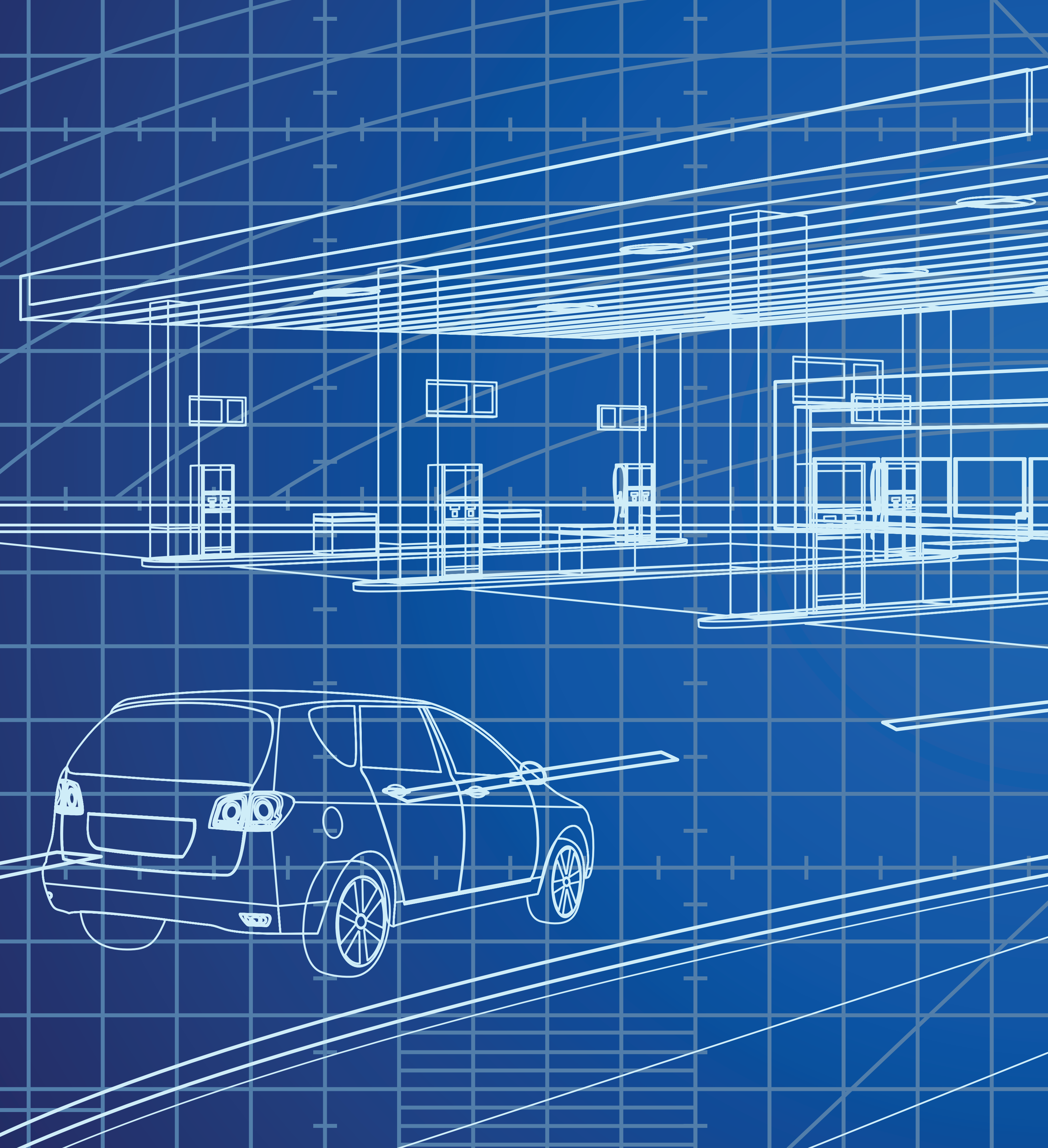
United Kingdom
Petroleum Industry Association

UKPIA Future Vision

The Downstream Oil Sector in a Low-Carbon World

July 2019



About UKPIA

The United Kingdom Petroleum Industry Association (UKPIA) is the trade association for the UK downstream oil sector. We represent the interests of our members and associate members across the industry, who are involved in the refining, distribution and marketing of oil and gas products in the UK.

Members

Associate members

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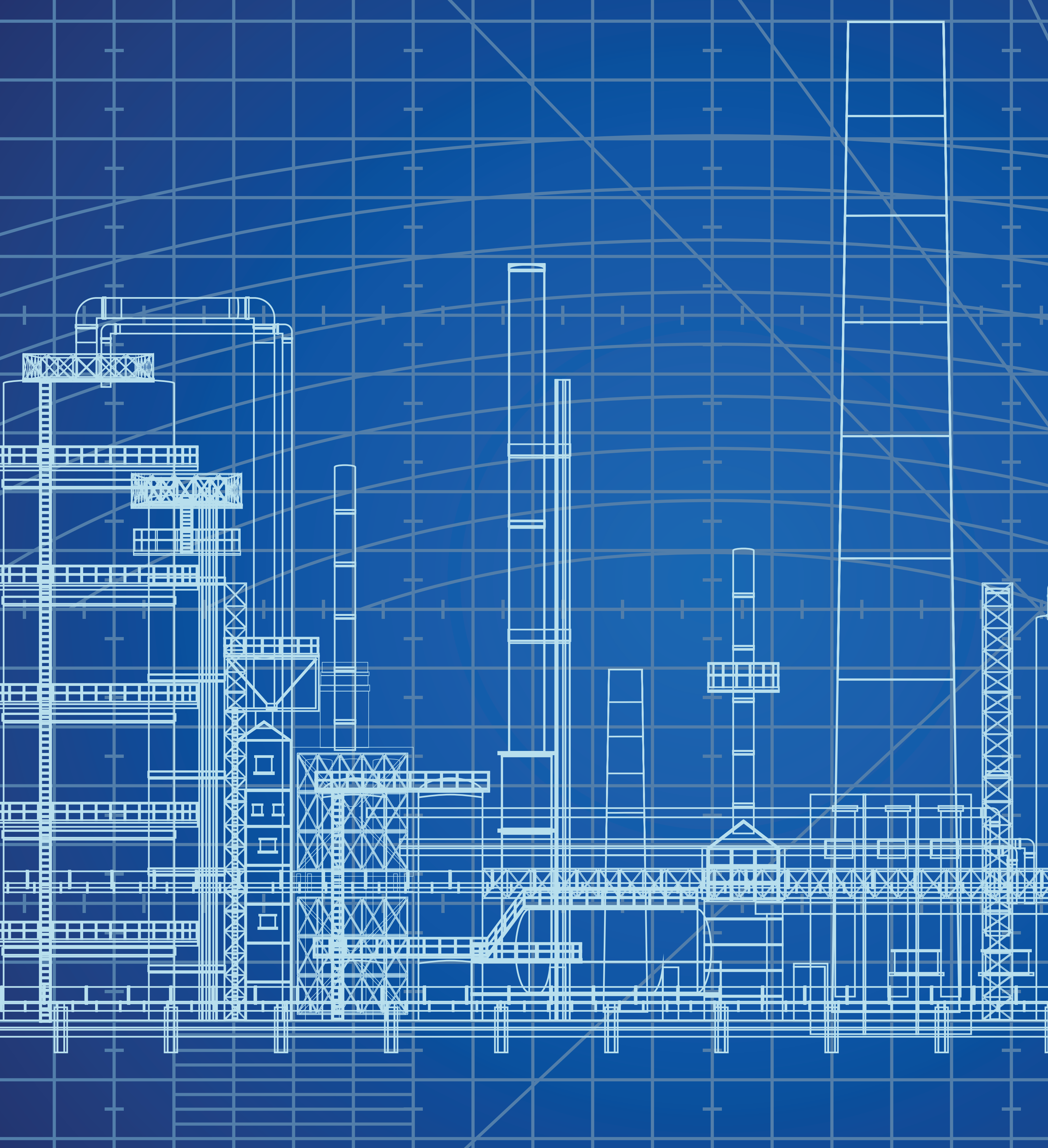

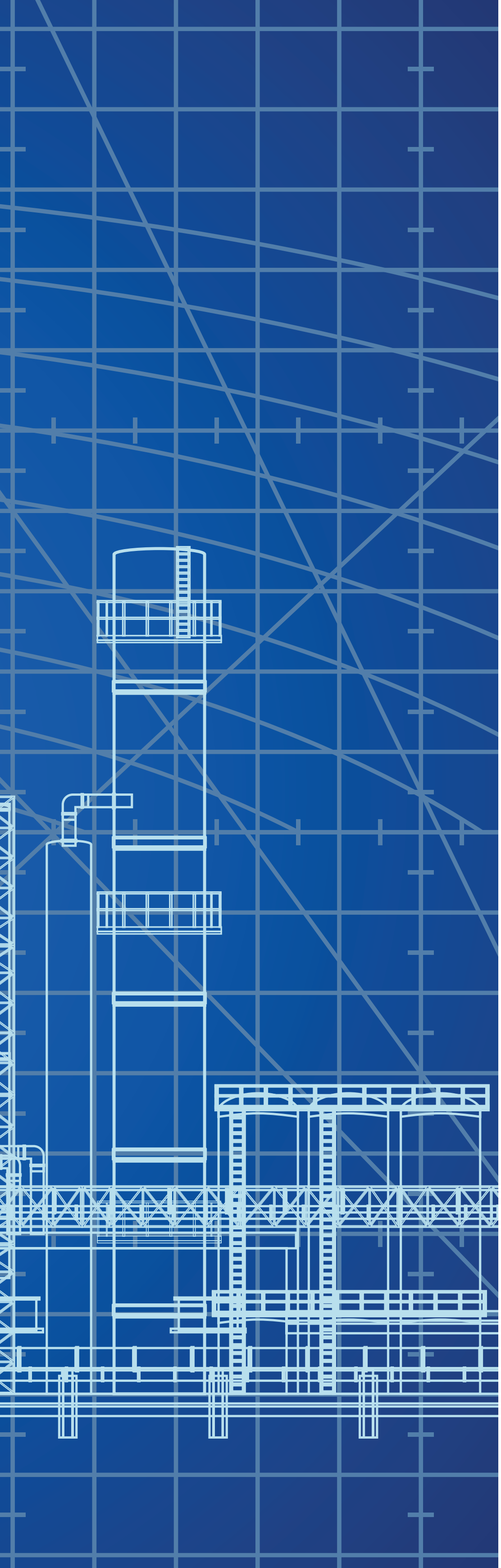

UKPIA

Contents

Foreword

Stephen Marcos Jones
| Director-General,
UKPIA

As we look forward to the middle of this century, it is clear that how the energy sector operates will change considerably. The challenges of climate change, a circular sustainable economy and environmental impacts on economic activity will require new approaches in terms of how we think about mobility and transportation, industrial operations and manufacturing, heating and waste management.

Companies within the UK downstream oil sector, making use of their international links and expertise, can individually develop new ideas, strategies and technologies needed to successfully navigate the years ahead. As in all sectors, the downstream oil sector will need to consider how it can contribute to decarbonisation goals, whilst providing security, reliability and affordable products to wider society.

To do this we need a clear vision for the future of our industry.

This publication seeks to provide one. Whilst not looking to predict or prescribe how the future downstream oil sector will look, UKPIA has set out to paint a vivid picture of the range of possibilities on offer for the refining and fuel marketing industries. As we do so, we also outline the opportunities available through innovation to achieve a circular economy thanks to developments in feedstocks, operations, fuels and products. UKPIA's vision for the long-term future of the downstream oil sector is a positive one.

It is a future **where new, low-carbon[1] liquid fuels** and products can make as much of a contribution to decarbonising the transport we use as can Electric Vehicles (EVs). **Where refinery manufacturing processes can operate with maximum efficiency**, potentially utilising carbon-reducing technologies such as carbon capture, or working with other sectors in industrial clusters to decarbonise together. **Where individual downstream oil companies can utilise their expertise and infrastructure to deliver** low-carbon fuels and products directly to the consumer, potentially in an entirely reimagined forecourt experience.

"The downstream oil sector companies each have a golden opportunity to synchronise with society's goals of sustainability, better management of carbon and continued economic growth."

A successful future downstream oil sector is not in conflict with the UK's low-carbon goals, nor is its role merely as a stepping stone in the transition away from fossil fuels. Our industry is a key part of the UK's low-carbon energy future.

UK downstream oil sector companies will each have multiple options to transform in order to continue to provide socio-economic benefits to all. Across the UK changes that could be made may occur over time and without uniformity: achievements in decarbonising light road vehicles will likely occur more easily than for heavy goods vehicles or in aviation; carbon capture technology or industrial clustering might prove to be better suited to certain facilities than others. However, regardless of the shape these changes may take, the fact remains in the short-, medium- and long-term there will be an important role for liquid hydrocarbons in the UK.

In setting out this vision, we offer policymakers and wider society a snapshot of how – supported by an overarching policy framework and industrial strategy – the downstream oil sector can be a key contributor to solving society's challenges: it can continue to support hundreds of thousands of highly-skilled jobs, achieve significant carbon emissions reductions, and help realise the UK Government's ambitions to create industrial clusters.

As the world changes – through consumer demand, government policy changes and bold technological innovations such as artificial intelligence and the development of new fuels – the downstream oil sector companies each have a golden opportunity to synchronise with society's goals of sustainability, better management of carbon and continued economic growth.

UKPIA's vision for the long-term future of the downstream oil sector is a positive one.

Introduction – UKPIA Future Vision

This report is UKPIA's contribution to the debate about how we produce the energy to meet consumer demand within a changing regulatory framework, both now and in the decades to come. It is our belief that the downstream oil sector can play its part in that effort.

The current role of the UK downstream oil sector | Earlier this year, UKPIA published a commissioned analysis from Oxford Economics, entitled *The Economic Contribution of the UK Downstream Oil Sector*[2], which set out the importance of the industry to the UK today in terms of economic value.

To make sure that the downstream oil sector's important contribution to UK plc continues in the decades ahead, we need to identify potential future concepts that individual companies could elect to follow and work with government and other stakeholders to achieve global climate ambitions.

Why do we need a vision? | The UK's downstream oil sector is at a major crossroads. As governments look for ways to achieve net-zero carbon emissions[3], companies within the oil refining, distribution, supply and retail industries are being challenged like never before to respond to the long-term structural challenges that have emerged in recent years and will continue to emerge over the coming decades.

Whilst some argue that climate goals can only be achieved by completely removing fossil fuels from our economy, UKPIA believes that such ambitions do not preclude an important role for liquid hydrocarbons – which can be made low or neutral-carbon on a lifecycle basis. While it is important to reduce carbon emissions, in a net-zero world it is also important to manage those remaining carbon emissions.

What our vision seeks to achieve | This vision sets out the many functions that the downstream oil sector's companies could play in meeting decarbonisation goals as well as in other societal objectives such as in securing highly-skilled jobs, creating negative-carbon technologies and developing industrial clusters that underpin a strong UK manufacturing sector.

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UKPIA's vision illustrates a future where:

- **Low-carbon liquid fuels play their part in decarbonising transport** as a flexible alternative to other technologies, such as Electric Vehicles. It is important to ensure that enough research and development goes into low-carbon liquids for aviation and maritime sectors[4], which have been identified as difficult to decarbonise given their energy density requirements.

- **UK refineries produce low-carbon fuels and continue to decarbonise** and are able to process sustainable feedstocks; biological, from wastes and other non-fossil sources. Refineries could (subject to appropriate regulatory support) work together with other sectors in industrial clusters to enable other parts of industry to grow while doing so in a way that can manage emissions collectively.

- **The consumer's experience at the forecourt changes in line with the coming changes in mobility of people and goods** The consumer experience at the forecourt may evolve at the 8,500 petrol filling stations found across the UK today: potentially different retail offers while people refill and recharge, integrating with logistics to better deliver the on-demand economy and being ready for widespread automation.

How would UKPIA's vision be achieved? | Our vision does not look to set out a prescription for how companies in the UK's downstream oil sector should develop, but it does highlight some of the positive roles that companies in this industry can individually play in the UK – if they have the opportunity to deliver products on a level-playing field with other energy providers.

Refineries could (subject to appropriate regulatory support) work together with other sectors in industrial clusters to enable other parts of industry to grow while doing so in a way that can manage emissions collectively.

Acknowledgements | We would like to thank the following organisation for contributing their time, resources and inputs during the course of this project:

- Concawe
- FuelsEurope
- The Port of Rotterdam
- Vereniging Nederlandse Petroleum Industrie (VNPI)
- Energy Systems Catapult

The UKPIA Future Vision for the Downstream Oil Sector

A major contributor to the UK economy

- The downstream oil sector plays a big part in the success of UK plc in terms of £21 billion in gross domestic product and the 300,000 jobs it supports
- Major centres of engineering excellence are located around downstream infrastructure - refineries, terminals and forecourts - across the UK

To ensure the downstream sector continues to play this vital part in our energy future, companies will need to...

Plan for a low-carbon future

- By 2050 demand for liquid fuels will change, but they will still be needed
- The downstream oil sector can be an enabler of the low-carbon transition
- Liquid fuels can help society achieve its low-carbon ambitions

Potential ways to achieve a low-carbon downstream sector include...

Embracing new products, technologies and processes across our industry

- Energy efficiency and new technologies – such as carbon capture – can decarbonise industry
- Low-carbon fuels can be readily distributed via existing downstream infrastructure requiring minimal changes in consumer behaviour
- Refineries of the Future can be research and development hubs for low-carbon fuels

Embracing new ways of moving people and goods across the transport network

- Changing technology and consumer behaviour will alter how we move by air, land and sea
- The Forecourt of the Future may need to reimagine the role of mobility in an age of increased choice
- Liquid fuels will still be needed in high energy density transport – heavy goods vehicles, aviation and shipping

Working with others to unlock the low-carbon future

- Opportunities exist for the downstream sector to work with other industries and stakeholders to decarbonise
- Industrial clusters could unlock the door to a low-carbon economy
- Leadership, vision and modular development could put refineries at the heart of decarbonisation

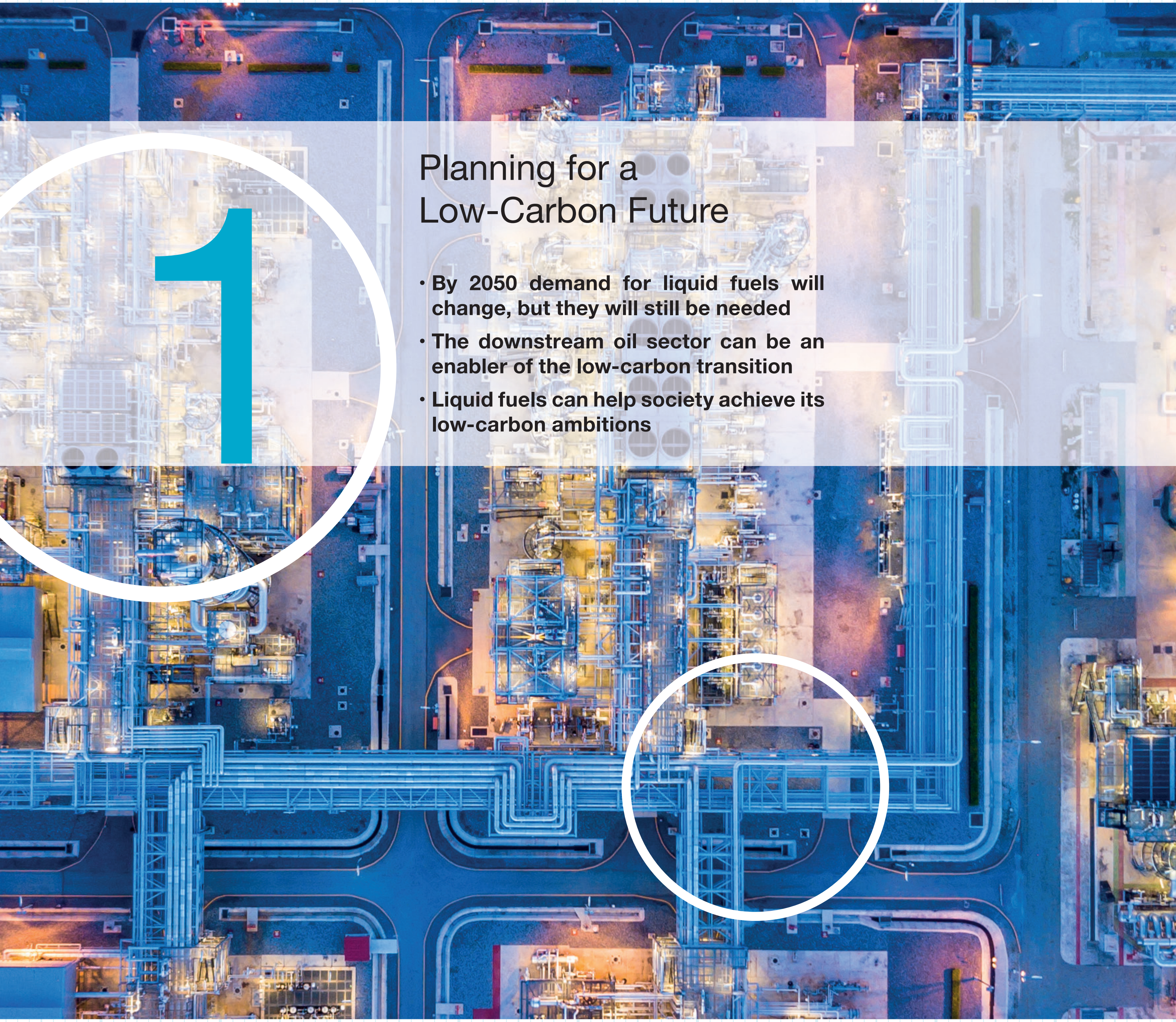
Putting in place the policies that support and incentivise change will mean we must...

Work with government to unlock the low-carbon future

- A low-carbon downstream sector will require investment of time, personnel, capital and business leadership
- Government has a key role in creating an investment climate to support decarbonisation
- Engagement with government is vital to unlocking the low-carbon future

Achieving these ambitions will ensure that the downstream oil sector continues to be...

A major contributor to the UK economy



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Planning for a Low-Carbon Future

- **By 2050 demand for liquid fuels will change, but they will still be needed**
- **The downstream oil sector can be an enabler of the low-carbon transition**
- **Liquid fuels can help society achieve its low-carbon ambitions**

- Scenarios looking at the energy transition required to achieve a low- or net zero-carbon economy, such as those published by the International Energy Agency and UK Committee on Climate Change, show a marked reduction in demand for liquid hydrocarbons in the decades ahead. Nonetheless, they also recognise the continued need for these products in some sectors, such as aviation, heavy goods vehicles and marine.
- The early development of low-carbon fuel production would help achieve ambitious carbon abatement objectives, reducing the disruption and upheaval associated with the introduction of alternative technologies. This would make best use of significant existing infrastructure, whilst lowering carbon emissions in the short- and medium-term.
- Low-carbon liquid fuels provided by the downstream oil sector could therefore be a key enabler in the transition to a low- or net zero-carbon economy.

1.1. What drives changing demand for liquid hydrocarbon fuels?

Efforts to put international environmental and sustainability frameworks in place have been in train for 30 years. From the Rio Summit in 1992 to the 2015 Paris Agreement, there has been a long-term global movement to create agreed practices to respond to climate change driven by human activity. The latter agreement commits national signatories to accelerate and intensify previous efforts to respond to climate change, by working to keep global temperature rises this century to below 2^{oC} above pre-industrial levels, and to pursue efforts to limit such rises to 1.5^{oC}.

The UK has played an important role in the development of this global agenda, with successive governments advocating challenging ambitions to reduce emissions at an EU level, as well as domestic climate policy like the 2008 Climate Change Act. In June 2019, this level of ambition was taken further with legislation committing the UK Government to achieve net-zero emissions by 2050[5].

These international and domestic efforts to tackle climate change by transitioning to a low- or zero-carbon economy may affect the demand for many of the products traditionally manufactured by the downstream oil industry. In the UK, a range of key policies and regulatory drivers have been announced and implemented to varying degrees, with targeted impacts for different sectors of the economy and wider society.

1.2. 2050 decarbonisation scenarios

As a result of these policy drivers – both in the UK and globally – we anticipate that the demand for petroleum products may change considerably. But to what extent will that demand change in a low-carbon future? As new technologies are developed and widely adopted by consumers, what part will oil continue to play in the energy mix?

To answer these questions, industry and policymakers are reliant on scenario planning to inform strategic decisions. With scenario creation, the intention is not to predict the future but to develop an understanding of how different drivers and policies might influence that future, and to provide potential pathways to achieve the outcomes described by each scenario[6].

Detailed and highly complex models can help provide medium- to long-term energy projections, taking into account the key policies and other assumptions made under each scenario.

Key policy ambitions and potential options for sector decarbonisation

Road

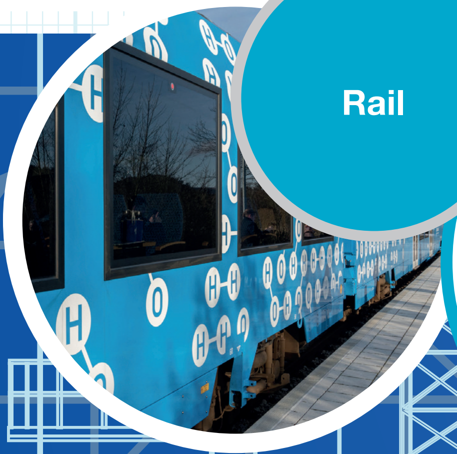
- Reduce roadside nitrogen dioxide (NO_2) concentrations by ending the sale of new conventional petrol and diesel light vehicles by 2040[7]
- Support the adoption of ultra-low emission vehicles (ULEVs) through the Clean Growth Strategy and 'Road to Zero' strategy[8]

- Battery electric vehicles (BEVs)
- Hydrogen fuel cell electric vehicles
- Plug-in and non-plug-in hybrid vehicles
- Petrol and diesel light vehicles meeting revised Real Driving Emissions (RDE) standards
- Liquid Petroleum Gas (LPG) and Compressed Natural Gas (CNG) fuelled vehicles
- Retrofitted exhaust gas treatment technologies for buses and HGVs
- Low-carbon liquid fuels

Shipping

- Reduce sulphur content of marine fuel oil by complying with revised International Marine Organisation (IMO) MARPOL Annex VI regulations from January 2020[9]

- 'Scrubbers' to remove SO_2 from exhaust emissions in ships using high sulphur fuel oil (HSFO)
- Low sulphur fuel oil (LSFO), marine gasoil (MGO) or other types of fuel including low-carbon alternatives



Rail

- Challenge the rail sector to issue a vision for lowering its emissions[10]
- Remove all diesel-only trains from the rail network by 2040[11]

- Retrofitting diesel-electric and electric trains with hydrogen fuel cells
- New hybrid and hydrogen fuel cell trains
- Increased electrification of the rail network

Aviation

- International Air Transport Association (IATA) commitment to a reduction in net emissions of 50% by 2050 from their 2005 level[12] across the aviation sector
- The European Commission Flightpath 2050 project that aims to reduce emissions per passenger kilometre by 75% by 2050[13]

- Low-carbon liquid fuels (N.B. there are no emerging substitutes for jet fuel[14], with feedstock restrictions for renewable jet fuel)
- Improved efficiency of aircraft operations and infrastructure improvements
- Market-based measures to reduce or offset emissions, i.e. aviation CO_2 included under EU ETS[15], International Civil Aviation Organisation's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)[16]

Heat

- Reduce emissions and decarbonise the electricity and the gas grid, i.e. through the injection of biogas and hydrogen[17] Substitute domestic LPG demand with alternative energy sources, i.e. natural gas, renewable electricity or heat pumps

- Support for businesses to improve energy productivity by at least 20% by 2030
- Phase-out high-carbon fossil fuel heating for new and existing buildings and housing off the gas grid during 2020s[18]
- Support the recovery of industrial waste heat for recycling or third-party use
- Fuel switching for industrial processes to low-carbon energy sources
- Improvements to housing energy efficiency

Petrochemicals

- Demand for petrochemical products is forecast to increase significantly in Europe by 2050[19].

- Further development of circular economy principles to boost resource efficiency, reducing demand for raw materials and petrochemical feedstocks (2040-2050)
- Increased imports from lower feed and energy cost regions may also have significant impact

To inform development of the UKPIA Future Vision, four different scenarios have been selected; two developed by the International Energy Agency (IEA), which consider the energy mix across a number of sectors at EU-28 level, along with two further scenarios developed by the Energy Technologies Institute (ETI). The latter use a systems approach to model the UK energy transition with the aim to inform debate about how the UK will generate power and heat and move people and goods in the future[20].

Modified IEA "New Policies" scenario | The IEA World Energy Outlook 2018 (WEO 2018) "New Policies" scenario (NPS) provides a measured assessment of where today's policy frameworks and ambitions, together with the continued evolution of known technologies, might take the energy sector in coming decades. Since the IEA NPS is available only at EU-28 level, UKPIA has made the simple assumption that UK demand will continue to represent the same proportion of EU-28 demand through to 2050 as it did in 2017, based on data from the UK Digest of Energy Statistics (DUKES)[21]. The IEA NPS scenario has also been modified to include lubricants and bitumen, where demand has been maintained at 2017 levels through to 2050.

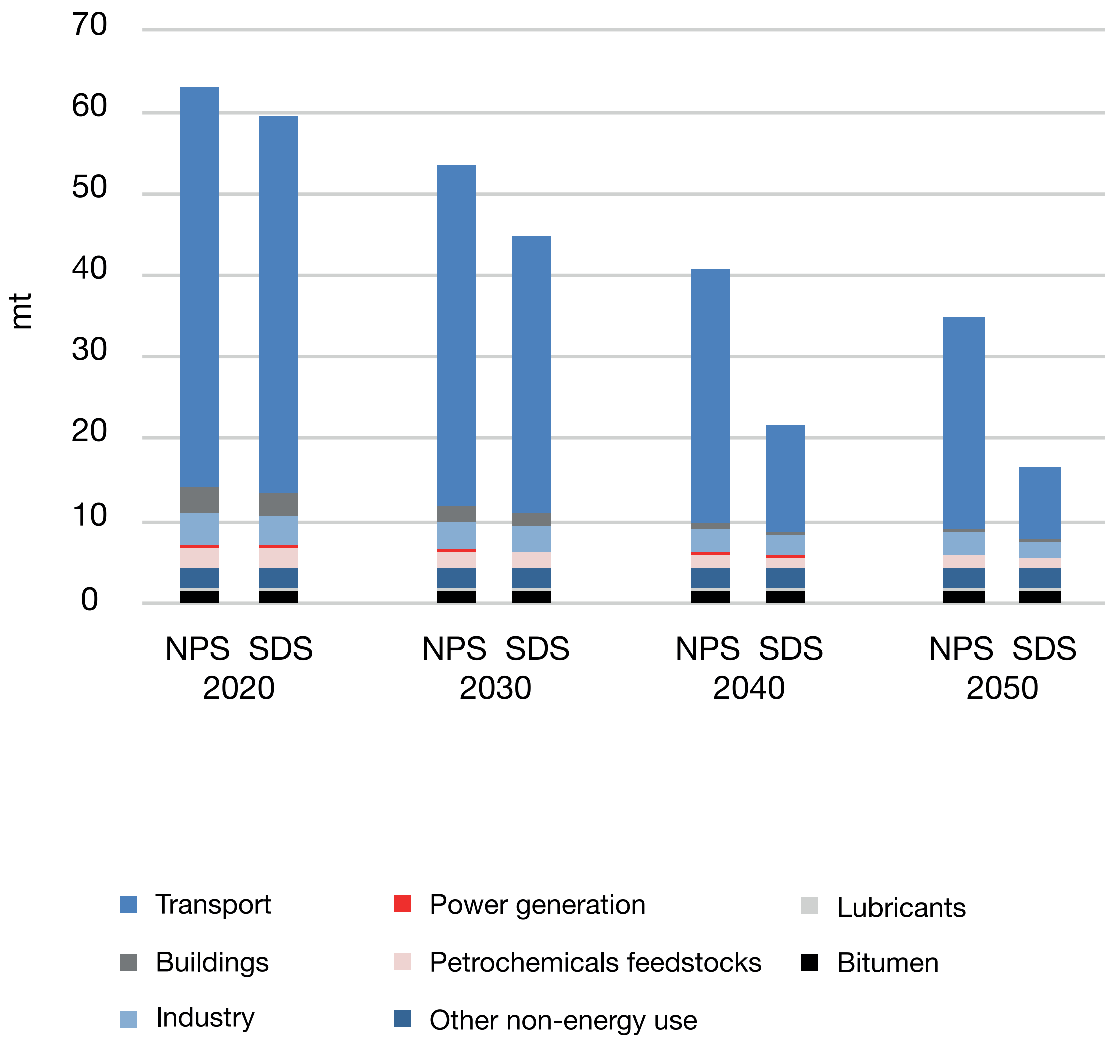
Modified IEA "Sustainable Development" scenario | The IEA WEO 2018 "Sustainable Development" scenario (SDS) starts from selected key outcomes under the UN Sustainable Development Goals[22] and then works back to the present to see how they might be achieved:

- Delivering on the Paris Agreement. The Sustainable Development Scenario is fully aligned with the Paris Agreement's goal of holding the increase in the global average temperature to "well below 2°C".[23]
- Achieving universal access to modern energy by 2030.[24]
- Reducing dramatically the premature deaths due to energy-related air pollution.[25]

The SDS sets out the major changes that would be required to deliver these goals simultaneously and also considers the linkages between energy and water. UKPIA has made the same assumptions in deriving UK demand as made for the NPS and has again included lubricants and bitumen at the same levels of demand.

The UK demand evolution for liquid fuels under both the IEA NPS and SDS are shown in Diagram 1.

Diagram 1.
UK Demand for liquid fuels
– modified IEA New Policies and Sustainable Development scenarios



ETI "Clockwork" scenario | The ETI Clockwork scenario is based on a policy-led premise that:

"Well-coordinated, long-term investments allow new energy infrastructure to be installed like clockwork. The regular build of new nuclear, CCS plants and renewables ensures a steady decarbonisation of the power sector. National-level planning enables the deployment of large-scale district heating networks, with the local gas distribution network retiring incrementally from 2040 onwards. By contrast, due to a strong role for emissions offsetting, the transportation system remains in the earlier stages of a transition and people and companies continue to buy and use vehicles in a similar way to today, albeit with regulation and innovation continuing to improve their efficiency."[26]

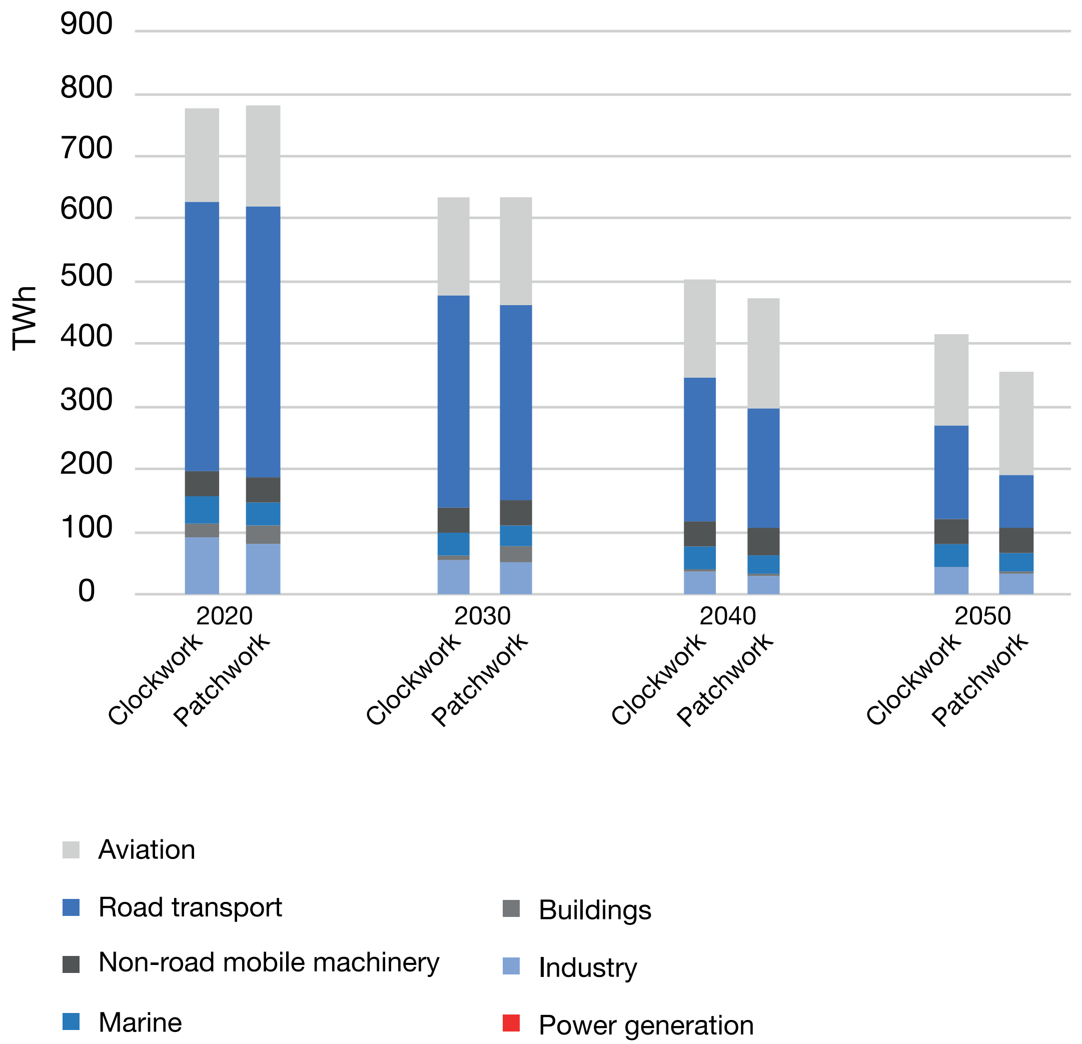
Heavy goods vehicles and the aviation sector are likely to need to rely on conventional fossil fuels for the foreseeable future.

ETI "Patchwork" scenario | In comparison to the policy-led premise adopted in the ETI Clockwork scenario, the ETI Patchwork scenario is based on a premise that central government takes less of a leading role, and that decarbonisation is prompted by regional policies and actions taken by society and individuals:

"With central government taking less of a leading role, a patchwork of distinct energy strategies develops at a regional level. Society becomes more actively engaged in decarbonisation, partly by choice and partly in response to higher costs. Popular attention is paid to other social and environmental values, influencing decision-making. There is a more limited role for emissions offsetting, meaning more extensive decarbonisation across all sectors, including transport. Cities and regions compete for central support to meet energy needs which is tailored to local preferences and resources. Over time, central government begins to integrate the patchwork of networks to provide national solutions."[27]

The demand evolution under the ETI "Clockwork'
The UK demand evolution for liquid fuels under both the ETI "Clockwork' and "Patchwork" scenarios is shown in Diagram 2. (N.B. these two scenarios use energy content as TWh rather than mt as used in the IEA scenarios).

Diagram 2.
UK Demand for liquid fuels
– ETI “Clockwork’ and “Patchwork” scenarios



All four scenarios show significant changes in demand for petroleum products by 2050, with some considerable differences in how demand will evolve, depending on the assumptions adopted under each scenario. Significant reductions are seen from where UK petroleum product demand (including biofuels) stood in 2017 at just under 70mt, with 2050 demand falling to 35mt under IEA NPS; under 17mt under IEA SDS; the equivalent of around 34mt and 41mt under the ETI "Clockwork" and 'Patchwork" scenarios (N.B. the ETI scenarios exclude lubricants, bitumen and petrochemical feedstocks, which represent an additional 5mt or so.)

Under all four scenarios, liquid fuels are replaced by other energy carriers, in particular, renewable electricity and green hydrogen. Key points are as follows under all scenarios:

- Liquid fuels continue to play an important role in aviation and HGV road transport
- Petrol demand falls sharply post 2030 with increasing electrification of the light vehicle fleet
- Use of liquid fuels for space heating of buildings falls to very low levels and is retained only for buildings (mostly historical) which are difficult to retro-fit with alternative forms of heating.
- Considerable uncertainty remains around the future of marine fuels, with many different options (e.g. LNG, dual-fuel, hydrogen and ammonia) under consideration.

Importantly, all of the scenarios are dependent on the availability of a wide range of new technologies with different levels of technology readiness, significant investment and early adoption and implementation of ambitious policies across the economy. This will require a fundamental change in the energy market and changes in societal behaviour to achieve the anticipated outcomes.

1.3. 2050 decarbonisation scenarios - the impact on CO_2 emissions

The two IEA scenarios provide estimates for EU-28 CO_2 emissions up to 2040 only, when the total CO_2 emissions are 2,652mt under the NPS and 1,433mt under the SDS. If these figures are extrapolated forward to 2050, then emissions fall to 2,216 and 917mt, reductions of around 61 and 84% compared to the 1990 baseline for the EU-28 plus Iceland[28]. The level of UK emissions reduction under these two scenarios is likely to be higher, as the UK has decarbonised quicker than many other countries[29,30], but these figures cannot be derived from the EU-level information available under the IEA scenarios. Investment cost information is not available for the two IEA scenarios.

The ETI scenarios have both been developed to meet a UK climate change target of an 80% reduction in greenhouse gas (GHG) emissions by 2050 compared to the 1990 baseline, but achieve this through different pathways[31].

Under the ETI "Clockwork" scenario, central government and national-level planning play an important role in supporting large scale investment in CCS, nuclear power generation and district heating networks, with large scale changes in use of the gas distribution network from 2040 onwards. However, transformation of the transport sector is largely dependent in this scenario on the uptake of hybrid and plug-in hybrid EVs, with emissions reduction for HGVs being market-led, driven by the cost of liquid fuels, including lower-carbon liquid fuels.

Consumer behaviour plays a much greater role in earlier stages under ETI "Patchwork" scenario, with "renewables finding support at all levels of society; central government backing large scale projects such as offshore wind, while local authorities and communities support combined heat and power (CHP), onshore wind and solar power generation." CCS deployment and hydrogen production from biomass and coal occurs later, "although biomass uptake is limited by societal concerns about land-use change and biodiversity, as well as market failures".[32]

The total cumulative investment cost estimated for the ETI "Patchwork" scenario is higher at £2,390 billion, compared to £2,269 billion under the "Clockwork" scenario.

With amendment of the UK Climate Change Act 2008 on 26th June 2019 to adopt a minimum of 100% reduction in UK GHG emissions compared to the 1990 baseline[33], the UK is effectively committed to net-zero GHG emissions by 2050. Three sets of options have been developed by the Committee on Climate Change (CCC)[34] to support adoption of a net-zero target:

- **Core options** are those low-cost low-regret options that make sense under most strategies to meet the current 80% 2050 target. They also broadly reflect the Government's current level of ambition (but not necessarily policy commitment).
- **Further Ambition options** are more challenging and on estimates by CCC are generally more expensive than the Core options.
- **Speculative options** currently have very low levels of technology readiness, very high costs, or significant barriers to public acceptability. It is very unlikely they would all become available.

Three net-zero emissions scenarios are presented, each using a different combination of speculative options. Although these have not been assessed by UKPIA, low-carbon liquid fuels have been included in the energy mix for each of these scenarios and are of particular importance for "hard-to-treat" sectors such as aviation.

1.4. The case for low-carbon fuels

The need for international and domestic efforts to tackle climate change by transitioning to a low- or zero-carbon economy has now been clearly established. In the short term, under the Climate Change Act 2008 and the fifth carbon budget (2028-2032), the UK Government has set a target for a 57% reduction in GHG emissions by 2030 and now in the longer term, a net-zero target for 2050 compared to the 1990 baseline. Although the UK is currently set to outperform against the third carbon budget (2018 to 2022), it is not on track to meet the fourth (2023 to 2027) and subsequent emissions targets[35].

Achieving these targets represents an enormous challenge for the UK as a whole. It will require a complete transformation of the UK energy system and consumer behaviour, along with innovative solutions, facilitative government policy, new skills to develop these solutions and the financial means to fund major new investment.

Achieving these targets represents an enormous challenge for the UK as a whole. It will require a complete transformation of the UK energy system and consumer behaviour.

Low-carbon liquid fuels will be of vital importance in the drive to reduce emissions in the transport system, not only during the transition period, where liquid fuels will continue to be required to provide energy for transport and smooth and efficient operation of the economy and society, but also in the longer term as highlighted under all of the decarbonisation scenarios considered, including the CCC net-zero scenarios.

There are a wide variety of energy carriers with low carbon intensity that have potential to fulfil these requirements in mobility applications across all sectors[36]. These have been assessed by Concawe, the technical body representing the European refining sector, with the most promising options in terms of their theoretical potential to achieve even net-zero emissions being electricity (renewable), advanced biofuels, so-called e-fuels (if produced using renewable electricity) or combinations supported by carbon capture and utilisation and storage (CCUS) (see Chapter 2). Key to the longer-term use of liquid fuels is the ability to reduce the life cycle carbon intensity in an affordable and efficient manner.

When comparing different technologies for the reduction of CO_2 emissions in the road transport sector, it is important to consider the energy consumption and emissions in every step of the process from the production of crude oil, or other feedstock materials, through transportation, refining, formulation and distribution of the finished fuels ("well-to-tank"), to the consumption of the fuel in the vehicle ("tank-to-wheels"). The "well-to-wheels" (WTW) approach breaks down the CO_2 emissions into different stages.

Pathways to reduce the WTW CO_2 intensity of liquid fuels can then be addressed under five main categories:

1. **Vehicle-efficiency enhancement:** The future evolution of vehicle designs and internal combustion engines, optimised for efficient combustion of fuels designed for these engines.

2. **Extraction of crude oil and refining into products:** Opportunities to improve energy and CO_2 efficiency, during both extraction of crude oil (upstream) and refining (downstream).

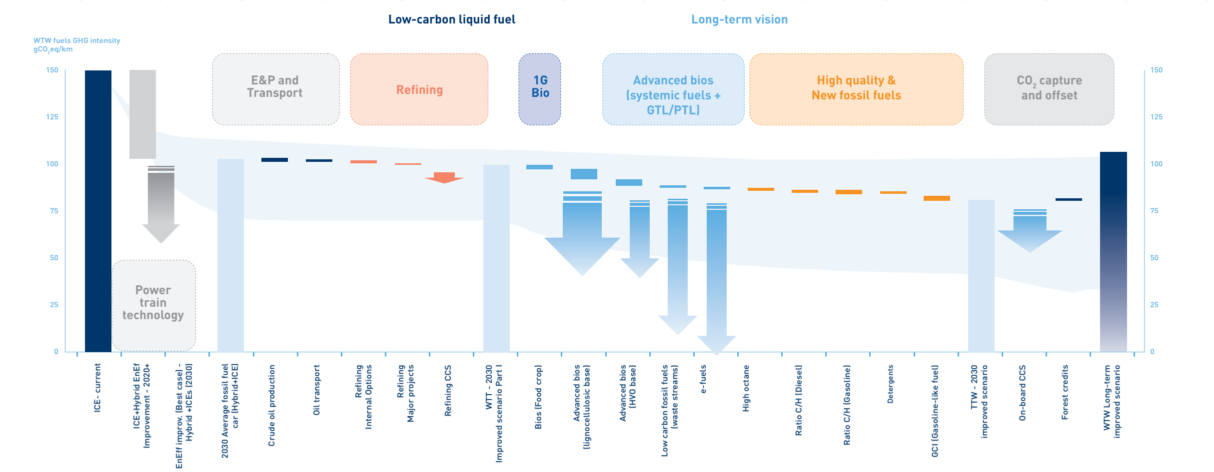
3. **Alternative low-carbon liquid fuels:** Exploring the potential WTW reduction through the effective deployment of sustainable and low carbon bio- and synthetic fuels, including power-to-liquids technologies (e-fuels).

4. **Improving performance of petroleum-based fuels:** The modification of fuel properties to optimize these for the latest internal combustion engines.

5. **Other technologies/options:** These are in the very early stages of development but could include on-board CCS and later conversion/storage of the final CO_2 emitted at the tailpipe as the final step of the GHG mitigation chain.

As an example, the CO_2 emissions associated with diesel and gasoline have been summarised in Diagram 3, which shows a high-level assessment for a C-segment passenger car.

Diagram 3.
Concawe Low-Carbon Pathways model



Fewer technology options are currently available for CO_2 emissions reductions in the HGV sector. Similarly, for aviation, there are significant challenges, with forecasts of increasing demand but no emerging technologies that allow full substitution of hydrocarbons by 2050.

Low-carbon liquid fuels will therefore continue to be important in achieving GHG emissions reductions in the long-term but will also pay an important role in the short-term in achieving 2030 emissions targets.

1.5. The impact of decarbonisation measures on non-GHG emissions

The implementation of decarbonisation measures will also result in significant reductions in air emissions such as nitrogen oxides (NO_X), sulphur dioxide (SO_2) and particulate matter (PM_{10}). Similarly, measures to improve air quality will also lead to reductions in CO_2 emissions.

Road transport | In July 2017 the UK Government set out its intention to end the sale of new conventional petrol and diesel cars and vans by 2040 and its plan for tackling roadside nitrogen dioxide (NO_2) concentrations[37]. This was further elaborated in the Clean Growth Strategy[38], published in October 2017 and the Road to Zero (RtZ) Strategy[39], published in July 2018. The Clean Growth Strategy sets out a broad range of possible ultra-low emission vehicle (ULEV) uptake levels by 2030 (30-70% of new car sales and up to 40% of new van sales), to meet future UK carbon budgets and to build a new market for zero emission vehicle (ZEV) technologies in the UK. Although these measures are focussed on improvements in local air quality through the reduction of vehicle tailpipe emissions, these are also accompanied with reductions in CO_2 emissions in comparison to vehicles fuelled with crude-derived petrol and diesel.

A number of national and local government initiatives have recently focussed on emissions reduction from bus fleets, primarily to address local air quality issues but also to improve fuel efficiency. Examples of the technologies implemented include retrofitting of exhaust gas treatment technologies, such as selective catalytic reduction (SCR), thermal management technology, hybridisation and more extensive modification for fuel conversion to Compressed Natural Gas (CNG), Liquified Natural Gas (LNG), plug-in electric motors, hydrogen fuel cells or LPG. High biofuel content fuels (e.g. 20-30%) have also been used by some operators, but these do not address air quality issues unless combined with SCR.

Fewer technology options are currently available for non-GHG emissions reduction in the heavy goods vehicle (HGV) sector, although retrofitting has also been implemented as described above. However, energy efficiency improvements, different forms of electrification (e.g. powertrain hybridisation and the potential for electrified road systems), along with the development of different energy carriers (e.g. CNG, renewable fuels or hydrogen used in fuel cell vehicles) and potential changes in HGV operation (including automated/driverless trucks, road trains and/or cargo optimisation) are all expected to reduce GHG and non-GHG emissions by mid-century, despite an anticipated increase in freight volumes.

Refining | The implementation of CO_2 reduction technologies in refineries, associated with their continued focus on energy efficiency improvement and process optimisation, also results in reduced emissions, with further reductions associated with deployment of new technologies for production of low-carbon fuels. As described in Chapter 2, the Low Carbon Pathway for refining[40] will see a variety of options implemented for CO_2 reduction as shown in Diagram 4. Implementation of many of these technologies will also result in reductions of air pollutant emissions through improvements in energy efficiency or substitution of existing fuel-firing.

Diagram 4.
Refinery CO_2 emissions reduction technologies

Ongoing

Improvements in refinery process efficiency:
- Catalyst improvements
- New heat exchangers
- Improvements in Energy Management Systems
- Inter-unit heat integration

2020

Increased recovery of low-grade heat for district heating and electricity production
Use of low-carbon energy sources:
- Replacement of on-site CHP by decarbonised grid electricity and gas
- Further reductions in liquid fuel firing
- Improved recovery of hydrogen and LPG from refinery fuel gas

Increased use of imported low-carbon electricity
- Electrification of rotating equipment currently powered by steam
- Substitution of fired boilers and heaters by electric heaters
- Hydrogen production from electrolysers using imported renewable electricity

2050

Partial capture of refinery CO_2 emissions (CCUS)
- Requires reduction of emissions (NO_x, SO_2 and PM_{10}) before carbon capture

* *Implementation of many of these technologies will also result in reductions of non-GHG emissions through improvements in energy efficiency or substitution of existing fuel-firing.*

2 The Downstream Oil Sector of the Future

- **Energy efficiency and new technologies – such as carbon capture – can decarbonise industry**
- **Low-carbon fuels can be readily distributed via existing downstream infrastructure requiring minimal changes in consumer behaviour**
- **Refineries of the Future can be research and development hubs for low-carbon fuels**

- Downstream oil sector companies each have major opportunities to consider how their processes and operations can be repurposed to achieve even greater improvements in energy efficiency, on top of the substantial progress made already.

- It is technically possible for companies to produce a range of new low-carbon liquid hydrocarbons to be delivered to the consumer, which will require an innovative approach to how our fuels are sourced, manufactured and ultimately used by the consumer. A low-carbon liquid fuels solution could make use of existing infrastructure for deliveries and requiring little, if any, behavioural change by consumers.

- Carbon Capture technologies offer some of the most exciting opportunities both to reduce carbon emissions and even make use of captured carbon to create new products.

- Refineries individually offer a wealth of opportunities as locations to research and develop low-carbon fuels. As refining companies each look to develop their Refinery of the Future, a number of such resources will need to be drawn upon by them and facilities developed.

2.1. What are low-carbon fuels?

To continue to play a full part in the economy for the long-term, downstream companies may each need to consider how to do things differently across the full range of activities that our industry delivers – from the refinery to the forecourt.

As shown in Chapter 1, low-carbon liquid hydrocarbons can play an important part in the decarbonisation of our society, environment and economy. These low-carbon fuels are an exciting prospect with a wide number of potential avenues for development, and a number already exist in different forms and to varying degrees.

These include:

- **Biofuels |** Biofuels have become a common component of the modern fuels sector, with mandated requirements in the UK to include a proportion of products manufactured from biological sources, wastes and residues in fuel sold to the consumer.

- **Renewable Fuels from a Non-Biological Source (RFNBO) |** RFNBOs are fuels produced via electrolysis using renewable power and synthesis. A primary example is a process where hydrogen, produced from a low-carbon source, reacts with CO_2 to produce a hydrocarbon chain that is also referred to as power-to-liquid (PtL) or an e-fuel.

- **Low-carbon fossil fuels (LCFF) |** LCFFs are produced from non-organic waste, or non-waste fossil feedstocks from non-renewable energy that may have a carbon content lower than conventional petrol or diesel. Typical examples include gases such as LPG and LNG, as well as fuels produced from non-recyclable plastic, non-organic Municipal Solid Waste (MSW) and crude oil refining with Carbon Capture Utilisation and Storage (CCUS).

- **Development fuels |** 'Development fuels' are a UK concept, and are a legislative obligation to encourage lower carbon fuels in the 'hard to decarbonise' transport sectors (e.g. the HGV and aviation sectors). The approach by the UK government is "to incentivise those fuel pathways which need greater support and fit the UK's long-term strategic needs".[41] Development of such fuels in the UK could not only fulfil domestic needs, but also present potential export opportunities for the technology and, should enough feedstock be available, the fuels themselves.

Low-carbon liquid hydrocarbons can play an important part in the decarbonisation of our society, environment and economy.

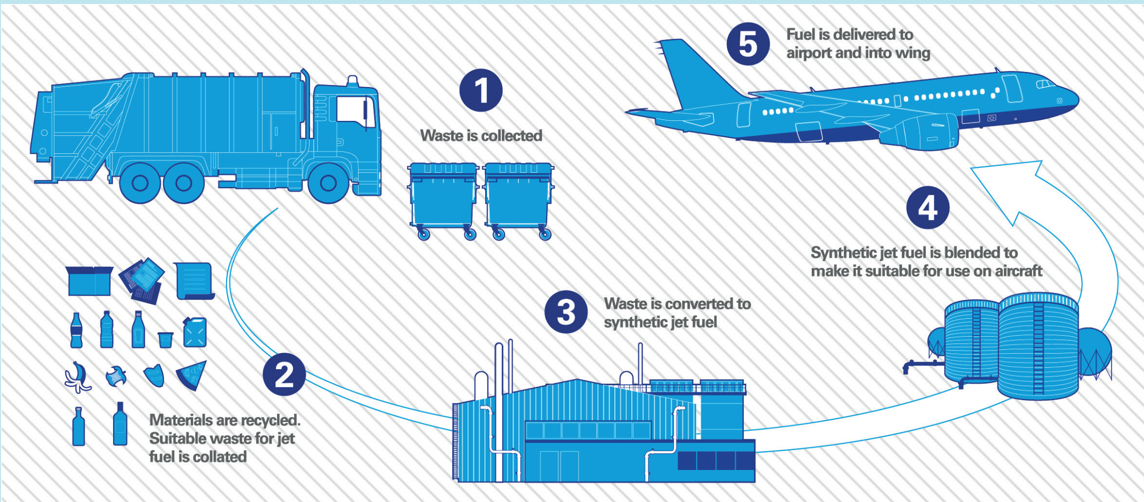
Case Study

Making household wastes into jet fuel – Sierra BioFuels[42]

In 2016, BP announced a major global investment of US$30 million (£23 million) in Fulcrum, a pioneer in the development and production of low-carbon aviation fuel. The ambition is to deliver sustainable aviation fuels derived from waste from Fulcrum's first commercial biofuels plant in Nevada, US, expected to open in the first half of 2020. "Once the Sierra BioFuels Plant begins commercial operations, it plans to convert approximately 175,000 tons of household garbage into more than 10.5 million gallons of fuel each year – the equivalent quantity of aviation fuel is enough to supply over 1,600 A320 aircraft."

Fulcrum's process is expected to reduce greenhouse gas emissions by more than 80%, compared to the production of traditional aviation fuel.

Such a process and technology could, therefore, be a new source of feedstock for aviation jet fuel long term in an area that due to the need for high energy density does still appear to need a liquid fuels solution or equivalent.



Source: image provided by BP

2.2. How can the sector produce low-carbon fuels?

If low-carbon liquid fuels can play a role in the future transport system and energy mix, what might it take to produce them, and what resources are available for their development? There are a number of different pathways to achieving low-carbon fuels. Whilst not exhaustive, and many other approaches may be feasible in the future, they could include:

Natural gas | Natural gas is mostly methane (CH_4), and with its high hydrogen-to-carbon ratio has a higher molecule energy, and therefore a lower carbon release (6-11%) when used in place of conventional fuels[43]. It is most useful when used in a compressed or liquified form. This could include **Compressed Natural Gas (CNG), Liquified Natural Gas (LNG), Gas to Liquids (GTL)** or **hydrogen.** Introduction of biogas (not from fossil sources) would be expected to bring lower carbon emissions depending on their production.

Vegetable oils and animal fats | Vegetable oils can be converted to **Fatty Acid Methyl Esters (FAME)**, otherwise known as biodiesel. Alternatively, they may be hydro-treated to become **Hydrogenated Vegetable Oils (HVO)**. HVO occurs when vegetable oil or waste fats are hydrogenated to form a paraffinic molecule that can be fractionated into naphtha, gasoline, kerosene and diesel blending components – they have an advantage over FAME since it is a 'drop-in' fuel and, therefore, not limited by blend wall limits in fuel standards.

Alcohols | Conventional alcohols are made by fermentation of sugar crops (i.e. wheat, sugar beet) and are used as gasoline blending components. They include **methanol, ethanol** and **butanol**. Other forms of alcohol – such as **advanced ethanol** and other **biofuels** – are made from non-edible parts of the plant and energy crops, such as straw. Further processing alcohols can refine them into hydrocarbon molecules that can then be blended into gasoline, jet kerosene and diesel. The introduction of flexi-fuel vehicles to the UK market in future could allow higher blends of alcohol in petrol, such as E85, which is available in Sweden. However, at the moment there are few flexi-fuel vehicles in the UK.

Other pathways | Various other low-carbon pathways could potentially be utilised to develop new fuel types. This includes:

- **Gasification**, a process that converts solids or liquids into synthetic gas or syngas.
- The **Fischer-Tropsch process** that produces synthetic hydrocarbons that can be blended directly into fuels.
- **Pyrolysis** and **Hydrothermal Liquefaction (HTL)** that converts dry and wet solid feedstocks respectively into liquid fuels.
- **Power-to-Liquids (PtL)** or **e-fuels**, that takes recovered CO_2 reacted with renewable or low-carbon hydrogen to produce synthetic fuels.
- **Direct Sugar to Hydrocarbons (DSHC)**, where sugars and other potentially cellulosic feedstocks are fermented using microorganisms to produce products that can be further hydrotreated and fractionated into finished fuels.
- **Biofuel from Algae**[44] – Algae consumes carbon dioxide while growing and can be grown in wastewater purifying it in the process where it produces biodiesel precursors or fermentable sugars.

Case Study

Converting crude refineries into biorefineries – Total La Mède Refinery

In 2015, Total announced plans to transform its La Mède refinery into a unique facility in France and in 2019 France's first converted biorefinery began operations.

According to Total: "Our La Mède biorefinery…will produce 500,000 metric tons of HVO-type biodiesel per year. The HVO technology … produces a sustainable and high-quality biofuel, similar in nature to fossil fuels and therefore has no adverse effect on engines. The La Mède biorefinery project is coupled with a plan for continuous improvement of the facility's energy efficiency, with the aim of reducing energy consumption by 8% by 2020."[45]

It is noteworthy that rather than build a completely new site, La Mède has chosen to adapt its refinery including the option to upgrade "certain petroleum product refining operations, but halt processing of crude oil" which highlights that evolution of existing refineries even into 100% non-fossil feedstocks is possible, and already happening in Europe.

Total has set out that it will maintain existing refining activities and develop new ones, including:

- Building an 8 MW solar farm using technology developed by Total affiliate SunPower, to meet 50% of the site's power needs.
- Building a unit to produce AdBlue®, an additive that reduces nitrogen oxide emissions by diesel engines and whose market is expanding strongly.
- Set up Oleum South, a centre with full-scale instructional facilities that will provide training in exploration and production professions

Source: image from Total.com with permission

One of the considerable tests that will face fuel manufacturers and policymakers when looking to maximise the take-up of low-carbon fuels could be availability of feedstocks to meet consumer demand. The resources needed to produce alternative liquid fuels are much higher in comparison to conventional fossil fuels, particularly as many of these fuels are reliant on either biofuel production or waste products.

In the UK, feedstock sources include around 6.2 million hectares of croppable land[46] and 40 mt of municipal solid waste (MSW) generated annually (50% of which is recycled)[47], and given such relatively low volumes the UK may well need to source further feedstocks from the international market. It is likely that such feedstocks will also need to meet carbon and sustainability criteria without adding to carbon through indirect land use change.

The UK does however, have an abundant supply of wind energy for renewable electricity which could be used in power-to-liquids or manufacture of renewable hydrogen.

Existing refinery sites provide potentially well-suited locations to construct facilities and enable the development of low carbon fuels.

2.3. Developing the Refinery of the Future

Very few of the low-carbon fuels identified above will be feasible without the advanced manufacturing capability to deliver them as well as, ideally, the manufacturing capability itself being low-carbon. What then, needs to happen for the UK to improve on the existing refineries that could individually deliver these low-carbon fuels?

The UK has six major oil refineries with the oldest of these facilities, the Grangemouth refinery in Scotland, beginning operations in 1924[48]. Over the course of nearly a century, refineries in the UK have constantly evolved in response to new environmental and safety regulations, to consumer demand (such as the dieselisation of transport fuels in the early 2000s), all whilst finding their own specialisms that have helped them remain competitive in a global market.

It is worth considering that existing refinery sites provide potentially well-suited locations to construct facilities and enable the development of low-carbon fuels.

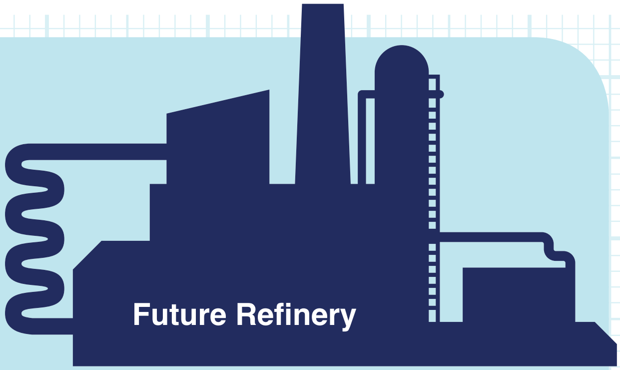
Facilities already at a typical refinery include:

- Industrial land available for construction and development
- Refinery engineering and technical expertise (chemical, mechanical & electrical)
- Refineries supporting R&D facilities
- Highly trained process operators
- Maintenance and fabrication personnel already on site
- Operational and storage expertise (liquids, gases, power etc.)
- Laboratory facilities and expertise
- Refinery utilities (water, steam, power etc.)
- Potential for heat integration
- Expertise in handling dangerous chemicals and waste process by-products
- A strong safety and environmental protection culture
- Emergency equipment with trained staff
- Connections to key primary energy links, e.g. existing power grid, liquid fuel and gas distribution infrastructure can bring practicably any new fuel to market

The UK Government's Industrial Strategy "sets out how we are building a Britain fit for the future – how we will help businesses create better, higher-paying jobs with investment in the skills, industries and infrastructure of the future"[49] and a Refinery of the Future could deliver these quality jobs, invest in people as well as the infrastructure of the future.

No two refineries look the same. There are many reasons for this, including but not limited to: varying crude slates, process units and integrations at each site. It is also highly likely that newly built refineries and those which adapt to future conditions will emerge so that they too might offer highly specialised fuels for their customers and will be based on their specific product niches. However, there are nonetheless some conceptual changes that could be made to the UK's refineries that would offer reduced carbon emissions from the manufacturing process units themselves. They broadly fall into three themes[50].

Three themes for the refinery of the future



1. Improve efficiency (both processes and utilities)

- **Process efficiency improvements** – This captures many potential improvements in refinery process technology, inter-unit heat integration and upgrading of low-grade heat as well as integration with other industries such as petrochemicals (some of the these have already happened in the UK).

2. Lower the carbon footprint of energy sources

- **Internal Fuel measures –** The continued move away from liquid fuel firing still offers some nearer-term potential for carbon abatement with likely substitution by natural gas and as low-carbon fuels become available, those too.
- **Cogeneration Substitute** – All UK refineries have, or are building combined heat and power (CHP) units for steam and electricity generation.
- **Electrolytic production of hydrogen production –** In future, refineries may have the option to use intermittent electrolysis as a source of low-carbon hydrogen in place of stem methane reforming (SMR). Hydrogen is essential in fuel production and will play an even greater role in manufacture of PtL fuels. There are other low-carbon hydrogen technologies that might also come into play in this space such as methane pyrolysis and hydrogen production by thermal or chemical splitting of water, although these may require carbon capture.
- **Low grade heat** – Refineries use high temperature steam as a heat but otherwise waste low grade heat can be recovered for use as a source of energy either in the refinery itself or by other users e.g. district heat networks.

3. Capture CO_2 for long term storage or use

- **CO_2 capture (SMR and general)** – Carbon capture technology offers potentially the most significant carbon abatement opportunities for a refinery and would also apply as a carbon abatement solution for other industries and sectors of the economy.

The current downstream oil sector, as well as directly providing 123,800 jobs and £8.6 billion in GDP also supports security of supply "by retaining a mix of domestic refining and imported product presence of domestic refineries"[51]. Maintaining domestic refining capabilities in the medium-term is important for energy supplies, therefore, but also provides some emissions benefit which results from UK refineries being on average less emitting than the global average, but also because emissions are not required in importing finished products. The difference in emissions can be 35% higher if product is imported from outside the EU when considered against domestically refined product[52].

A UK-based Refinery of the Future while benefitting security of supply, could also reduce reliance on imported feedstocks as imported crude oil (in 2017, just 14% of UK refinery feedstocks were likely to be UK-produced[53]) is replaced by new domestic feedstocks obtained using the pathways identified above.

The current downstream oil sector, as well as directly providing 123,800 jobs and £8.6 billion in gross domestic product also supports security of fuel supply.

2.4. What the Refinery of the Future could look like

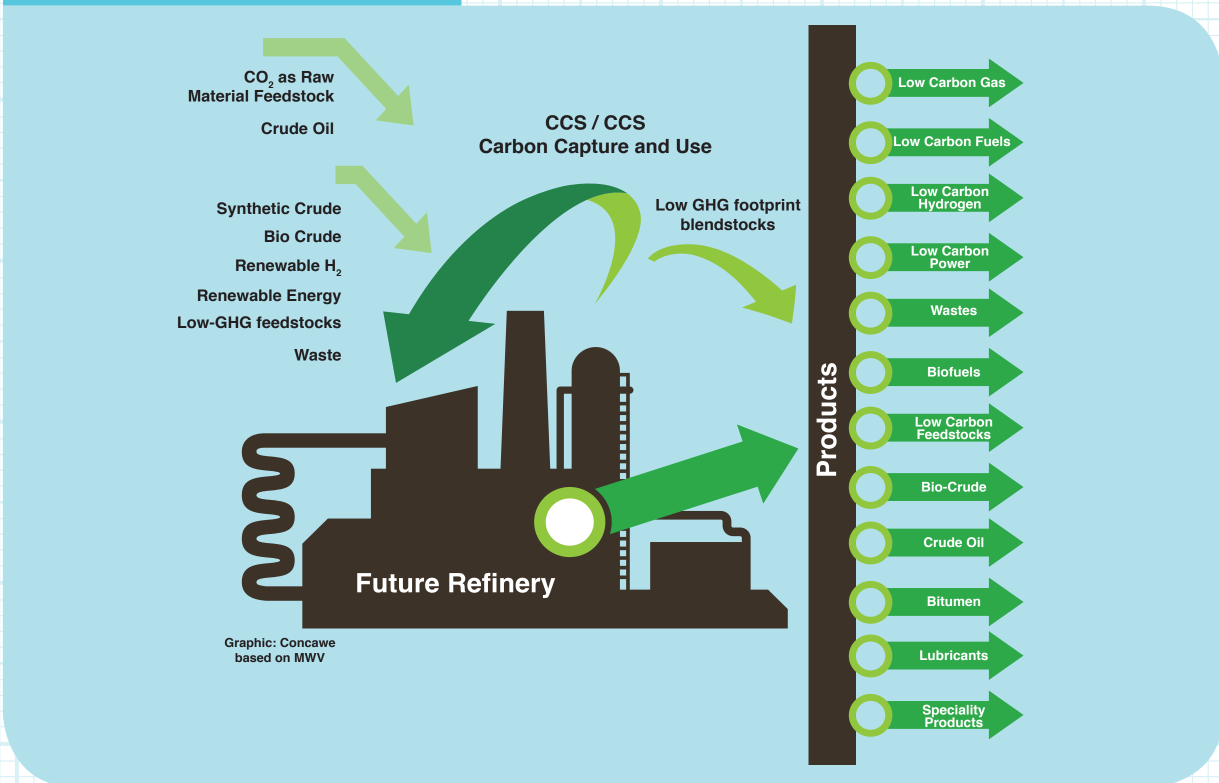
UKPIA foresees that a Refinery of the Future could be a highly efficient manufacturing plant that has considerably lower carbon and air quality emissions than is the norm now, is able to produce low-carbon fuels from new feedstocks and could be at the centre of highly integrated supply chain that makes optimum use of the resources available.

This includes:

- Utilising people's skills;
- Choosing the right feedstocks – whether recycled or where necessary fossil derived (where emissions can be offset elsewhere);
- Using shared infrastructure, subject to an appropriate regulatory framework, to lower emissions across the whole that go beyond the capabilities of individual businesses.

All of this could come together to deliver the low-carbon products of the future that themselves could unlock lower carbon emissions in their use, such as improved engine efficiencies from optimised fuels.

Refinery of the Future



Graphic: Concawe based on MWV

This future could be achievable given the wide variety of low-carbon liquid fuels that could be available given the right conditions for their development, as well as the multiple possible processes and ways of working that have already been identified and are being developed to produce them.

Carbon Capture and Utilisation offers an opportunity to create a carbon-based economy, where downstream oil and gas companies can be pioneers in the commercialisation of a new market of petrochemical and energy-related products.

Case Study

OMV Refinery in Austria turning plastics into fuel

Within the EU, we are already seeing examples of how refineries can do more than just refine crude oil. The major central Europe refiner OMV opened a £10m plant in Austria in 2018 that can turn plastics into base oils that could be treated in the same way as traditional fossil-based crude oil.

Using these plastics that were otherwise meant for incineration, reduces the emissions that would have arisen from incineration. It also reduces the need for oil exploration and production and recovers plastic waste in a way that can generate an economic return.

As Manfred Leitner, an OMV Executive Board member stated "This technology allows us to use a barrel of oil multiple times. This means that less plastic is incinerated, and greenhouse gases are reduced. The ReOil method thereby contributes to the OMV sustainability goals related to CO_2 efficiency[54].

Source: images provided by OMV

2.5. Carbon capture technologies

Refineries have already made significant strides in improving the environmental performance of their operations. Over the last two decades UK refineries have increased their fuel efficiency, with 5.7% of fuel used to power refineries in 2017 compared to 7% in 1995[55] – an improvement of 19%. Investment in CHP units, integration with petrochemical plants adjacent to refinery sites and development of more sophisticated control and monitoring systems have all contributed – and continue to contribute – to making downstream operations more efficient.

To meet government's net-zero ambition we must bear in mind that no single technology – either currently in existence or in development – is a 'silver bullet' for industrial decarbonisation. Multiple technologies will need to be deployed to reduce dependency on any single potential model to remove CO_2 from the refining process, however, as noted in the Committee on Climate Change's recent report on Net-Zero "Scenarios require that carbon capture and storage (CCS) deployment starts immediately with substantial deployment in all regions by the 2030s"[56] and there is real urgency in the need to deploy carbon capture at scale sooner rather than later.

What is carbon capture? | Of the many different technological routes that might play a key role in the downstream sector's transition to a low-carbon future being considered, some of the most promising are ways to capture, store and use the emissions generated within industry. This approach – Carbon Capture Utilisation and Storage (CCUS) – relates to a number of different methods where CO_2 from refinery flue gases and from the atmosphere can be captured and used in different processes or stored permanently.

Once carbon has been captured, cleaned and compressed it can then either be used (CCU) after being converted into a commercial product or stored (CCS) in a suitable long-term site, such as a saline aquifer or depleted oil field.

What is carbon usage? | Whilst CCS on its own removes carbon from a source for storage, CCU offers an opportunity to create a carbon-based economy, where downstream oil and gas companies can be pioneers in the commercialisation of a new market of petrochemical and energy-related products.

As CCU technologies improve so that CO_2 can be used in the creation of new materials and processes – such as polymer, alternative fuels, aggregates and in district heating networks – the economic viability of carbon as a commodity could be expected to increase as more uses are found, thus making CCU an increasingly attractive option for the downstream oil sector and beneficial to growing areas of society.

These various approaches to CCU could all become economically viable opportunities for carbon utilisation after it is compressed and transported.

What is carbon storage | Methods of carbon storing are typically focused on trapping CO_2 within geological features. To achieve this, the carbon needs to be compressed, which could be partially or fully done at refinery sites or within an economically viable distance (perhaps within an industrial cluster). Current options for CCS are saline aquifers, depleted oil wells and other subsea geological formations. Regardless of which option is pursued, storage sites need to be **cost efficient**, provide **long-term stability** and be **environmentally sustainable**.

International examples of CCS have demonstrated the viability of the technology:

- In Norway, feasibility studies for storing CO_2 in saline aquifers have been conducted and permits issued to run test sites in the Sleipner aquifer in the North Sea to test this as a storage option[57].
- Plans in the UK for at least 5 CCUS hubs (including the CleanGas project at Teesside) have been outlined in the recent report on CCUS by the BEIS Select Committee.
- There are also several examples of carbon capture facilities elsewhere – planned and some in operation – such as the CarbonNet project in Australia for the initial capture of 1.5 million tonnes of CO_2 per annum
- In the United States, tax incentives have been used to create a number of opportunities for lower cost industrial CCUS facilities with the 45Q legislation having been pointed to by some as a policy that “could make a big difference in the deployment of more projects.”[58]

It is notable that the use of carbon capture can be helpful as a means to create ‘green-hydrogen’ given the potentially large requirement for hydrogen suggested by pathways in BEIS’ Clean Growth Strategy. The benefit of carbon capture in hydrogen production[59], is that where hydrogen is produced using SMR, CO_2 is obtained as a product along with the hydrogen (so-called grey or brown hydrogen). Using carbon capture the CO_2 can be removed for use or storage to provide so-called blue hydrogen.

Carbon Capture and the UK | Given the potential for carbon capture technologies to deliver at scale decarbonisation of industrial processes, it appears that effort to deliver carbon capture in the UK must be a pressing priority as acknowledged by Government and industry with initiatives such as the Oil and Gas Climate Initiative (OGCI) which includes a number of UKPIA member companies as founders and participants[60].

Carbon capture is a technology that can be considered a natural fit with the oil and gas sector given the familiarity with many of the chemicals involved as well as with their treatment and transport. The strong links are shown by the fact that “Of the 17 CCUS facilities in operation today, 16 involve oil and gas companies, including five operated by OGCI members” [61].

As has already been acknowledged by the BEIS Carbon Capture Action Plan there are reasons why CCUS has not been able to be deployed in the UK as yet and it is welcome that BEIS “are reviewing the barriers to the deployment of industrial carbon capture and …will consult on emerging findings, including the options for establishing a market-based industrial carbon capture framework, in 2019”[62].

While volumes of carbon captured globally could need to increase markedly (IEA estimate the need for capture or storage of 2,300 million tonnes annually by 2040[63]) there are already positive efforts to deliver CCUS projects in the UK where downstream oil sector companies are already playing their role such as with the CCUS Council (which includes representatives from some of UKPIA’s members[64]).

Carbon capture is a technology that can be considered a natural fit with the oil and gas sector given it's the familiarity with many of the chemicals involved as well as with their treatment and transport.

Options for CCU could take many forms, including:

Reforestation and marine fertilisation[65]

Where trees and phytoplankton take up CO_2 during their growth to increase plant and food production – trapping carbon for up to 100 years.

Enhanced oil recovery[66]

A mature CCU technology[67], where compressed CO_2 is injected into oil reservoirs.

Bioenergy from plant matter[68]

A high-tech option that uses energy from biomass processes as a replacement fuel in refinery operations. While only trapping carbon for a short period, the Bioenergy with Carbon Capture and Sequestration (BECCS) process creates an opportunity for achieving below-zero carbon targets.

Converting CO_2 into chemicals[69]

Where CO_2 streams could be used in the production of useful chemical compounds such as urea, salicylic acid or other products that in many cases use fossil-derived feedstocks at present e.g. ethylene. Depending on the chemicals produced this can be a long term (100+ years) way to trap carbon.

Remediation of alkaline industrial waste[70]

Where alkaline industrial waste is treated with captured CO_2 dissolved in water (carbonic acid) in order to neutralise the waste that might otherwise cause issues e.g. in water bodies. As with chemical use above this can be a long term use for the carbon depending on the precise use.

These various approaches to CCU could all become economically viable opportunities for carbon utilisation after it is compressed and transported.

3 Working with Other Industries to Unlock the Low-Carbon Future

- **Opportunities exist for the downstream sector to work with other industries and stakeholders to decarbonise**
- **Industrial clusters could unlock the door to a low-carbon economy**
- **Leadership, vision and modular development could put refineries at the heart of decarbonisation**

- Companies within the downstream oil sector will need to consider the potential to work with companies outside of the sector, due to the huge opportunity to achieve even greater decarbonisation across the economy.

- Novel business models such as industrial clustering, delivered alongside the technological changes of the last chapter, could mean participation in a vibrant lower-carbon economy in the longer term.

3.1. Industrial clusters and low-carbon business models

In 2017 the Industrial Decarbonisation and Energy Efficiency Roadmap Action Plan was jointly published between the UK Government and industry, in order to help the downstream sector make the low-carbon transition whilst maintaining its competitiveness[71]. This work outlined actions that our sector needs to pursue in order to achieve society's low-carbon ambitions. This includes considering how it works with other industries, such as chemicals, renewables, as well as parts of its existing supply chain, especially upstream oil. These new inter-sector business models could ultimately be crucial to a competitive and enduring future for the downstream sector.

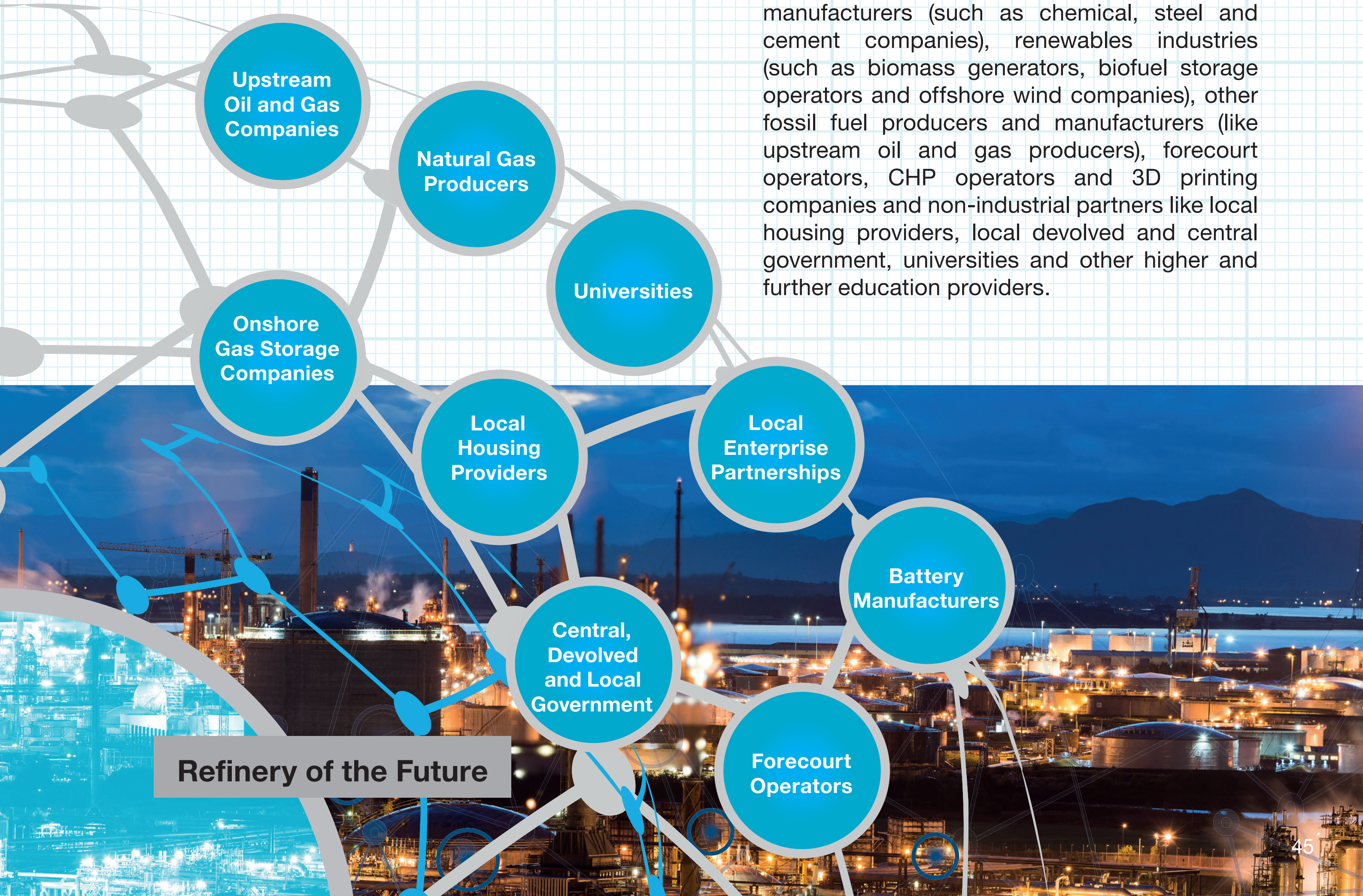
As the refining sector looks for ways to maintain its status as a major employer in a highly skilled industry, one possible role is to play a part in the establishment of high-technology industrial clusters that contribute to the economy by creating low-carbon products in a carbon neutral way.

What is an industrial cluster? | Clusters are regional concentrations of related industries in a particular location. They consist of companies, suppliers and service providers and are able to draw on government agencies and other institutions to provide specialised training, information, research and technical support. A cluster may allow each actor within it to benefit as if it has greater scale or as if it had joined with others without sacrificing its flexibility.[72] Companies operating in a cluster may be linked by a shared workforce, supply chain, customers or technologies, and includes core industries and the companies that support them in a mutually beneficial business ecosystem[73].

The ‘cluster concept’ seeks opportunities between adjacent industries for integrated processes, operations and business models. In particular, clusters offer an opportunity for businesses to improve energy efficiency, produce lower-carbon products and technologies and decarbonise their operations than could be achieved alone. By delivering energy savings, companies are able to reduce emissions by optimising the use of their resources, whilst sharing costs, using waste- or by-products such as CO_2 or heat more effectively and creating new revenue streams.

Refineries at the heart of clusters | The downstream oil sector has a presence across almost every region of the UK, and each UK refinery exists in geographical proximity to other energy intensive industries. This is potentially a major opportunity for the refining sector to play a central part in the UK’s energy transition, with refineries leveraging their scale, expertise and resources to participate in clusters and enable the low-carbon energy transition.

The potential list of stakeholders for the refining sector to engage within a cluster is extensive, ranging from adjacent energy intensive manufacturers (such as chemical, steel and cement companies), renewables industries (such as biomass generators, biofuel storage operators and offshore wind companies), other fossil fuel producers and manufacturers (like upstream oil and gas producers), forecourt operators, CHP operators and 3D printing companies and non-industrial partners like local housing providers, local devolved and central government, universities and other higher and further education providers.



Case Study

The Port of Rotterdam industrial cluster

In the Netherlands, the Port of Rotterdam is a pioneering example of industrial cooperation, with five oil refineries forming the core of a petrochemical cluster, with a combined distillation capacity of 58 million tonnes of petroleum products and petrochemical feedstocks. Beyond the core of these five refineries, several other refineries in the Netherlands, Belgium and Germany are supplied with crude via pipelines from the Port of Rotterdam.

Crude is delivered to the Port by large tankers, able to unload at oil terminals in a single visit, and then transported by pipeline to the refineries in Rotterdam and its hinterland, including to refineries in Vlissingen, Godorf, Gelsenkirchen and Antwerp, helping to make the Port of Rotterdam one of the largest fuel hubs in the world.

The Port and its industrial partners adopted a shared aim to lower carbon emissions across their operations and considered potential pathways they could follow to contribute more to the Netherlands' ambitions under the Paris Agreement. Against current emissions, the cluster has been able to identify four potential decarbonisation scenarios[74], with the two outlined below able to reduce emissions by as much as 98%:

- Biomass and CCS **– 98% lower by 2050 –** CCS plays a large role again with the intention to use the captured carbon more alongside a switch to biological feedstocks for the chemical industry.

- Closed Carbon Cycle **– 98% lower by 2050 –** Fossil fuels are still used but only as products (not energy in the Port) that can be recycled.

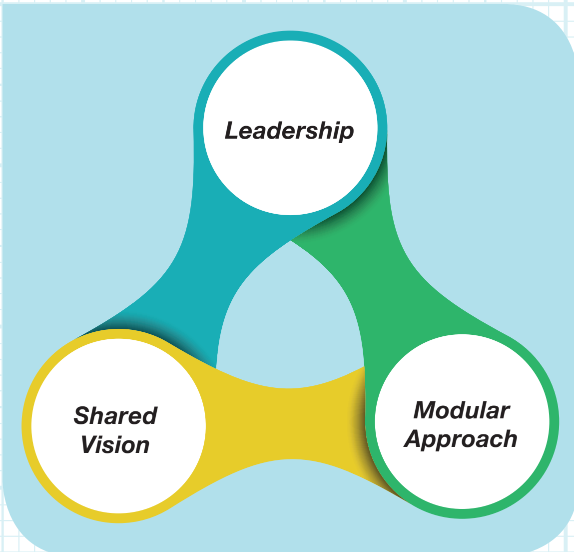
Source: Image from Port of Rotterdam with permission

Clusters in the UK | One of the actions identified by the joint UK Government-Industry action plan for decarbonising the downstream oil sector was to pinpoint potential clustering opportunities around UK refineries. This involves assessing the potential each refinery location has in becoming a part of a wider industrial energy-led cluster so that by products such as heat and CO_2 can be used by third parties, and infrastructure networks (i.e. industrial heat recovery, carbon capture and heat networks) can be shared by cluster participants.

This action plan has been bolstered by the UK Government's Grand Challenge 'Industrial Clusters Mission', which sets out the aim to create a net-zero carbon cluster by 2040 and at least one low-carbon cluster by 2030[75]. The challenge identifies six potential clusters, which are identified by emissions. All but one contains a refinery and considerable downstream oil infrastructure.

How does industry make clustering a success? | To make them a success, however, a number of factors need to exist to set up and establish clusters in and around UK refineries. This will require in most cases a common infrastructure, supply chain innovation and local talent pool that embraces new technology. It will depend on the support and involvement of third parties, such as governments and public bodies involved in the planning process, permitting of industrial sites and supportive regulatory framework. And significant pre-work will need to happen to identify potential constraints and opportunities.

However, even with all these components in place there are, in our view, three fundamental elements without which industrial clusters cannot succeed. Any effective cluster initiative involving the downstream oil sector would hinge on **strong leadership**, the existence of a **shared vision** between cluster participants and a willingness for the cluster to evolve and progress in a **modular and phased** way.



Clusters offer an opportunity for businesses to improve energy efficiency, produce low-carbon products and technologies and decarbonise their operations than they could achieve alone.

Ensuring these elements exist will depend on the creation of a new governance model supported by appropriate regulation and government policy to enable such an approach. Any cluster that does not satisfy these needs – particularly buy-in from senior leaders in the companies within a proposed cluster – will not succeed in developing the necessary investment case from those companies.

Strong Leadership: The strongest cluster initiatives are private sector-driven, with interventions sustained by groups of companies that believe they will benefit by working together to fill gaps in the cluster ecosystem and which are staffed with industry expertise and a cross-sector mentality. Individual leaders within these companies will, therefore, be invaluable in championing a successful initiative, able to move their companies into closer alignment with the overall cluster objectives.

Modular Approach: Ensuring the appropriate scale and sustainability of any new cluster will be critical, as well as any information gaps that might inhibit access to capital to support investment. Successful clusters must therefore think carefully about the pace at which they form and consider a modular approach that focuses first on the core businesses in the cluster, followed in time by a measured expansion to new participants.

Shared Vision: Cluster objectives will need to be defined by a shared vision between a critical mass of companies within a cluster, who understand collectively and individually the benefits it can bring. For the downstream sector this vision may include a focus on Carbon Capture technology, the use of residual heat, hydrogen development or another key theme to support decarbonisation.

Cluster objectives will need to be defined by a shared vision between a critical mass of companies within a cluster.

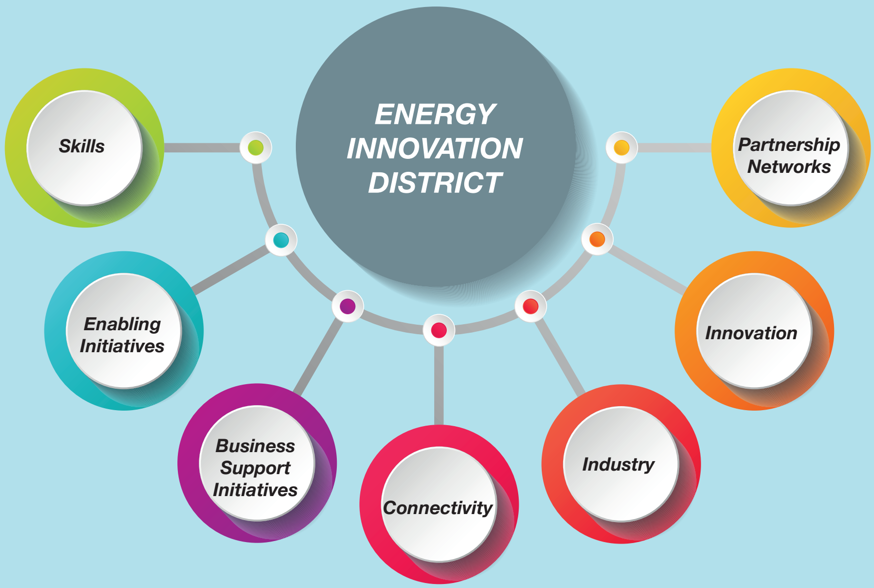
Case Study

Sharing Skills in Cheshire Energy Hub's Energy Innovation District

In the North West of the UK, the Energy Innovation District has identified skills as one of a set of core components that – as a result of lower energy costs – could deliver 'a strategy to drive innovation, supports industry to succeed and encourages growth and investment'[76].

The Cheshire Science Corridor Enterprise Zone already extends to part of the Energy Innovation District. It stretches across the Cheshire and Warrington sub-region incorporating three local authority areas. It recognises and capitalises on the fact that the area already incorporates some of the most significant national and international science-based businesses and research establishments. Awarded Enterprise Zone status in 2016, it brings together some of the best opportunities for new development and attraction of new businesses within the corridor. With the growth of a planned cluster in this area, the energy hub "initially established a successful Graduate Recruitment Programme and now provides the conduit for collaboration across various energy initiatives"[77].

One of the aims looking forward is to bring some of its participating member companies together to "shape the skills and qualifications needed to generatea future pipeline of skilled labour from within the UK. Ensuring that industry and academia work symbiotically to provide a skilled workforce to enhance the emerging industry and keep the UK at the forefront of the global market".



Source: Adapted from Cheshire Energy Hub

4

The Future of Mobility

- **Changing technology and consumer behaviour will alter how we move by air, land and sea**
- **The Forecourt of the Future may need to reimagine the role of mobility in an age of increased choice**
- **Liquid fuels will still be needed in high energy density transport – HGVs, aviation and shipping**

- Carbon fuel developments and ways of doing business will likely lead to significant changes in the way that people and goods move by air, land or sea.

- As the UK car parc's energy needs change, as technology and consumer behaviours change, the potential impact on the consumer-end of the industry may be significant. Anticipating these possible changes, the Forecourt of the Future may need to entirely reimagine the role of mobility, bringing enhanced yet more complex choice across the economy.

- Low-carbon liquid fuels will (based on the third-party research) maintain a vital role in transport sectors that require a high-energy density, such as HGVs, aviation and marine transport. Alongside carbon abatement realised through new fuels, we anticipate further energy efficiency through 'platooning' of HGVs and different delivery mechanisms such as 'the last mile'.

4.1. Changing mobility in a low-carbon future

Anticipating the major changes to the types of fuels that will be available to consumers in the decades ahead, it is clear that how consumers interact and use the energy produced by the downstream oil sector will likely undergo a fundamental shift. The retail experience enjoyed by individuals, families and businesses that has stayed relatively static since the dawn of the private motor vehicle industry may change significantly.

Passenger and light commercial vehicle makers have adapted to ever more stringent tailpipe emissions standards issued by legislatures[78]. This trend can be expected to continue with consumers likely to see major changes to the overall composition of the national and global vehicle fleets and how people interact with the fuel retail sector.

Electric and plug-in hybrid vehicles | These changes have been most visible when it comes to the adoption of electric vehicles and plug-in hybrid vehicles (PHEVs). In recent years, thanks to tailpipe emissions standards, the sales of PHEVs and EVs have grown rapidly – 10 times more hybrids and EVs were sold in 2018 than in 2009[79]. As of 2018, PHEVs and EVs still represent less than 0.5% of the total UK vehicle parc[80]. However, as this figure grows in the coming decades – along with an increase in electricity grid capacity supplying zero or low-carbon electricity and 'smart' grid management to accommodate the increased demand for charging vehicles – industry will have to prepare to deal with how the fuels and products they provide intermingle with these developing technologies.

Connected and autonomous vehicles | Another key change on the transport horizon is the development of connected and autonomous vehicles (CAVs). As efforts are made to achieve emissions reductions, connected and automated vehicles could execute more efficient driving patterns - such as minimising aerodynamic drag and avoiding unnecessary acceleration and braking – and also enable optimised engine operation and vehicle right-sizing. The extent of emissions reductions is also argued to be inextricably linked to changing ownership models[81].

There is uncertainty around when implementation of CAVs will occur due to a lack of consensus on costs and consumer attitudes[82], however it is likely that the earliest adoption will be for road freight transport, in the form of 'platooning' – when two or more HGVs are linked using connectivity technology and automated driving support systems, so the vehicles maintain a set, close distance for part of a journey to minimise aerodynamic drag and therefore improve efficiency[83]. A policy framework for 'platooning' was published by the European Commission (EC) in February 2019[84], and estimates for implementation on motorways is set for the mid-2020s[85].

Heavy goods vehicles | Improvements in HGV fuel efficiency via platooning and other drive optimisation are predicted to increase through to 2050 as these vehicles continue to be primarily powered by combustion engines[86]. The intense duty cycle of these vehicles necessitates the use of high energy density sources of energy – such as liquid and compressed gas fuels. These efficient engines could be supported by advanced exhaust after-treatment, such as AdBlue®, and some level of hybridisation, technologies that can viably be installed on a vehicle as large and investment intensive as an HGV.

These measures could ensure HGVs of the future maximise miles they can get from the energy they use and are able to enter clean air zones (CAZs) when necessary. By 2050, this requirement is likely to be greatly diminished, as urban areas seek to address some of the challenges of 'the last mile' of goods deliveries by introducing consolidation centres[87]. A consolidation centre has already featured as a condition for obtaining planning permission for the new 22 Bishopsgate development in London[88]. The importance of optimising the last mile is essential to address the evolving demands of the consumer.

Mobility as a Service (MaaS) | The tradition of personal car ownership is predicted to change fundamentally in the years ahead, with the increasing provision of the Mobility as a Service (MaaS) concept[89], as more consumers participate in ride-sharing transport networks (such as Uber or Lyft) or participate in car club or shared ownership schemes (such as Zipcar). Whilst this may reduce the number of vehicles on UK roads, it will simultaneously increase their utilisation. Such a shift would place an increased importance on vehicle downtime. Particularly as CAVs become more commonplace, ways to minimise this downtime by connected vehicles 'knowing' if forecourt pumps and chargers are vacant could result in vehicles filling-up between journeys.

Changing consumer interactions | Mobility is also set to be also be influenced by other technological developments not limited to the transport sector, in particular the changing nature of financial transactions and consumer behaviour. Downstream retailers are already beginning to offer payment via smartphone at existing forecourts. This is expected to increase as smartphone payments become ubiquitous and expand into other forms of digital payments, including 'wearable' technology[90]. As consumer expectations change, the trend of forecourts offering a greater range of products beyond fuel could also transform. The convenience of simultaneously purchasing food is growing in popularity[91] whilst in rural areas a forecourt may be the only shop in a community.

As consumer expectations change, the trend of forecourts offering a greater range of products beyond fuel could also transform.

Over recent years we have seen e-commerce retailers strive to improve the efficiency of 'the last mile' - offering consumers greater flexibility while clustering delivery routes through initiatives such as Amazon Locker. We have also seen a rapid shift from card to mobile payments and are in the early stages of wearables adoption. These evolutions in retail, combined with the diversity of energy products available at the forecourt, will all contribute to the development of future energy hubs.

4.2. Developing the Forecourt of the Future

As a result of these predicted changes and trends, it is possible that the UK's forecourts by 2050 will also alter considerably. Forecourts may need to feature a combination of charging and liquid fuel offerings to varying degrees, depending on the availability of real estate. The number of liquid fuel products may be similar to today, but with local demand considerations and a much greater proportion of low-carbon fuel in the products themselves. There will also likely be a difference in the fuel retail experience in both urban and non-urban environments.

Urban forecourts | Due to CAZs being adopted in many urban areas[92], cities will likely feature the highest proportion of PHEVs and EVs. The impact of this is that urban forecourts will likely feature rapid charging points (primarily aimed at top-up charging, given that the majority of regular charging might still be expected to take place in locations where vehicles can charge more slowly). These urban charging facilities might also exist alongside a limited liquid fuel offering. Consumers might browse nearby shops, wait in an on-site café with Wi-Fi or wait in their car and be brought a beverage they have purchased via their smartphone. Almost all payments will be able to be completed with a smartphone or wearable device.

Thanks to expectations of increased ride- or car-sharing schemes in urban areas, there may be dedicated chargers with high throughput to maximise vehicle utilisation. Urban forecourts might be able to signal to nearby vehicles on low charge or near empty tanks whether they have a pump or charger vacancy to minimise queuing and replenish liquid fuel tanks during periods of low road activity. On-site cafés can be powered by renewable energy, such as PV solar panels[93].

Non-urban transport hubs | In non-urban areas, forecourts could diversify into a local mobility hub where a larger suite of liquid transport fuels and chargers will be available. These forecourts could meet the demands of the 2050 consumer by catering to their various needs in one location. Hubs might feature a wider offering of liquid fuel products and a larger quantity of charging points. There could be dedicated bays for car share scheme vehicles, shopping, or optimised food offerings based on consumer preferences.

These hubs might also offer a more diverse range of food and other consumables, with facilities available for on-site mobile working and rapid meal offerings. Consumer convenience could determine the forecourt experience as much as the fuel and charging facilities, with staff offering an all-round retail interaction in addition to their safety and operational responsibilities[94].

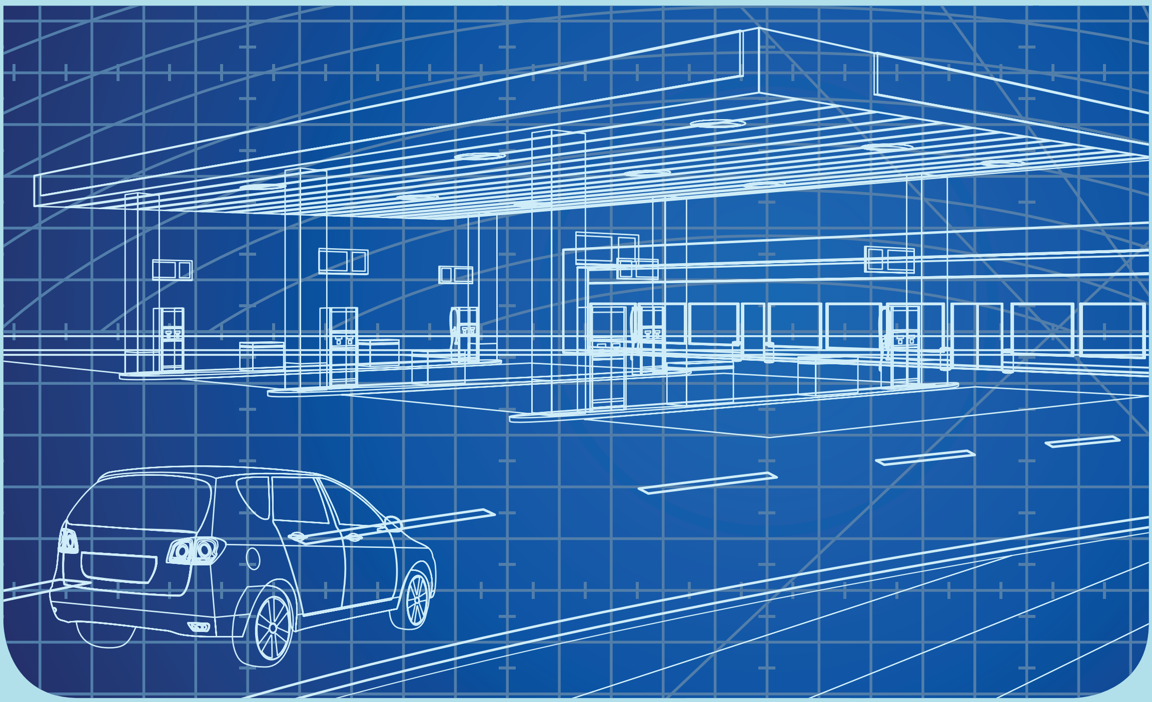
Case Study

Foundations of the Forecourt of the Future

In 2019 we can already see the building blocks of the Forecourt of the Future emerging where a diversifying transport energy mix is already fuelling a different kind of forecourt.

Sweden ranks third for EV sales in Europe[95] and has a biofuels policy with the overall objective to achieve zero net carbon emissions by 2045[96]. This approach is resulting in a technologically diverse vehicle parc that the retail network has begun to meet the demand for. For example, the Circle K retail site at Värnamo offers consumers standard diesel and 95 RON petrol alongside B100, E85 (high blend biofuels) and fast charging for Electric Vehicles[97]. The site also offers AdBlue® for the latest diesel vehicles.

This diverse product offer is combined with a café and convenience store; demonstrating how a retail forecourt can evolve to meet the latest consumer demands. This approach of adopting multiple low-carbon fuels provides the template for the mobility hub of the future.



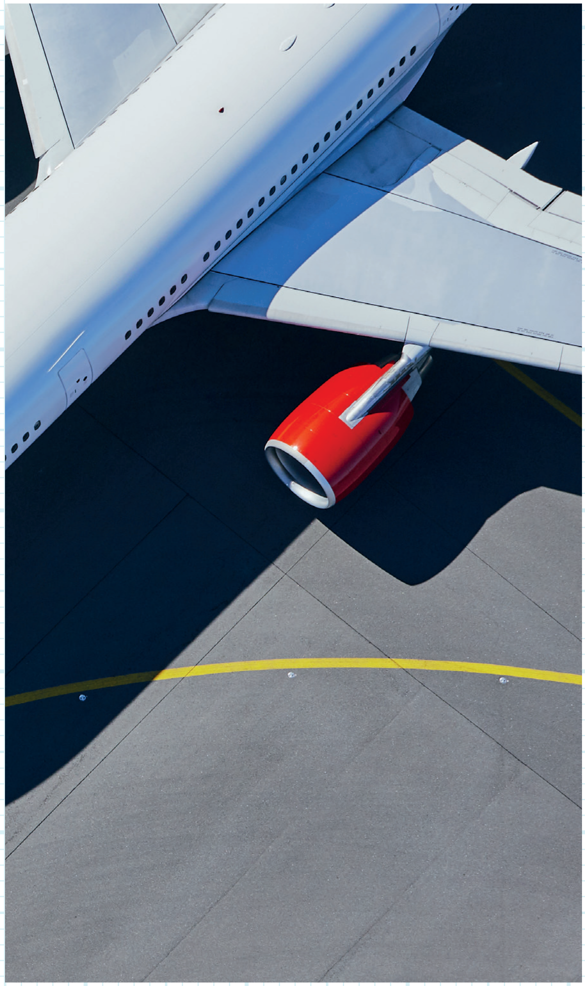
4.3. Changes to aviation and marine mobility

Changes in the aviation and marine transport sectors will not be as rapid as surface transport due to more limited options for these sectors[98]. This is coupled with predicted growth in aviation and marine activity to 2050 – satisfying economic growth demand[99]. Improvements in fuel efficiency in both sectors are ongoing[100], with focus on air quality improvements running in parallel. Continued reliance on liquid fuels in marine and aviation sectors means the UK downstream industry will play an integral role in their decarbonisation.

Shipping | International shipping carries approximately 90% of world trade by volume and has integrated itself as an essential route for trade[101]. Measures to improve carbon emissions have been announced[102], and an important milestone will occur in 2020 as the sulphur content of marine fuels globally will be capped at 0.5% by mass – resulting in expected improvements in SOx emissions[103]. Up to 2050, efforts will continue, with sulphur limits likely to further decrease, and more sophisticated exhaust after-treatment systems become adopted and retrofitted[104].

The high utilisation and energy density demands of marine transport will necessitate continued use of liquid and compressed gas fuels, with limited electrification under certain circumstances[105]. The UK Downstream industry is striving to meet the increasing demand for low sulphur marine fuels, and adapt to ongoing fuel suitability as exhaust after-treatment demands evolve.

Aviation | Aviation is the most energy density demanding sector of mobility, with the utilisation of “maximum energy for the least mass” its primary driver. Thus far, no viable alternative to jet engines has been identified[106], however IATA have set targets to mitigate CO_2 emissions from air transport[107]. As aircraft and aircraft engine manufacturers seek to improve fuel efficiency and aircraft operations and traffic management improves, many believe it is clear that low-carbon fuels will need to be adopted to reduce the net emissions contribution of aviation[108]. Fuels that the UK downstream industry can look to provide in the coming decades.



Continued reliance on liquid fuels in marine and aviation sectors means the UK downstream industry will play an integral role in their decarbonisation.

5

Working with Government to Unlock the Low-Carbon Future

- **A low-carbon downstream sector will require investment of time, personnel, capital and business leadership**
- **Government has a key role in creating an investment climate to support decarbonisation**
- **Engagement with government is vital to unlocking the low-carbon future**

- The potential for the downstream oil sector to play a full part in the UK's transition to a low-carbon future is, in our view achievable, but only in the right environment.
- UKPIA believes industry is ready to work with government to create the right conditions for low-carbon investment.
- Policy incentives will be needed to induce the capital projects and corporate investment needed to realise the potential.

5.1. The importance of working with other stakeholders

To realise the ambitions outlined in the previous chapters, the downstream oil sector may need to make big changes to how it has traditionally operated, manufactured and marketed its products. Much of what could achieve widespread decarbonisation of the downstream sector as well as developing new products will require substantial investments of time, personnel, capital and business leadership. Governments – by setting regulatory standards and creating either a welcoming or hostile business environment – have a critical role in shaping how industry participants make investments and how companies balance their decisions between risk and opportunity in the global market place.

This final section suggests where changes – large and small – to the existing policy framework could unlock the potential outlined in this vision.

Governments have a critical role in shaping how industry participants make investments and how companies balance their decisions between risk and opportunity in the global market place.

5.2. Policy areas requiring industry and government focus to support the low-carbon transition

Low-carbon liquid fuels | We believe that advanced liquid fuels have a critical role to play in a low-carbon economy, helping to contribute to the UK's emission reduction goals. While there are policies already in place for some low-carbon fuels, UKPIA believes that there is no 'silver bullet' to address the variety of needs of consumers' needs across the transport network.

Policy area	Potential for change
Considering emissions of vehicles **Department for Transport**	**Look to ensure efficient decarbonisation of vehicle emissions** A technology neutral approach that incentivises a range of low-carbon technologies could offer the most efficient means to reduce carbon emissions across the UK. Linking together existing information on carbon emissions in vehicle manufacture to expected tailpipe emissions (of the CO_2 Emissions Standards) when considering policies and incentive schemes for particular vehicle types/models (such as the Plug-In Car Grant) is an option that would come closer to assessing life-cycle emissions. The DfT's Transport Energy Model considers existing vehicle technologies and some fuels but as noted in this vision, there are many possible low-carbon fuels types that could also impact on a vehicle's life-cycle emissions that need to be considered (currently the model is able to adjust for some biofuels content). In the long term, there may well be a carbon pricing mechanism that extends beyond the existing traded sectors that could deliver efficient and technology neutral decarbonisation for fuels both during their manufacture and use.
Developing new low-carbon fuels **Department for Transport**	**Incentivising further research and development into all low-carbon fuel technologies** Existing policy under the Renewable Transport Fuels Obligation (RTFO) incentivises the development of advanced biofuels, but does so only for fuels that meet a very specific set of criteria. While the need for clear criteria is required (especially for sustainability and 'real' carbon savings), the current system could be more flexible, allowing individual companies to develop more of the low-carbon liquids options available. The lifecycle approach above could also provide a framework through which to target innovation funding based on lifecycle GHG savings.

Future downstream oil sector infrastructure | We believe that the Refinery of the Future could be a low-carbon manufacturing hub – reducing its own emissions, while delivering the flexibility to produce high quality, low-carbon products. Fundamentally, policies that allow low-carbon liquid fuel development will be vital, while the improvements in process emissions could be delivered through efforts on industrial clustering and carbon capture while also delivering a strong and resilience UK infrastructure base that could positively impact on balance of payments and security of supply.

Policy area	Potential for change
Improving efficiency with new technologies **Department for Business, Energy and Industrial Strategy**	**Further optimising refinery operations through greater digitalisation and deployment of energy efficiency technologies** Technological developments could allow refineries to achieve even greater efficiency improvements through the increased use of digitalisation in their processes. These different low-carbon technologies are at different stages of technology maturity, and R&D programmes will need to be incentivised to encourage them into the implementation phase. This could help improve sustainable raw material availability and process efficiency, which should bring costs down during both the demonstration and deployment stages. In terms of deploying technologies, Enhanced Capital Allowances are already available for specific technologies to decarbonise industry. However, ECA schemes could be extended so that industrial-scale projects that improve energy efficiency can be considered eligible based on efficiency improvement with appropriate verification (design and technology is already assessed through the government's Combined Heat and Power Quality Assessment Programme).
Allowing refineries to research and develop new solutions **Regulatory Bodies**	**Deliver a regulatory framework that allows for innovation** The scale of potential changes at refineries needed to develop into the Refinery of the Future will require positive working relationships between refinery operators and Competent Authorities that can consider changes to operations that are in line with growth as well as environmental objectives.

Policy area	Potential for change
Incentivising Industrial decarbonisation in the UK **Department for Business, Energy and Industrial Strategy**	**Deliver a mechanism so companies can prioritise investment in industrial decarbonisation** **Carbon abatement technologies** One incentive could be for an increased industrial carbon price – currently indicated in the UK by our membership of the EU ETS – which could deliver a better business case for investment in abatement technologies to meet cap and trade schemes. This has the additional benefit that specific technologies are not incentivised but could be assessed against their full merits. Should specific technologies (e.g. CCUS) be deemed vital based on evidence of abatement potential then successful incentives have been delivered elsewhere that could prove similarly attractive in the UK. One example from the United States is the 2018 introduction of the 45Q legislation that allows for carbon credits beyond the cap and trade mechanisms already in place. **Major infrastructure investments** Specific infrastructure to deliver industrial decarbonisation could benefit from further support, including: • capital lending for building large infrastructure projects (e.g. carbon capture storage /transport facilities), • policies that reduce financial investment risk The UK Guarantees Scheme has already provided guarantees for a number of large-scale projects in the UK and could benefit carbon capture projects in the same way. Certainty that CCUS projects could apply for this, and other, schemes would be welcomed by prospective investors. Likewise, the Industrial Energy Transformation Fund can be of use in this regard as decarbonisation and energy usage are intrinsically linked in a refinery.

Clustering | Clustering offers benefits across industries beyond what they could achieve alone. Such clusters can also meet other UK concerns, in particular improving productivity and helping regional economic development. UKPIA believes that the role of government in delivering industrial clusters may not be only legislative but could focus on playing a leadership role to act as a champion at local, regional, devolved and central government levels.

Policy area	Potential for change
Clustering Leadership **Department for Business, Energy and Industrial Strategy**	**Support from government and local leaders to give confidence that prospective clusters are developing in such a way that will retain long-term viability and in ensuring a supportive legislative landscape.** The Industrial Clustering Mission shows government's objective: a net-zero industrial cluster by 2040 and seeking to support this with the Industrial Strategy Challenge Fund and work which has already sought to identify key cluster-potential locations. Finding a way to confirm to emerging clusters that their objectives and plans are in line with government's objectives could encourage a move from well-intentioned discussion to actual investment and change on the ground.
Evolution of clusters **Department for Business, Energy and Industrial Strategy**	**It will be necessary to accept a modular approach to building membership and integrations that will best deliver successful UK clusters** It is key that there be understanding that clusters will take time to develop and need to be flexible enough to embrace new businesses. Companies need to be supported in developing a common vision, but acknowledgement from government that businesses will need time to react and that a cluster's membership may change over time will be important in allowing such development
Developing Skills **Department for Education**	**Clusters will offer the potential for significant early training and upskilling of the workforce** Thanks to the co-location of business interests, industrial clusters could help maximise skills by providing opportunities to companies to pool their training resources to benefit their respective workforces, allow for secondments across businesses and help to manage resources for common projects more effectively. The Apprenticeship Levy has the functionality for share apprenticeship accounts which could offer a way to fund such resource.

Future of mobility and the forecourt | We believe that as transport evolves, so will the forecourts that consumers interact with. Flexible new policies are needed in this area, enabling changes to occur in response to consumers' needs and wider mobility trends.

Policy area	Potential for change
Planning and regulating forecourts **Local and Competent Authorities**	**Planning of forecourts will need to be able to accommodate changing business models and emerging health and safety considerations as the consumers demands change** With the large changes expected in the downstream sector, it is essential that planning authorities take a flexible approach, working with operators to manage sites in such a way that they can respond to the new needs of the customer. This directly relates to managing risks around having more/different energy sources on site (e.g. electric charging, low-carbon liquids and hydrogen) as well as growing business areas beyond energy supply such as logistics, retail and others.
Energy the forecourt delivers **Department for Transport**	**Consumer demand should determine which filling/charging locations are most appropriate** To allow individual companies to respond to consumer demand, the removal or avoidance of any mandates for particular filling/charging infrastructure is key.

End notes

1. The terms 'low-carbon' and "lower-carbon" are used to describe an economy or energy source that results in reduced CO_2 emissions. Although the term "low-carbon" is used predominantly in this document it is used interchangeably with "lower carbon"

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4. Committee on Climate Change, 'Net Zero The UK's contribution to stopping global warming', (May 2019), Figure 5.3, p144

5. The Climate Change Act 2008 (2050 Target Amendment) Order 019, SI 2019 No. 1056: see http://www.legislation.gov.uk/uksi/2019/1056/pdfs/uksi_20191056_en.pdf

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10. The Rail Industry Decarbonisation Taskforce, 'Initial Report to the Minister for Rail', January 2019. See https://www.rssb.co.uk/Library/improving-industry-performance/Rail-Industry-Decarbonisation-Task-Force-Initial-Report-to-the-Rail-Minister-January%202019.pdf

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13. European Commission, 'Flightpath 2050: Europe's Vision for Aviation', 2011. See https://ec.europa.eu/transport/sites/transport/files/modes/air/doc/flightpath2050.pdf.

14. FuelsEurope, 'Vision 2050 – a pathway for the evolution of the refining industry and liquid fuels', September 2018. See https://www.fuelseurope.eu/wp-content/uploads/DEF_2018_V2050_Narratives_EN_digital.pdf

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19. See, for example, the CEFIC/Ecofys report 'European chemistry for growth: unlocking a competitive, low carbon and energy efficient future' available at https://cefic.org/app/uploads/2019/01/Energy-Roadmap-The-Report-European-chemistry-for-growth_BROCHURE-Energy.pdf

20. The ETI first published its scenarios for a low carbon energy system transition in 2015 in its 'Options, Choices, Actions' paper. They were updated in 2018 to take into account signature of the Paris Agreement and publication of the UK Government's Clean Growth Strategy and are available at https://www.eti.co.uk/options-choices-actions-2018

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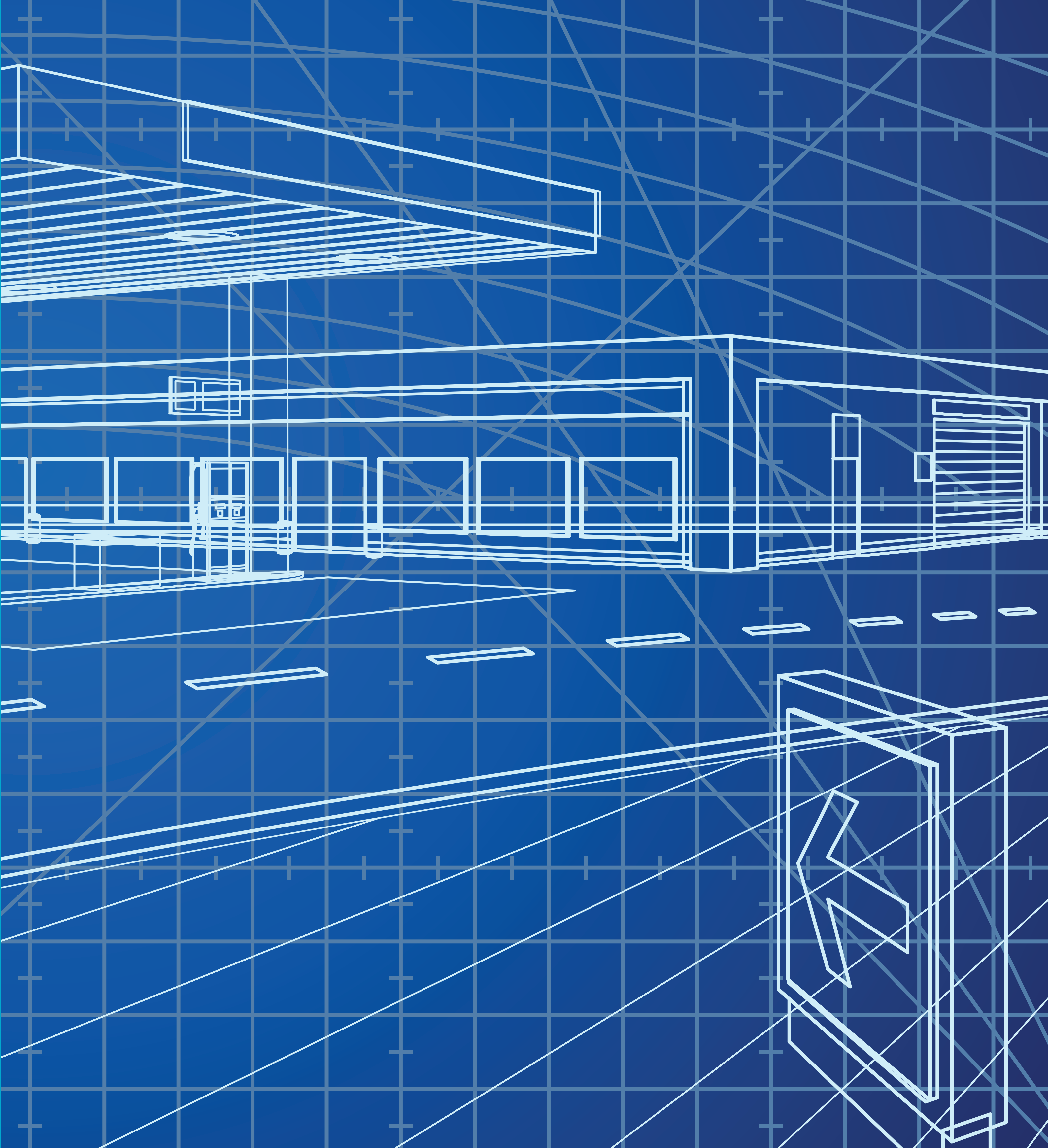

UKPIA

United Kingdom
Petroleum Industry Association

UKPIA |
37-39 High Holborn, London WC1V 6AA

+44 (0) 2072 697 600
info@ukpia.com

ukpia.com