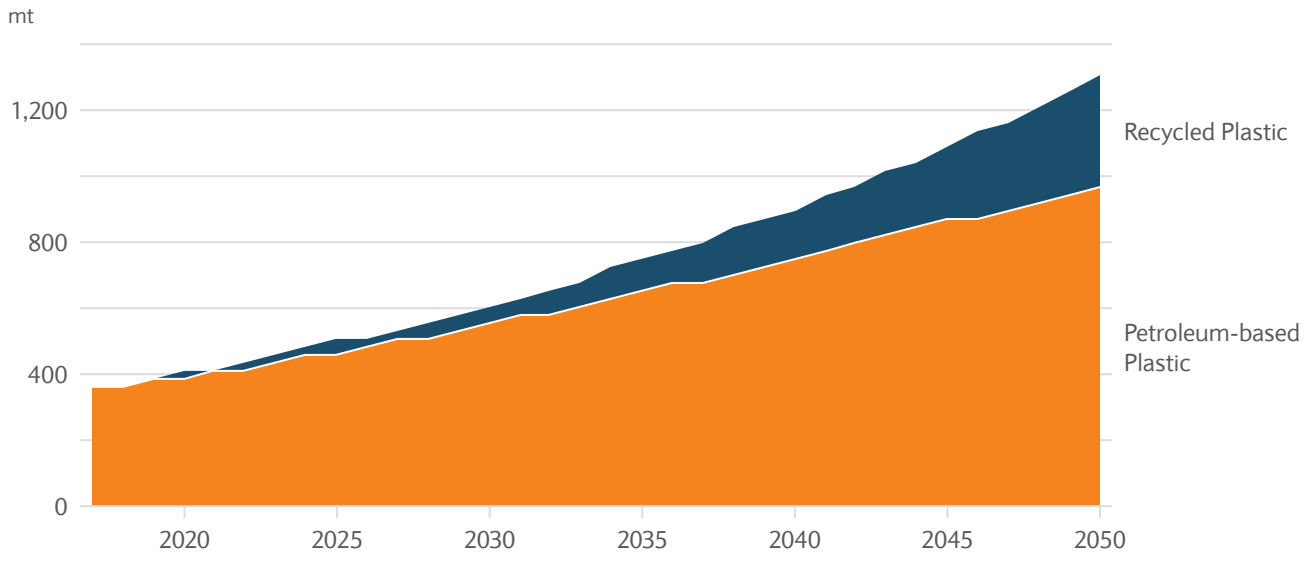
Dynamism: Our best-case scenario assumes recycling reaches 75% and production growth slows to 1% by 2050, due to policy measures and the adoption of alternative materials.

Deadlock: In the worst-case scenario recycling reaches 20%, while the growth in plastic production slows to 3.75% by 2050 due to a lacklustre policy approach and minimal uptake in plastic alternatives.

Growth in plastic demand is a key source of oil demand to 2050. A complete ban on single use plastics would reduce our estimate of oil demand in the development scenario by 6mb/d in 2050.

FIGURE 30

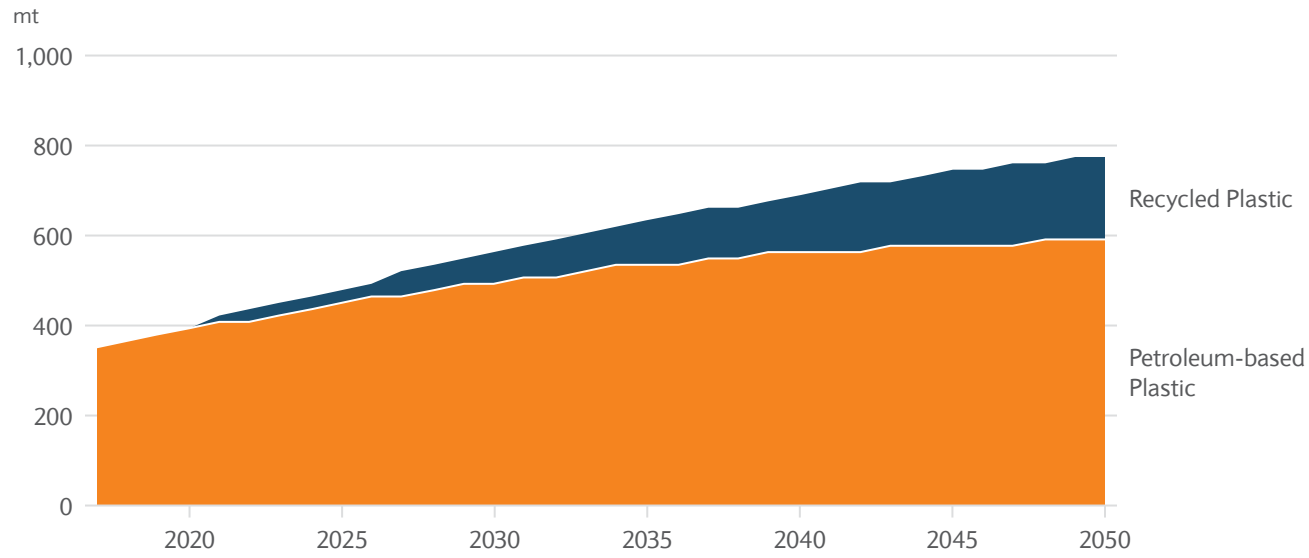
Global plastics forecast – Development scenario – 2017 to 2050E (mt)



Source: Barclays Research, IEA

FIGURE 31

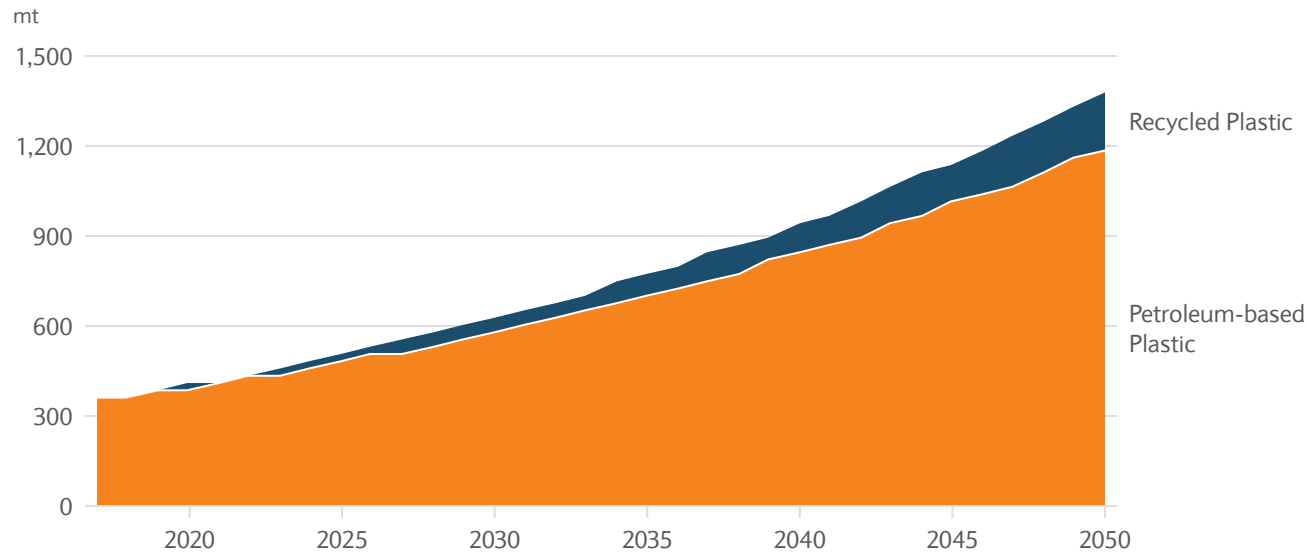
Global plastics forecast – Dynamism scenario – 2017 to 2050E (mt)



Source: Barclays Research, IEA

FIGURE 32

Global plastics forecast – Deadlock scenario – 2017 to 2050E (mt)



Source: Barclays Research, IEA

Sector Outlook: Other Transportation – Marine & Aviation

Current oil consumption:
10 million barrels per day

Likely consumption by 2050:
14 million barrels per day

Sea and air travel will boost oil demand

Despite recent trade disputes and nationalistic undertones gaining support across democratised economies, international trade is set to increase substantially for the foreseeable future, with obvious implications for oil demand across sea and air transport, and we see this continuing through to 2050. Further, better living standards in emerging economies and Asia, coupled with increased urbanisation, should bolster domestic air travel in China, India, and other populous countries substantially. The prospect of commercial space travel will also demand more oil.

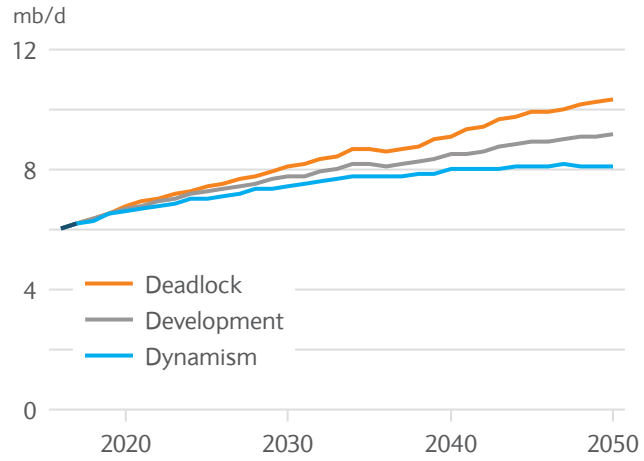
Aviation Outlook

We think aviation will be one of the key drivers of global oil growth in the next few decades, under all three of our scenarios. There are currently limited viable alternatives to petroleum-based jet fuel for airline travel. Airlines are under pressure to curb emissions, which should increase efforts to develop sustainable aviation fuel (SAF). However, the technical barriers are substantial and meaningful SAF penetration is a long way off – as is finding a viable alternative for the internal combustion engine. As a result, our best-case Dynamism and worst-case Deadlock scenarios show a difference in oil demand of only 2.2 mb/d by 2050.

With the number of aircraft predicted to grow roughly 4% a year – reflecting 5% air traffic growth offset by modest efficiency gains – there should be more than 12 million aeroplanes by 2050, up from about 4 million in 2017. Growth is likely to continue to outpace GDP as air travel continues to grow, reflected by that fact that roughly 80% of the world population are yet to travel on an aeroplane.[15]

FIGURE 33

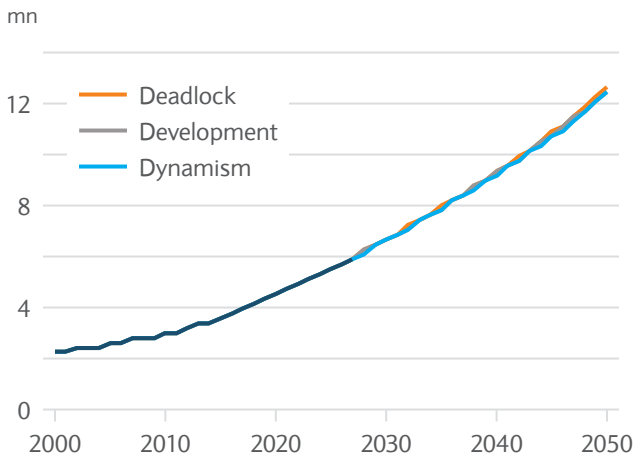
Aviation fuel demand (mb/d) in our 3D scenarios – 2016 to 2050E



Source: Barclays Research

FIGURE 34

Total worldwide aircraft fleet – 2000 to 2050E

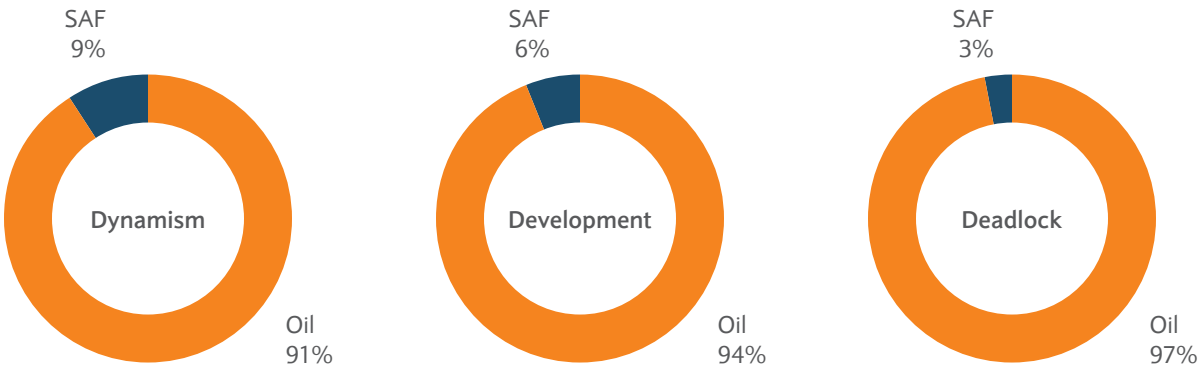


Source: Barclays Research, Flight Global

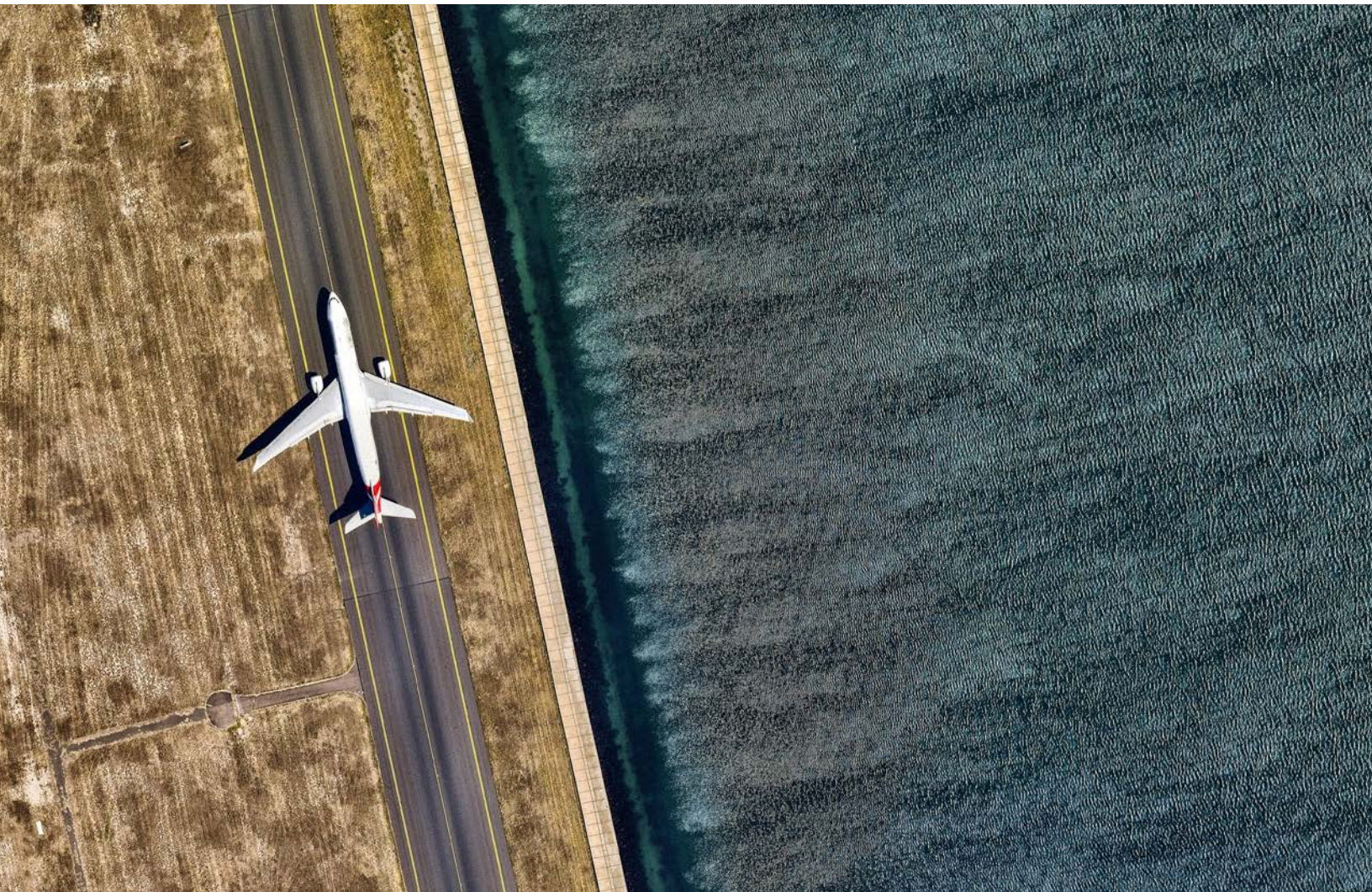
15 https://www.cnbc.com/2017/12/07/boeing-ceo-80-percent-of-people-never-flown-for-us-that-means-growth.html

FIGURE 35

Aviation fuel mix – 2050E



Source: Barclays Research (SAF being sustainable air fuel)



What do our scenarios predict?

Development: In our base case we expect jet fuel to increase by over 50% by 2050, with oil constituting about 94% of jet fuel feedstock and SAF the rest. This projection assumes that the global aircraft fleet will grow by 211%, with modest fuel efficiency gains and increased domestic travel in China and India.

Dynamism: In our best-case scenario, we think SAF could penetrate nearly 10% of the market for jet fuel by 2050 as a result of supportive policies being adopted by European and US airlines, combined with technological advances. Despite fuel efficiency gain estimates of nearly 10%, we still foresee a 40% growth in oil by 2050. Our relatively tight scenario band stems from the technical difficulties in finding viable alternatives to jet fuel, with little scope for batteries or other power train engines.

Deadlock: In our Deadlock scenario, we predict that demand for jet fuel will increase 70% by 2050 — with oil making up 97% of the feedstock. This assumes an even greater increase in the number of aeroplanes, little fuel efficiency gains, and broader increases to domestic travel in emerging markets, including Asia-Pacific and Africa.

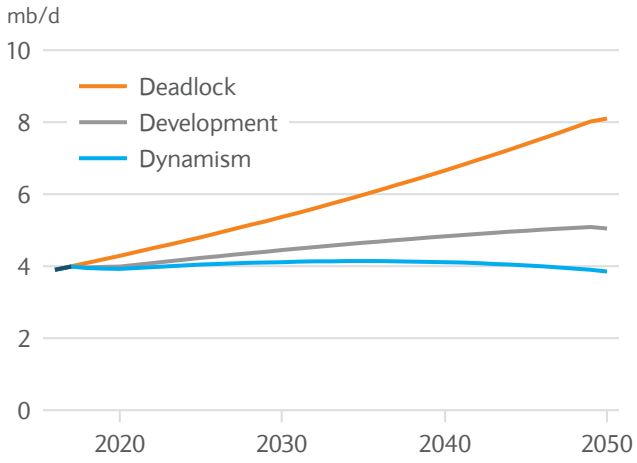
Maritime outlook

With over 250,000 ships predicted to sail our seas by 2050 (up from under 100,000 in 2016), we believe oil demand could reach 5.1 mb/d by 2050, up over 25% from today's levels. Our Dynamism and Development cases range from 3.9 mb/d to 8.1 mb/d, with variations in fuel efficiency and fuel mix as the key determinants.

The sector is closely linked to economic and trade activity, but oil demand could be influenced by various factors, including policy measures and technology, with some risk coming from trade disputes in the near term. On the whole, we expect these factors to generally offset global growth and for oil demand for Maritime to be generally flat from today's levels.

FIGURE 36

Global Oil Demand for Maritime Activity Scenario Analysis – 2016 to 2050E



Source: Barclays Research, IEA, BP

Development: We expect modest annual efficiency gains for the existing fleet but a gradual step-up in efficiency (to 7% gains annually) in new ships up to 2050.

Dynamism: We anticipate faster adoption of efficiency measures, topping at around 7.5% by 2050. This prediction could underestimate the industry's ability to be more efficient and to introduce new lighter materials in ships in the medium term.

Deadlock: Expected non-compliance with International Maritime Organization (IMO) regulations limiting sulphur in the fuel mix could result in no annual efficiency gains.

Sector Outlook: Power

Current oil consumption:
5 million barrels per day

Likely consumption by 2050:
Fewer than 1 million barrels per day

Losing share under all scenarios

Oil consumed in the Power sector is at historical lows, and we expect it to continue to decline under all three of our scenarios. Today, oil is still mostly used in the power sector in oil-rich regions with heavy subsidies in place, like the Middle East. However, growing investment in natural gas power is likely to accelerate the decline of oil in this sector.

Our scenarios for oil consumption in Power sector range from 0.5 mb/d to 3 mb/d.

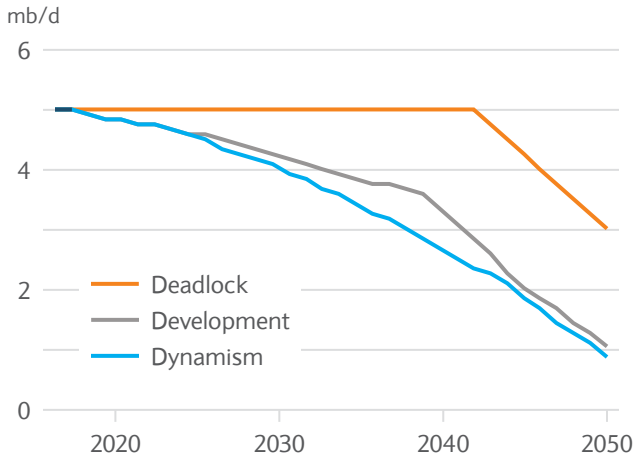
Development: We expect to see a continued gradual decline of oil demand for the Power sector, especially in the early 2040s. We anticipate that the sector will require around 0.8 mb/d by 2050, down from 5 mb/d today.

Dynamism: Our Dynamism scenario assumes a steeper annual decline in oil, especially in the late 2020s.

Deadlock: Here we assume the demand for oil in the Power sector holds up in the medium term, but will also start to decline meaningfully in the early 2040s. Based on current trends, we don't see much scope for a reversal of oil's role in this sector.

FIGURE 37

Global oil demand for power scenario analysis – 2017 to 2050E



Source: Barclays Research

Oil consumed in power is at historical lows with renewables rapidly increasing in competitiveness.

Oil and a sustainable future

The path of oil demand over the coming decades will be driven by a number of complex and overlapping factors: Economic and population growth, renewable energy, technological innovation, governmental focus on low-carbon policies, and consumer choices will all play a crucial role in shaping the global energy mix by 2050.

From here, the most rapid changes in oil demand are likely to be seen in the power and car industries. For power, change will come from material growth in renewable generation and a greater uptake of natural gas. For cars, it will come from the mass adoption of battery electric vehicle adoption – led by Europe and Asia – which we expect from 2020.

The already significant contribution of Petrochemicals to oil demand is set to grow further: demand for petrochemicals has increased by more than 50% over the past 10 years, and another 50% uplift in demand is feasible by 2050. Increased regulation in response to single-use plastics may mitigate growth in this segment, but much of the demand increase we envisage relates to construction, consumer goods, agriculture, and other unconnected areas. As a result, a complete ban on single-use plastics would lead to a reduction of only 5% relative to our base-case forecast for oil demand.

Our research indicates that though the range of potential outcomes for oil demand by 2050 is extremely wide, that in each of our envisaged scenarios, oil is still set to remain a substantial part of the overall energy picture. Uncertainty over the long-run demand levels has the potential to cause meaningful price volatility. In all the likely pathways we foresee, meaningful investment in the energy sector will therefore be needed to prevent a price spike given volumes lost to natural decline.

About the author

Lydia Rainforth is a Managing Director in our Equity Research team with close to two decades experience in the energy sector. Lydia started at Barclays in 2009 where she joined the nascent European equity research team. Prior to this she started her career covering Russian oil and gas companies at Lehman Brothers. The Global Energy team aims to provide industry-leading and thought-provoking research across the sector, from the early stages of exploration through to the end retail business. Lydia and team have a special interest in the development of renewable energy and the growing role of environmental, social and governance factors in investing. Ms Rainforth holds a first-class honours degree from the University of Cambridge.

Special thanks to **Zachary Sadow** for his contribution to this report. Zac was an Energy Analyst at Barclays from 2010 to 2019. He is an Adjunct at Columbia University and a PhD candidate at the University of Nottingham.

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