Department for Transport

Low carbon fuels strategy

Call for ideas

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Department
for Transport

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Foreword

Low carbon fuels (LCFs) have been instrumental in reducing the UK's greenhouse gas emissions for more than a decade. Transport has a huge role to play in achieving net zero, and greener fuels are critical to that transition. This document explains the progress we have made so far, and sets out future opportunities and challenges as we decarbonise our economy.

Those opportunities exist across transport - including road, rail, maritime, aviation, and off-road machinery. The continued adoption of low carbon fuels will complement the shift towards public transport, active travel and electric vehicles. But we must be careful to preserve robust sustainability standards, so that low carbon fuel production brings clear benefits, without creating any further environmental problems.

Our Transport Decarbonisation Plan commits us to harnessing the full potential of LCFs to grow domestic industry and jobs, making the most of the outstanding technical expertise and capacity we have in the UK. To draw all this work together, we will publish a Low Carbon Fuels Strategy. Now we are calling on industry and stakeholders to help shape that strategy.

This document sets the scene, explores our progress, and outlines the focus of the forthcoming Strategy. Your responses will help us get it right. This is also an invitation to share your views through workshop discussions, and written submissions, which we hope will stimulate productive conversations.

The Strategy's ultimate goal is to set a clear and practical vision for low carbon fuels to help us deliver net zero greenhouse gas emissions by 2050. With your help, we can maximise the potential of LCFs for the UK economy, create thousands of new jobs, and play our part in fighting climate change.

The Rt Hon Grant Shapps MP
Secretary of State for Transport

Executive summary

1. Over the last 15 years, low carbon fuels (LCFs), supported by policy measures such as the Renewable Transport Fuel Obligation (RTFO), have been one of the main decarbonisation measures in transport. They include different liquid and gaseous fuels, such as biofuels or renewable hydrogen, which offer carbon savings compared to fossil fuels when looking at their whole life cycle.

2. As we move to net zero, LCFs will remain essential in our efforts to reduce greenhouse gas (GHG) emissions in transport. Currently, LCFs are mainly used to reduce emissions from road vehicles by blending biofuels into petrol and diesel. In the long term, the largest proportion of LCFs is likely to be required in aviation and maritime, i.e. transport modes with limited alternatives to liquid and gaseous fuels.

3. There are huge opportunities for UK production, both for current market participants and new entrants, building on existing skills, expertise and infrastructure available in the UK. Industry figures for 2017 suggest that about 10,000 people were employed in the UK biofuels sector.[1] Current efforts to establish a sustainable aviation fuel industry (SAF) in the UK could support between 4,900 and 11,500 UK jobs by 2040, with up to 5,100 jobs directly associated with domestic production.[2] With production sites often located in areas in need of regeneration, the UK LCFs sector can contribute both to greener growth and to levelling up.

4. As part of the Transport Decarbonisation Plan,[3] published in July 2021, the Department committed to develop a low carbon transport fuels strategy. This strategy will set a vision of how the use and production of low carbon fuels is expected to evolve through the first half of the 21st century and how to make best use of the opportunities these fuels offer.

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[1] REA (2018), REView Renewable Energy View 2018, available at: http://www.nnebooks.co.uk/REA/REA%20REview%202018/index.html#22

[2] Ricardo/E4Tech (2020), Targeted Aviation Advanced Biofuels Demonstration Competition – Feasibility Study Final report, available at: https://www.e4tech.com/uploads/files/final-report-aviation-abdc-feasibility-study-issue-v1-0.pdf

[3] DfT (2021), Decarbonising Transport. A Better, Greener Britain, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1009448/decarbonising-transport-a-better-greener-britain.pdf

5. The strategy is to be considered in the context of both the Transport Decarbonisation Plan and our wider Net Zero Strategy.[4] It will also build on other government strategies such as the Biomass Strategy,[5] the Resources and Waste Strategy[6] and the UK Hydrogen Strategy.[7]

6. As a first step, this call for ideas sets the scene through summarising progress to date and looking at some of the broad opportunities and challenges. A second document, to be published towards the end of 2022, will set out a vision for the sector and look at ways to deliver it, working closely with the industry.

7. The call for ideas sets out key developments for demand, supply, UK production and policy, and summarises wider interdependencies. Each chapter outlines our initial thinking about how challenges and opportunities could be addressed through the strategy development process.

8. Chapter 1 outlines the need for a strategy to establish a common understanding of the opportunities and challenges ahead for the LCF sector, to underpin future investments and identify any regulatory gaps. It is vital that we harness the opportunities of the expected transition while avoiding pitfalls such as stranded assets or technology lock-in.

9. Chapter 2 looks in detail at the shifting demand for LCFs across different transport modes. It sets out existing knowledge and highlights further information that might be needed about the speed and nature of the broad transition from road use to aviation and maritime in particular. As part of the strategy, the Department also plans to develop deployment scenarios.

10. Chapter 3 looks at current supply of LCFs, describing the range of current feedstocks and production pathways as well as exploring the potential expansion into new feedstocks and technologies, reflecting increased overall demand, changes in availability and technology advances. Further work in this area will also to be supported by feedstock research being commissioned by the Department.

11. Chapter 4 describes the current UK LCF production industry and the strong potential that exists to grow this further, especially for SAF. We are very interested in industry views on this assessment, and how we could continue to provide

[4] BEIS (2021), Net Zero Strategy. Build Back Greener, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033990/net-zero-strategy-beis.pdf

[5] For more information see BEIS (2021), Biomass Policy Statement, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1031057/biomass-policy-statement.pdf and BEIS (2021), The Role of Biomass in Achieving Net Zero. Call for Evidence, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/978812/role-of-biomass-achieving-net-zero-call-for-evidence.pdf

[6] Defra (2018), Resources and Waste Strategy for England, available at: https://www.gov.uk/government/publications/resources-and-waste-strategy-for-england

[7] BEIS (2021), UK Hydrogen Strategy, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf

appropriate policy support and build on existing capacities, skills and infrastructure.

12. Chapter 5 explains the vital role of policy in supporting LCF production and supply, overcoming the ongoing cost differential when compared with fossil equivalents. The RTFO has been the main policy intervention supporting the sector so far, accompanied by some capital funding for early-stage technology, and we have begun work to establish a separate support framework for SAF. We are keen to build on the success of the RTFO and maintain the benefits it has brought, while also reflecting the changing needs of the sector.

13. Chapter 6 explores the complex environment in which LCFs are situated which requires the balancing of the needs of different sectors in the economy. Links to other policy areas (e.g. waste and agriculture) and technological developments need to be carefully considered as well as the importance of ensuring sustainability.

14. The chapters invite views and ideas on the following key themes (for a full list of questions see Annex A):

    - Are important trends, risks and opportunities sufficiently captured in this document or are any key aspects missing (e.g. in terms of technology development, production pathways, interactions with other markets and policies)?
    - What are the key challenges and opportunities that need to be addressed to help maximise the environmental and economic benefits of LCFs?
    - What actions and measures need to be prioritised as part of developing the LCFs strategy to support the transport sector's transition to net zero?

15. The deadline for responses to this call for ideas is 3 April 2022. The Department welcomes contributions from anyone taking an interest in the development and deployment of LCFs and the decarbonisation of transport. Responses to this call for ideas will be taken into consideration in the second phase of the strategy development and will be supported through stakeholder workshops in the first half of 2022. Feedback and evidence received as part of this call for ideas and the stakeholder workshops will then inform the final strategy document.

How to respond

The period to respond to this call for ideas began on 7 February 2022 and will run until 3 April 2022. Please ensure that your response reaches us before the closing date. If you would like further copies of this document, it can be found at https://www.gov.uk/dft#consultations or you can contact LCFstrategy@dft.gov.uk if you need alternative formats (Braille, audio CD, etc.).

Please send responses to:

Name: Low Carbon Fuels Strategy

Address: Department for Transport, Low Carbon Fuels Division, Great Minster House, 33 Horseferry Road, London, SW1P 4DR

Email address: LCFstrategy@dft.gov.uk

When responding, please state whether you are responding as an individual or representing the views of an organisation. If responding on behalf of a larger organisation, please make it clear who the organisation represents and, where applicable, how the views of members were assembled.

Freedom of Information

Information provided in response to this consultation, including personal information, may be subject to publication or disclosure in accordance with the Freedom of Information Act 2000 (FOIA) or the Environmental Information Regulations 2004.

If you want information that you provide to be treated as confidential, please be aware that, under the FOIA, there is a statutory Code of Practice with which public authorities must comply and which deals, amongst other things, with obligations of confidence.

In view of this it would be helpful if you could explain to us why you regard the information you have provided as confidential. If we receive a request for disclosure of the information, we will take full account of your explanation, but we cannot give an assurance that confidentiality can be maintained in all circumstances. An automatic confidentiality disclaimer generated by your IT system will not, of itself, be regarded as binding on the Department.

The Department will process your personal data in accordance with the Data Protection Act (DPA) and in the majority of circumstances this will mean that your personal data will not be disclosed to third parties.

Data Protection

The Department for Transport (DfT) is carrying out this call for ideas to inform us of your organisation's views on low carbon fuels.

In this survey we're asking for:

- Your name and email, in case we need to ask you follow-up questions about your responses (you do not have to give us this personal information, but if you do provide it, we will use it only for the purpose of asking follow-up questions)

This consultation and the processing of personal data that it entails is necessary for the exercise of our functions as a government department. If your answers contain any information that allows you to be identified, DfT will, under data protection law, be the Controller for this information.

We will not use your name or other personal details that could identify you when we report the results of the call for ideas. Any information you provide will be kept securely and destroyed within 12 months of the closing date.

1. Introduction – A low carbon fuels strategy

The role of low carbon fuels in transport decarbonisation

Biofuels = fuels made from biomass (incl. wastes, residues, crops), *e.g. bioethanol, biodiesel, biomethane*

+ Renewable Fuels of Non-Biological Origin (RFNBO), *e.g. hydrogen produced via electrolysis using renewable electricity, fuels made from renewable hydrogen and carbon dioxide*

+ Recycled Carbon Fuels produced from fossil wastes
+ Fuels produced from nuclear electricity

Note: Further fuels may be identified as low carbon fuel; fuels listed are those currently considered to be able to deliver substantial carbon savings compared to fossil fuels.

Renewable fuels = fuels made from biomass and renewable electricity

Low carbon fuels = fuels that can provide GHG savings compared to fossil fuels on a life-cycle basis

Figure 1 – Overview of low carbon fuels terminology
Note: Terms like 'synthetic fuels', 'e-fuels' or 'sustainable aviation fuels' cut across the different fuel categories represented here and as such are not included in this table

2. LCFs can either be blended with conventional fossil fuels or used in their place, though the latter approach may require adaptations to vehicles[8] and infrastructure. The main benefit of these fuels is that they can deliver carbon savings compared to fossil fuels over their life-cycle, from the production of the

[8] For the purpose of this document, a vehicle is defined as a machine used for the transportation of people and goods such as cars, HGVs, shipping vessels or airplanes.

required resources, their conversion into fuel, to fuel distribution and use.[9] This is because LCFs are produced either from biomass which captured carbon emissions during its growth, from renewable electricity, or from fossil wastes which otherwise would have been emitted, incinerated or put in landfill (such as unrecyclable plastics or waste gases).

3. In 2020, LCFs supported under the Renewable Transport Fuel Obligation (RTFO) made up almost 6% of total road and non-road mobile machinery transport fuels and saved on average 82% carbon emissions compared to fossil fuels, with total savings equivalent to taking 2.5 million cars off the road.[10] They contributed to a third of all carbon savings from transport under current UK carbon budgets.

4. While these fuels offer significant GHG savings, careful consideration needs to be given to their limitations. LCFs can be produced from a wide range of resources using different technologies. This range offers flexibility but also means that the GHG performance of fuels may differ significantly. For instance, should the production of the fuel lead – directly or indirectly – to land use change such as deforestation, the GHG performance may be worse than a fossil fuel. Existing policy mechanisms such as the RTFO therefore include measures to ensure the scheme promotes the fuels with the highest possible savings. Policies also need to balance ambition for high deployment with making sure targets are not set at levels that inadvertently encourage the use of less sustainable fuels, which may be readily available at lower prices. In addition, as LCFs still generally rely on some form of government support to compete with fossil fuels economically, the benefits of their use need to be weighed up against costs.

5. The availability of sustainable resources is limited and transport demand may compete with demand from other sectors, raising questions concerning how resources such as biomass should be prioritised within the economy to deliver net zero, and where to incentivise their use. Priority uses may also evolve over time as new technologies become available. For example, bioenergy uses combined with carbon capture usage and storage (BECCS) can remove carbon from the atmosphere, and this potential to generate negative emissions may need to be taken into account when determining the role of biomass use in the future.

6. Finally, when used in conventional combustion engines that burn fuel, LCFs will not typically reduce tailpipe emissions significantly. Only some LCFs and applications may offer air quality benefits, such as hydrogen used in fuel cell vehicles.

7. These different limitations are important to note, and contribute to the assessment that the future use of LCFs will need to focus on transport modes that have limited alternatives to the use of liquid and gaseous fuels.

[9] In the case of recycled carbon fuels, this will include a comparison to a counterfactual.
[10] DfT (2021), Renewable Fuel Statistics 2020. Final Report, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1032684/renewable-fuel-statistics-2020-final-report.pdf

Changing role for low carbon fuels

8. Currently, LCFs are mainly blended into standard petrol and diesel sold at filling stations, incentivised through the Renewable Transport Fuel Obligation (RTFO). As passenger cars and lorries transition to zero emission vehicles, demand for petrol and diesel is expected to fall. Demand may remain in place slightly longer for heavier vehicles, where there could also be opportunities to use a higher proportion of liquid and gaseous LCFs until zero-emission vehicles become available, maximising savings from those existing vehicles. At the same time, demand from transport modes with more limited alternatives to liquid and gaseous fuels is expected to increase, including maritime and aviation.

9. This means that in the coming decades the sector is expected to undergo significant changes, transitioning from road fuels as the main use to aviation and maritime fuels.[11] New types of LCFs and feedstocks may also become commercially available as technologies and markets evolve. This will lead to changes to the renewable and fossil fuel production sites and infrastructure which exist today. As a consequence, businesses may adapt their business models and supply chains, and produce different fuels in the future, or might decide to use existing expertise for a different set of products (e.g. in the chemicals sector). Other market participants will enter the market for the first time. As this transition occurs, it is important that we make best use of the existing infrastructure and are able to build on the expertise we already have to ensure the UK benefits from the opportunities for green growth.

The need for a low carbon fuels strategy

10. While we know that the uses of LCFs will change in the coming decades, the uncertainties related to this transition are still high, given interdependencies with other domestic and international markets and policies. Government has set ambitious targets and incentives for decarbonising the transport sector to set a clear direction, including for the switch to zero emission vehicles and the deployment of sustainable aviation fuels. However, the speed at which these changes will occur is difficult to predict with certainty as they also depend on individual and business decisions as well as technological advances.

11. The purpose of developing this LCFs strategy is therefore to identify ways to improve planning certainty for all stakeholders involved in the LCFs sector. As a first step, this call for ideas will highlight some of the common challenges and uncertainties associated with the low carbon fuel sector, to ask questions about potential solutions and priorities.

12. On the demand side, examples of uncertainties include the speed of electrification of cars, vans and other road vehicles, to what extent the land-based freight sector (including road and rail) may rely on LCFs as an interim

[11] The exception is hydrogen which can qualify as a zero-emission technology.

measure, and how fast demand in aviation and maritime might ramp up. This makes it difficult to predict demand for different LCFs.

13. On the supply side, technology development and commercialisation of different pathways will impact on what feedstocks and fuels may be available and how their costs compare to alternative solutions. Decarbonisation measures in other sectors may also lead to competing demands for the same resources, impacting on the supply available to produce and use transport fuels. As part of the Biomass Strategy, the government will review the amount of sustainable biomass available to the UK and how this resource could be best utilised across the economy to help achieve our net zero greenhouse gas emissions target by 2050 while also supporting the delivery of our wider environmental targets. The LCFs strategy will build on those findings, although it will focus on the transport sector, and its scope also extends to LCFs derived from non-biomass resources.

14. Changes to both the demand and supply side will also affect the wider LCFs sector, the infrastructure used, and supply chains for the production and distribution of the fuels. To make use of new opportunities, investments are needed and so policy needs to ensure there is a certain degree of predictability and certainty.

15. On the policy side, the RTFO has helped to create a stable market for LCFs since 2008. Targets are set to increase up to 2032 and will continue at that level thereafter unless further increases are made in future. The Department has also consulted on a separate mandate for sustainable aviation fuels. However, while these mechanisms provide certainty that there will be an overall market for LCFs, they also allow obligated parties some flexibility on how to meet their targets, meaning they do not necessarily translate in specific volumes of a particular type of fuel. While this is ultimately for the market to decide, there is a risk that additional uncertainty related to the transition may hamper business and investment decisions.

16. The aim of the strategy is therefore to build a common understanding of the opportunities and challenges ahead and develop a vision for the sector to underpin future investments and identify any regulatory gaps. This is to ensure we harness the opportunities of the expected transition while avoiding pitfalls such as stranded assets or technology lock-in. Where possible, the strategy will also address specific uncertainties and risks.

Structure of this document

17. This call for ideas is a first step in the development of a low carbon fuel strategy for the UK transport sector. It sets out how LCFs are currently deployed in the transport sector and what changes may be expected in the coming decades. It also sets out some of the wider interdependencies of LCF deployment with other market and policy developments.

18. The document invites views on the key challenges and opportunities for the LCFs sector in the coming years. We are particularly interested in views on what the future strategy should focus on to help address current uncertainties and risk, and the potential to support further investments in the sector.

19. The document is divided into the following chapters:
    - Demand for low carbon fuels
    - Supply of low carbon fuels
    - The UK low carbon industry
    - The policy framework
    - Low carbon fuels in a wider context

20. Each chapter (except the last) sets out the status quo and then highlights some of the trends, challenges and opportunities. The last chapter focuses on some of the external factors impacting the market for LCFs to highlight some of the complexities.

Next steps and questions

21. The views and evidence received in response to this document will inform the development of the strategy, partly by helping to confirm priorities and topics for further stakeholder discussion. We aim to hold a series of workshops on specific topics in the first half of 2022; their content will also be determined based on the feedback received to this call for ideas. To strengthen the evidence base, the Department is also planning to commission further research, starting with a project on feedstock availability in early 2022. A final strategy document is expected to be delivered in late 2022.

22. This document summarises existing mechanisms and future challenges; it does not contain new policy proposals at this stage. In terms of UK-wide involvement, renewable fuels are a reserved matter, but there are links to a range of environmental and industrial policies. As part of the strategy development, the Department will therefore ensure the involvement of other government departments, devolved administrations or local authorities as appropriate.

23. To support the development of the strategy, we would like to invite views and feedback on the following questions:

    i. How can the low carbon fuels strategy best improve certainty about the deployment of low carbon fuels to support the decarbonisation of the transport sector and the growth of this industry in the UK?

    ii. Are there specific examples or best practices, the government should take into account when drafting the strategy?

2. Demand for low carbon fuels

Current demand for low carbon transport fuels

24. While LCFs offer significant GHG savings, fossil fuels are often still available at lower prices, and different types of LCFs are at different stages of commercialisation. The market is therefore generally shaped by policy interventions which seek to level the playing field and encourage the use of fuels providing carbon savings.

25. In the UK, the main support mechanism is the RTFO, which obligates fuel suppliers to supply a certain percentage of renewable fuels. Targets under the RTFO are therefore strong drivers of overall demand for LCFs. However, the RTFO is not prescriptive in terms of the specific LCFs supplied; its interventions focus on ensuring that all fuels meet strict sustainability criteria, the promotion of waste-derived[12] biofuels through extra incentives, and additional support for innovative fuels of strategic importance through a sub-target for so-called ‘development fuels’ (for more detail see Chapter 5).

26. At present, LCF demand is centred on those that can be blended with standard petrol and diesel sold at filling stations across the country, namely bioethanol and biodiesel (see also Chapter 3). This is one of the most cost-effective ways to meet targets under the RTFO and supply the fuel to the consumer. By blending biofuels into standard fuel, suppliers can make use of existing distribution infrastructure with limited to no adaptations required, provided the amount blended remains within certain limits (so-called ‘blend walls’[13]).

27. In addition, there is demand from fleet operators, local authorities or private individuals that have opted to use specific LCFs (e.g. biomethane, higher blends

[12] The term “waste-derived” in relation to the current RTFO refers exclusively to biogenic wastes and residues. In relation to recycled carbon fuels, the term may also refer to wastes from fossil sources but where that is the case, this document will typically use the term “fossil wastes”.
[13] The “blend wall” refers to the maximum limit to which biofuels can be blended into a fuel and comply with the fuel standard that most vehicles are approved to use.

of biodiesel or drop-in fuels[14]) to reduce their GHG emissions and have adapted vehicles and refuelling infrastructure as necessary. While current demand is focused on fuels used in the road sector and non-road machinery, demand is starting to grow for low carbon maritime fuels[15] or kerosene equivalents for blend into jet fuel.

28. As LCFs are used to replace fossil fuels and targets tend to be set as a proportion of fossil fuel supply, overall demand for LCFs is also significantly influenced by fluctuations and trends in oil and gas demand. This was apparent during COVID-19 related lockdowns, which also saw a decrease in total low carbon fuel demand.

29. Figure 2 outlines the proportions of the UK fleet by fuel type, showing that the existing fleet is still predominantly dependant on petrol and diesel.[16] Even with new car and van sales increasingly focussing on zero-emission technologies, there is likely still to be demand for petrol and diesel over the coming years, offering opportunities for the deployment of LCFs.

[14] Drop-in fuels are alternatives to liquid fuels that can be blended at higher levels without changes to vehicles or infrastructure.

[15] 2030 targets set by the International Maritime Organisation (IMO) are expected to drive requirements for low carbon fuels and this is starting to influence demand. See also IMO (2020), Roadmap to Zero Emission from International Shipping, available at: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Air%20pollution/Roadmap%20to%20Zero%20Emission%20from%20International%20Shipping%20-%20Japan%20March%202020.pdf

[16] DVLA/DfT (2020), Vehicle Licensing Statistics, available at: https://www.gov.uk/government/collections/vehicles-statistics

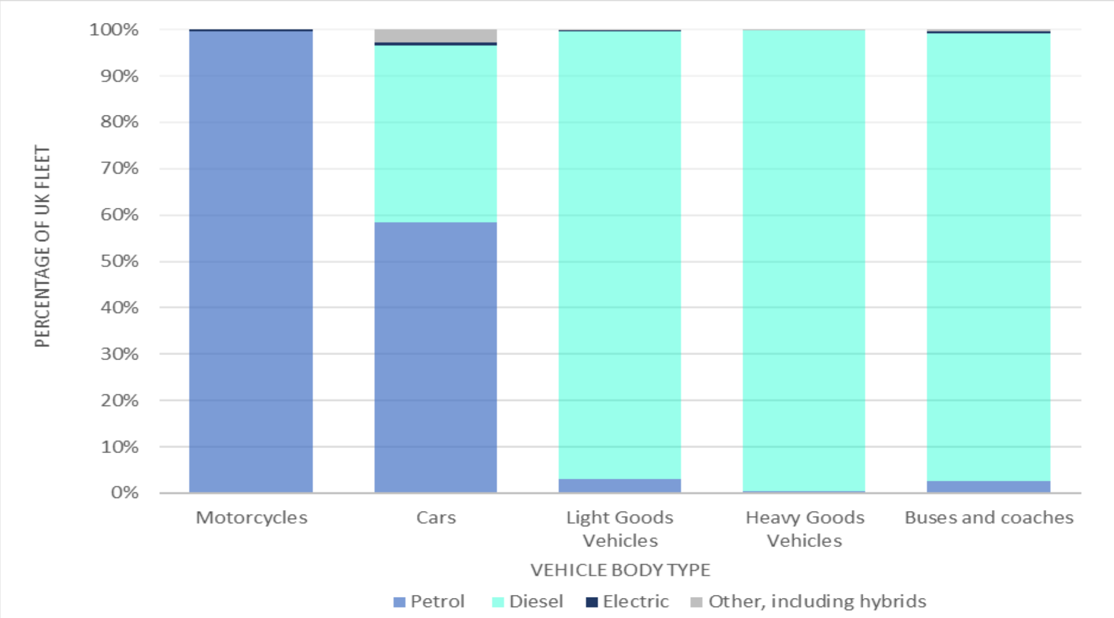

Figure 2: Types of road vehicle (by body type) licenced in the UK by fuel or propulsion type in 2020 (Source: DVLA/DFT Vehicle Licensing Statistics 2020)

30. The relative costs of deploying low carbon fuels, and accordingly demand across the different transport modes, are influenced by various factors. These include:

- **Composition of the existing vehicle fleet:** The number of vehicles with internal combustion engines will impact on total demand for gaseous and liquid fuels, while the relative share of petrol, diesel or gas-fuelled vehicles will determine what type of fuels are prevalent. The compatibility of an average vehicle with different fuels, including higher blends of biofuels beyond the "blend wall", will influence deployment options.
- **Ease of access to distribution and refilling infrastructure**: The degree to which LCFs and LCF blends can be made widely available depends on factors such as the number of different fuel types and grades that can be offered at filling stations across the country, options to transport the fuel (e.g. via pipeline, tanker or ship), regional variability (e.g. for transport options or blending facilities) and access to private fuel supplies.
- **Availability and costs of alternative decarbonisation measures:** This includes the number of battery and fuel-cell vehicles, the ease of access to charging facilities and comparative costs. Fleet-specific factors (e.g. the length of the duty cycle) may also influence how LCFs compare to alternative solutions, e.g. LCFs may be more appropriate for travelling long distances
- **Sector-specific decarbonisation and environmental measures**: Regulatory or reporting requirements (e.g. on air quality or regarding corporate social responsibility) may incentivise or disincentivise use of specific vehicle or fuel types.
- **Seasonal variations**: Blending of LCFs, in particular of biofuels, may vary throughout the year as fuels can behave differently at lower or higher temperatures.

- **Carbon intensity of a specific fuel**: As we move to net zero, GHG performance is likely to be increasingly important factor in choosing between different LCFs.

31. Based on these factors, the following sections outline current demand by transport mode.

Light road vehicles (cars, vans, motorbikes)

32. Demand from the road sector currently accounts for the main share of the LCFs supplied. LCFs used in cars, vans and motorbikes tend to be those blended into standard petrol and diesel. Standard diesel in the UK can contain up to 7% biodiesel (a blend referred to as B7), and standard petrol up to 10% ethanol (E10).

33. The exact share of biofuel blended in the petrol and diesel supplied via filling stations will differ between batches and suppliers, and also be subject to regional and seasonal variations. Historically, the average share of both diesel and petrol tends to be below the blend wall.[17]

Heavy goods vehicles

34. The heavy goods vehicle (HGV) sector mainly relies on diesel and consequently makes up a significant proportion of biodiesel demand. DVLA data suggests that growth in demand for biodiesel largely relates to the further increase in proportion of heavier diesel vehicles.[18] There is also some demand from the HGV sector for biodiesel blends higher than the standard B7 as well as for biomethane and hydrogen.

35. Around 60% of all HGV fleet operators use depot-based rather than public refuelling infrastructure, allowing them greater flexibility over the use of fuels and blends beyond standard petrol and diesel blends available to ordinary motorists. In addition, according to a recent industry report[19] more than half of the vehicles used in the HGV sector are estimated to be approved to use higher biodiesel blends than B7 (55% in 2021).[20] Using specific LCFs or blends allows fleets to achieve higher GHG savings, which could be significant in a sector currently

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[17] Renewable Transport Fuel Statistics suggest that in 2020 (before the introduction of E10 petrol) the average share of ethanol in petrol blends was 4.4% and the average biodiesel share in diesel blends 5.7% (including low sulphur gas oil and excluding hydrotreated vegetable oils, HVO).

[18] DfT (2021), Licensed heavy goods vehicles by propulsion and fuel type: Great Britain and United Kingdom, available at: https://www.gov.uk/government/statistical-data-sets/veh05-licensed-heavy-goods-vehicles.

[19] Zemo (2021), Market opportunities to decarbonise heavy duty vehicles using high blend renewable fuels, available at: https://www.zemo.org.uk/work-with-us/fuels/projects/2020-high-blend-biofuels.htm. and updated figures from internal Zemo 2021 data through the Renewable Fuels Assurance Scheme.

[20] This figure relates to compatibility with blends of up to 20-30% biodiesel. The proportion of HGVs approved for use of blends with up to 100% biodiesel is 13%.

carrying the largest proportion of domestic freight: 1,272 million tonnes in 2020, compared to 87 million tonnes by water and 69 billion tonnes by rail.[21]

As part of a range of decarbonisation measures, John Lewis Partnership (JLP) introduced biomethane HDVs into their fleet in 2012 and have committed that all will be running on the fuel by 2028, with 340 out of 600 currently transitioned. The biomethane used is made from waste and results in significant carbon reductions (85% according to John Lewis). Most of the specialist filling stations use gas taken directly from the grid which is then compressed, and dispensed into vehicles. The alternative is to deliver liquified gas to sites, compress and vaporise it, then dispense it into vehicles.

Image 1: John Lewis Partnership biomethane-fuelled HGVs

36. Adoption of such alternatives, however, tends still to be limited to a handful of operators. Around an estimated 800 vehicles (0.1% of the fleet) currently run on higher biodiesel blends, and 200 vehicles on hydrotreated vegetable oil (HVO), a 'drop in' fuel.[19] The high blends of diesel used are typically B20 or B30, i.e. blends with up to 20% or 30% biodiesel or in a few cases B100 (up to 100% biodiesel). Barriers to a wider uptake of these blends include the fact that standard filling stations typically only offer two types of petrol and diesel, costs for vehicles and vehicle adaptations, and warranties awarded by vehicle manufacturers for the use of those blends (as without those warranties fleet operators are unlikely to use the fuel). Drop-in fuels have the benefit of being compatible without any adaptations but (as is the case for the diesel-equivalent HVO) may come at a cost premium.

With just over 500 vehicles including HGVs, the London Borough of Hackney (LBH) operates one of the largest local authority fleets in London, including HGVs. LBH operate approximately 75% of their fleet on HVO and aim to have all their fleet and road registered plant operating on HVO within 12 months. It is estimated the switch offers up to 92% carbon savings compared to conventional EN590 diesel. LBH uses an on-site fuel management system to monitor and analyse fuel consumption and mileage data, allowing them to calculate their carbon footprint. HVO requires no additional maintenance or changes to operational procedures which has allowed for an easy switch at no cost to upgrading fleets or infrastructure.

[21] DfT (2021), Statistics Domestic freight transport by mode (Table TSGB0401), available at: https://www.gov.uk/government/statistical-data-sets/tsgb04-freight

Alfred Hymas, a bulk tipper Haulier from North Yorkshire, operate a mixed fleet of 80 vehicles, which runs on diesel blends with up to 30% FAME biodiesel (B30) in summer and B20 in winter. Working in partnership with Argent Fuels, Alfred Hymes made carbon savings of 4,276 tonnes in 2021 when switching to high blend biodiesel – equivalent of taking 259 cars off the road. The switch also provided cost savings, with fuel being a large proportion of the company's operating cost. Due to their onsite fuel facility the switch to higher blends has required little alteration, and their vehicle fleet required no alterations, seamlessly swapping between the B30 and standard fuel at any time.

37. An increasing number of HGVs are running on gaseous LCF including biomethane, biopropane and biobutane. However, these fuels can only be utilised in gas vehicles. This means that the rate of uptake is limited overall by fleet turnover and upgrades, although the growth of the second-hand gas vehicle market is helping smaller operators access the market too. At the end of 2021 there were estimated to be about 1,000 gas-fuelled HGVs running on biomethane, with numbers having grown significantly in recent years. Fleet operators are currently using a combination of depot-based and public refuelling infrastructure.

Buses and coaches

38. For buses and coaches, similar LCF alternatives beyond the standard petrol and diesel grades are available as for HGVs. According to industry data a relatively high number of buses are currently running on B20 or B30 (8,000 vehicles, 18.2% of the bus fleet) compared to the coach sector (250 vehicles, 9% of the coach fleet).[22] Biomethane has also been adopted to a small extent in the bus sector, where it is currently deployed in 350 specialised buses. Bus fleets use their own depot-based refuelling infrastructure and there are estimated to be 6-8 bus depots with this capacity in the UK.

[22] Zemo (2021), Market opportunities to decarbonise heavy duty vehicles using high blend renewable fuels, available at: https://www.zemo.org.uk/work-with-us/fuels/projects/2020-high-blend-biofuels.htm.

Nottingham City Transport (NCT) is the biggest transport operator in Nottingham, operating 330 buses. In order to reduce GHG emissions by 84%, Alexander Dennis buses were equipped with biogas fuel systems. Expansion of the centrally located gas fuelling station at NCT's city depot provides an open facility, accessible to HGVs making deliveries in and around the city centre. The fuelling station is designed to have the capacity to fuel 120 buses a day. Furthermore, the substation which delivers power to the equipment required to compress the gas prior to vehicle refuelling, enables NCT to operate and install electric charging infrastructure for electric buses, company fleet and private vehicles, when the compression equipment is idle. This maximises the investment and adds further value to the project. This change also supports the local gas suppliers, such as Road Gas producing biomethane at a nearby anaerobic digestion plant. The approach demonstrates principles of a circular economy, while reducing emissions as part of the supply process.

Image 2: NCT gas-fuelled bus

Non-road mobile machinery

39. The term 'non-road mobile machinery'[23] (NRMM) covers a wide range of machinery used in manufacturing industries, construction and quarrying that use different fuels. According to a recent BEIS publication, these account for 12 MtCO2 emissions a year.[24] Mobile generators are also included in this category. There is limited data on the use of LCFs in this sector, though RTFO statistics suggest that in 2020 4.5% of renewable fuel supplied was biodiesel destined for off road use.[25] There is also anecdotal evidence of low carbon fuel deployment, such as trials of HVO as a "drop in fuel" deployed in specific machinery in the rail sector.

Rail

40. Around 38% of the track in Great Britain is electrified but services on remaining lines are predominantly operated through diesel traction.[26] Given the long lifetimes of diesel locomotives, particularly in the rail freight sector, operators have shown increasing interest in the use of LCFs like HVO to reduce

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[23] As defined by the RTFO guidance. See DfT (2021), Renewable Transport Fuel Obligation: Compliance Guidance 2022, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/998434/rtfo-guidance-part-1-process-guidance-2021.pdf This definition can also include rail and inland shipping but these are referred to separately below.

[24] BEIS (2021), UK Net Zero Strategy Strategy, available at: https://www.gov.uk/government/publications/net-zero-strategy

[25] DfT (2021), Renewable Fuel Statistics 2020. Final report, available at: https://www.gov.uk/government/statistics/renewable-fuel-statistics-2020-final-report

[26] DfT (2019), Rail Factsheet, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/851082/rail-factsheet-2019.pdf

greenhouse gas emissions from the existing fleet. The largest rail freight operator in the UK DB Cargo currently operates 228 diesel and electric locomotives that transport in the region of 37 million tonnes of freight each year across the UK and into Europe.[27]

Maritime

41. Research commissioned by the government to inform the Clean Maritime Plan concluded that alternative low and zero emission fuels (such as ammonia, methanol and hydrogen) will be essential to realise emissions reductions at scale.[28] According to a recent market report, almost no LCFs are used in international shipping currently, with biofuels only making up 0.1% of final energy consumption.[29]

42. Future demand for specific fuels will be crucially influenced by their relative cost-effectiveness, which is subject to substantial uncertainty at present and requires further research. The relative cost-effectiveness of different fuels may be influenced by a range of factors and could therefore vary under different circumstances, this may include the type of vessel in use, its operating characteristics and refuelling destinations. The maritime market is made up of many different types of vessels, ranging from small recreational craft through to large cargo vessels and vessels with specialist uses such as fishing and windfarm installation, illustrating the potential that different decarbonisation solutions may be preferred in different segments of the sector.[30]

Aviation

43. Production and deployment of sustainable aviation fuels (SAF)[31] in the UK and globally is currently very limited. However, with total fuel use in aviation doubling between 1990 and 2019, despite significant aircraft efficiency improvements, there is a clear need for the use of SAF that can be easily combined with conventional jet fuel without significant aircraft or engine modifications. Some first volumes of SAF have been recently produced in the UK and the sector is expected to grow significantly.[32] Supported by government policy, a number of

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[27] DB Cargo (2021): 'DB Cargo UK successfully trials new HVO fuel in bid to decarbonise its operations' (Press Release), available at: https://uk.dbcargo.com/rail-uk-en/metaNavi/news/DB-Cargo-UK-successfully-trials-new-HVO-fuel-in-bid-to-decarbonise-its-operations-5764438

[28] Department for Transport (2019), Maritime Emissions Reduction Options, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/816015/maritime-emission-reduction-options.pdf

[29] IEA (2021), International Shipping Tracking Report, available at: https://www.iea.org/reports/international-shipping

[30] DfT (2019), Clean Maritime Plan, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/815664/clean-maritime-plan.pdf

[31] DfT (2021), Sustainable Aviation Fuel Mandate, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005382/sustainable-aviation-fuels-mandate-consultation-on-reducing-the-greenhouse-gas-emissions-of-aviation-fuels-in-the-uk.pdf

[32] Sustainable Aviation (2020), Sustainable Aviation Fuels Road-Map, available at: https://www.sustainableaviation.co.uk/wp-content/uploads/2020/02/SustainableAviation_FuelReport_20200231.pdf

SAF plants are developing across the country, and we are keen to support the development of this industry further, as reflected elsewhere in this document.

Future opportunities and challenges

44. As we move to net zero, the demand for LCFs is expected to change considerably. As outlined in Chapter 1, the demand for standard petrol and diesel blended with LCFs will decline, starting with the reduced demand from passenger vehicles as they are electrified. Until zero emission alternatives are commercially viable, focus in the road sector will shift towards use by long haul HGVs. At the same time, there will be increasing demand for LCFs from aviation and shipping, which are likely to need the largest proportion of low carbon liquid or gaseous fuel in the longer term, likely well beyond 2050.

45. The phase-out of new internal combustion engine vehicle sales will have a strong influence on future LCF demand for road use. However, uncertainty remains around the rate of retirement or replacement of existing petrol and diesel vehicles in the UK fleet.Our modelling of future deployment of LCFs for strategy will seek to reflect a range of scenarios for those vehicle retirements (see the end of the chapter for further information).

46. The reduced demand from light road vehicles may even increase availability of LCFs for heavier road vehicles and rail freight, where long vehicle lifetimes and current barriers to deployment of zero emission technologies presents an opportunity for LCF to play a critical role in the transition. For example, there could be opportunities for using higher blends of biodiesel in HGVs at least for an interim period. As part of the Transport Decarbonisation Plan, the Department has therefore committed to explore, in collaboration with stakeholders, potential measures to remove existing market barriers for use of these fuels in compatible vehicles.[33] Further information can be found in Chapter 2, including current market barriers.

47. While some LCFs can be used flexibly across a number of applications, the transition from use in one transport mode to another may also require substantial investments. Further information is available in Chapter 6. In some cases rapid increase in demand has driven supply and infrastructure challenges to be met by industry. For example biomethane use in specialised gas vehicles (which is supported also by fiscal policy) and increasing interest in 'drop in' fuels in the rail freight sector are driven by commercial decisions, including pressure from shareholders to reduce carbon emissions. Recognising these trends and their potential to drive wide-scale adoption of these fuels will also inform the development of future deployment scenarios for the Strategy.

48. In the longer term, reduced demand for renewable road fuels is likely to increase the availability of feedstocks for producing SAF. This requires bringing forward

[33] DfT (2021), Decarbonising Transport, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1009448/decarbonising-transport-a-better-greener-britain.pdf

conversion technologies that are commercially viable and scalable, and for substantial investments in plants and infrastructure to be made – both an opportunity and a challenge. There are also interdependencies that span across modes, such as the level of modal shift that can be expected in the freight sector or the scale of the hydrogen economy generally.

49. The table below provides an overview of current assumptions about future demand across different modes and significant areas of uncertainty that remain.

Transport Mode	Expected changes to demand	Comment on uncertainties
Cars, vans and motorcycles	Phase-out dates for the sale of new internal combustion engine (ICE) vehicles will mean that electricity is likely to become the preferred propulsion technique. Demand for existing petrol and diesel blends will decrease over time. The Committee for Climate Change (CCC) advice for the 6th carbon budgetrecommended that biofuels should be phased out from use in cars and vans by 2040 to prioritise them for use in other sectors.[34]	The precise pace of uptake of electric vehicles and other zero-emission technologies is still uncertain.However we will introduce a zero emission vehicle mandate setting targets for a percentage of manufacturers' new car and van sales to be zero emission each year from 2024.[35] If a large numbers of ICE vehicles remain, use of low carbon fuels in these sectors may be required for longer. Other approaches to reduce emissions include reducing reliance on cars and vans through increasing use of public transport and active travel. The pace at which this happens will also affect demand for LCFs.
Buses and coaches	Demand for bus services is expected to increase in line with shift to public transport. Due to air quality requirements especially in cities, early preference for zero-emission technologies (such as battery electric and hydrogen fuel cell) over biofuels as an interim measure is likely. The longer distances covered by coaches and different regulatory landscape means that the uptake of new technologies in the coach sector is likely to take longer.	There is a greater amount of uncertainty around the trajectory for decarbonising buses and this will likely vary across their different remits (e.g. domestic vs international), uses (e.g. tourism) and regions (e.g. urban vs rural). Uncertainty remains around the rate of adoption of renewable hydrogen buses as it is heavily dependent on the scale up of the wider hydrogen economy. Similarly, rate of uptake of electric buses will depend on the scale up

[34] Climate Change Committee (2020), Sixth Carbon Budget (online), available at: https://www.theccc.org.uk/publication/sixth-carbon-budget/

[35] BEIS (2021), Net Zero Strategy, available at: https://www.gov.uk/government/publications/net-zero-strategy

		of vehicle technologies and infrastructure.
HGVs	Phase-out dates for non-zero emission heavy duty vehicles will mean that batteries or hydrogen fuel-cells will become the preferred propulsion technologies in the long term. Demand for road freight is expected to continue to increase in the immediate future In order to achieve GHG savings from the existing fleet, biodiesel blends as well as gaseous fuels such as biomethane will continue to be deployed - potentially to a greater extent in certain compatible vehicles operating on suitable drive cycles.	Pace of commercialisation and uptake of different zero-emission technologies is uncertain, hence the need for LCFs as an interim measure. As outlined in the Transport Decarbonisation Plan, a proportion of freight may shift to other modes, particularly rail, which could also impact on demand for LCFs.
Non-road mobile machinery (exc. Rail)[36]	Analysis by the CCC suggests that LCFs could make a small contribution to help decarbonise NRMM in the medium term through acting as transition fuels.[37] Electrification and renewable hydrogen are expected to help decarbonise the sector in the long term, with machinery manufacturers already developing equipment capable of using them.	Pace of commercialisation and uptake of different zero-emission technologies is likely to impact on low carbon fuel demand.
Rail	Demand for LCFs other than renewable hydrogen in the rail sector is only expected to continue during the transition to zero-tailpipe emission traction. Diesel alternatives will likely be required into the 2040s to reduce GHG emissions from the existing fleet, particularly rail freight locomotives that can operate for 30 years or more. Demand from passenger rail operations is expected to be negligible given the focus on electrification of the lines and fleet.	We are seeing interest in use of biodiesel by rail freight operators for use in existing locomotives, including those with the greatest market share in the sector. There is currently a significant cost premium and some operators are only in the trial stages so it is unclear how widespread this demand could become.
Maritime	In the long term it is expected that the demand for alternative low and zero emission fuels (such as ammonia, methanol and hydrogen) will increase	There is substantial uncertainty at present about which specific low and zero emission fuels will be preferred in the future. This will be

[36] In legal terms 'non road mobile machinery' refers to internal combustion engine vehicles and machines only. For the purposes of this document this term also includes alternatively fuelled non-road machinery, such as those powered by hydrogen fuel cells.

[37] Committee on Climate Change (2020), Reducing UK Emissions Progress Report to Parliament, available at: https://www.theccc.org.uk/wp-content/uploads/2020/06/Reducing-UK-emissions-Progress-Report-to-Parliament-Committee-on-Cli.._-002-1.pdf

	substantially, particularly where battery electric technologies cannot be used. Under high decarbonisation scenarios, research estimates that the demand for these fuels starts ramping up significantly in the 2030s and that they will likely dominate the market by 2050	heavily dependent on individual decisions by global shipping companies, who are currently testing a number of decarbonisation options. Further research and demonstration projects are expected to be required during the 2020s, e.g. demonstration of pre-commercial vessels infrastucture using hydrogen or ammonia.[38]
Aviation	This is likely to be a key area of focus. It is expected that demand will increase, and production of SAF could meet 4%-8% of global aviation fuel use by 2035.[39] In the long term, liquid aviation equivalents will likely be needed for long-haul flights.	Whilst demand is expected to increase, it is currently uncertain which type of LCFs will be required e.g. specific shares of SAF and renewable hydrogen.

Table 1: Potential developments regarding LCFs demand by transport mode

Next steps and questions

50. To further develop understanding of how demand may evolve over time, we will review the potential variation in demand for LCFs across different transport modes as part of the strategy development. On this basis, the strategy will aim to identify a range of scenarios as to how LCFs demand may evolve across transport modes and what this means for overall demand, differentiating also by fuel types where possible.

51. While these demand scenarios may not be able to resolve all uncertainties, they will help identify credible ranges that, in combination with existing targets and ambitions, may improve planning security. We will engage with stakeholders to test these scenarios and the assumptions they will be based on.

52. To support this work, we invite stakeholder views and ideas on the following questions:

iii. Does this chapter accurately capture key trends, opportunities and risks in terms of low carbon fuels demand? If no, please expand on any aspects that you think are missing or inaccurate, or require further exploration.

iv. In your view, what are the key challenges relating to demand in the future transition of the sector?

[38] BEIS (2021), UK Net Zero Research and Innovation Framework, available at: https://www.gov.uk/government/publications/net-zero-research-and-innovation-framework

[39] Sustainabe Aviation (2020), Sustainable Aviation Fuels Roadmap, available at: https://www.sustainableaviation.co.uk/wp-content/uploads/2020/02/SustainableAviation_FuelReport_20200231.pdf

v. Apart from developing demand scenarios, are there any other actions the government should consider as part of the strategy development to address uncertainties and identify opportunities on the demand side?

vi. For the development of the demand scenarios, are there any key sources of information or data the government should consider?

vii. For the development of the demand scenarios, are there any specific aspects that government should consider (e.g. niche uses of low carbon fuels, competing demand from other sectors or technology development) and if so, do you have a view on how best to incorporate them?

3. Supply of low carbon fuels

Current supply of low carbon fuels in the transport sector

53. LCFs supplied in the UK vary widely. They are produced from different feedstocks originating from over 90 countries worldwide, demonstrating the global character of LCF supply chains. Overall supply of LCFs, as a share of fossil fuels, has increased over the years, though the national lockdown as a response to the COVID-19 pandemic saw total volumes decrease in 2020 compared to 2019.[40] This section provides an overview of the type of LCFs supplied in the UK.

Type of low carbon fuels supplied

54. The main LCFs supplied in the UK to date have been biodiesel (predominantly fatty acid methyl ester, FAME) and bioethanol. Of the more than 2.5 million litres equivalent of renewable fuels supplied in the UK in 2020 (representing almost 6% of total road and non-road mobile machinery fuel for the year), 64% consisted of biodiesel, and 22% of bioethanol (see graph below).

[40] All 2020 data in this chapter is taken from DfT (2021), Renewable Fuel Statistics 2020. Final report, available at: https://www.gov.uk/government/statistics/renewable-fuel-statistics-2020-final-report. Historic data on renewable fuels referred to in this chapter is taken from the annual Renewable Fuel Statistics available at: https://www.gov.uk/government/collections/renewable-fuel-statistics.

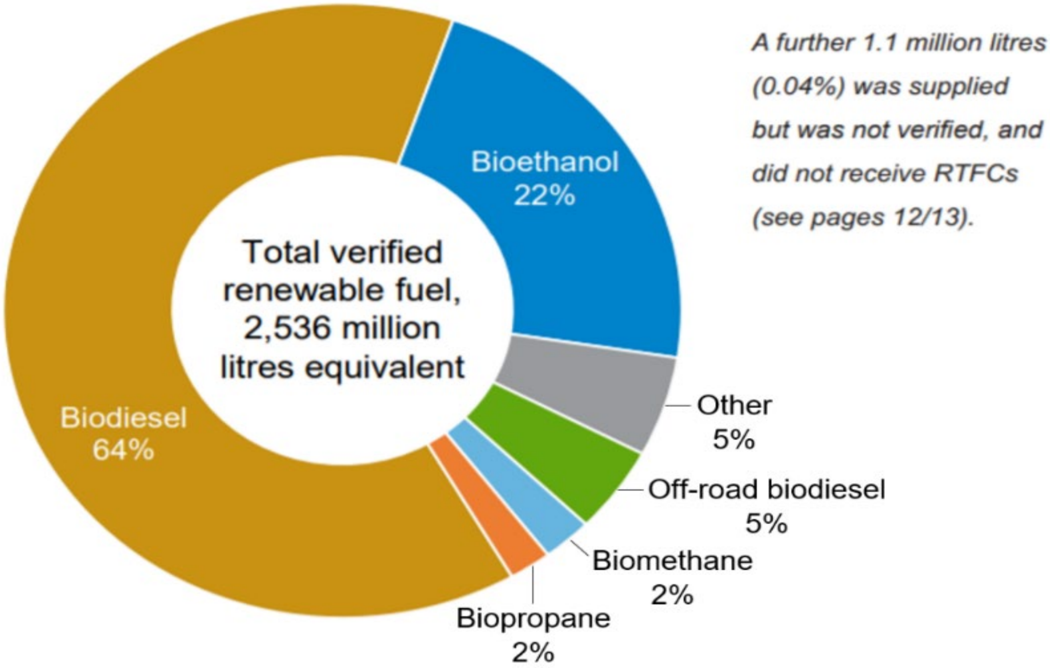

Figure 3 – Volume of verified renewable fuel under the RTFO by fuel type in 2020 (Source: Renewable Fuel Statistics 2020)

55. The respective share of biodiesel and bioethanol in the market has varied over the years. Historically, they tended to have similar shares in the market, though in recent years biodiesel has become the main renewable fuel supplied.[41]

56. Small shares of biomethane have also been part of the renewable fuel mix since 2015 and have increased over recent years to 2% in 2020. Biopropane, which was supplied under the RTFO for the first time in 2018, accounted for 2% of all renewable fuel supplied to the UK in 2020. Biomethanol similarly accounted for 2% of supply in 2020. ‘Development fuels’, innovative, waste-derived fuels of strategic importance, for which a specific sub-target was introduced under the RTFO in 2019 (see also Chapter 5), accounted for less than 1% of total renewable fuel supply in the UK in 2020. They included ‘development petrol’ produced from food waste, and renewable hydrogen.

57. More information on the different types of low carbon fuels supplied in the UK is also available in Annex C of this document.

Feedstocks used to produce low carbon fuels

58. The number and type of feedstocks used to produce LCFs has significantly evolved over the years. For 2020, RTFO statistics recorded more than 40 different feedstocks, up by 15% from the previous year. The increase in different feedstocks over the years is due to several factors including availability of feedstocks, technology development, economic benefits, and a drive towards higher GHG savings. 76% of all the renewable fuels supplied in the UK in 2020

[41] This may partly reflect that growth for bioethanol was until 2021 limited by the fact that standard petrol in the UK contained no more than 5% ethanol. The introduction of E10 (petrol with up to 10% ethanol) may see a rise in the bioethanol share, though other factors (e.g. overall demand for diesel) also play a role.

were produced from biogenic wastes, with 55% of all renewable fuels and 75% of all biodiesel being produced from used cooking oil. Other major waste feedstocks used in 2020 included food waste, brown grease and sewage sludge. This is a marked difference to the beginning of the RTFO, when renewable fuels were mainly produced from crops such as soy, corn, sugar beet and rapeseed oil.

Conversion technologies used to produce low carbon fuels

59. As the feedstocks used in the production of LCFs have evolved, so have the conversion technologies. The processing technologies used to convert feedstocks into fuel products are diverse. The technological readiness of different pathways ranges from established processes that are widely deployed and capable of producing fuels on a commercial scale (e.g. fermentation for bioethanol production, transesterification processes for biodiesel or anaerobic digestion for biomethane), to advanced fuels that are currently produced in small volumes and limited to niche applications.

60. Over time, fuel suppliers have also improved their processes and conversion efficiencies to improve the GHG performance of their fuels, with GHG thresholds under the RTFO increasing. An overview of LCF production pathways that are currently prevalent or expected to become prevalent can be found below (Figures 4 and 5).

61. Government has also encouraged technological innovations through advanced fuel demonstration competitions; further information can be found in Chapter 5.

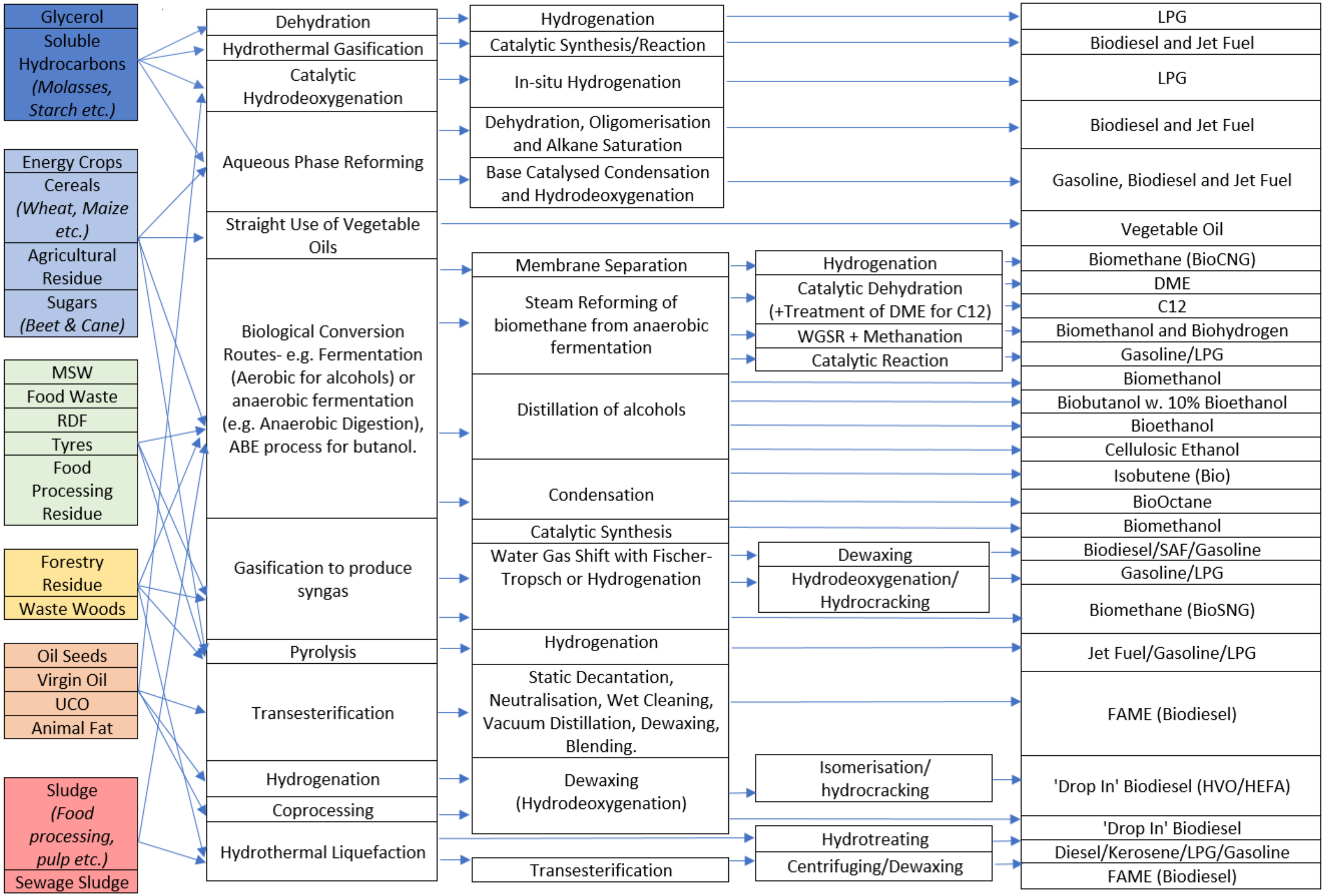

Figure 4 – Overview of prevalent biogenic production pathways for low carbon fuels (not exhaustive)

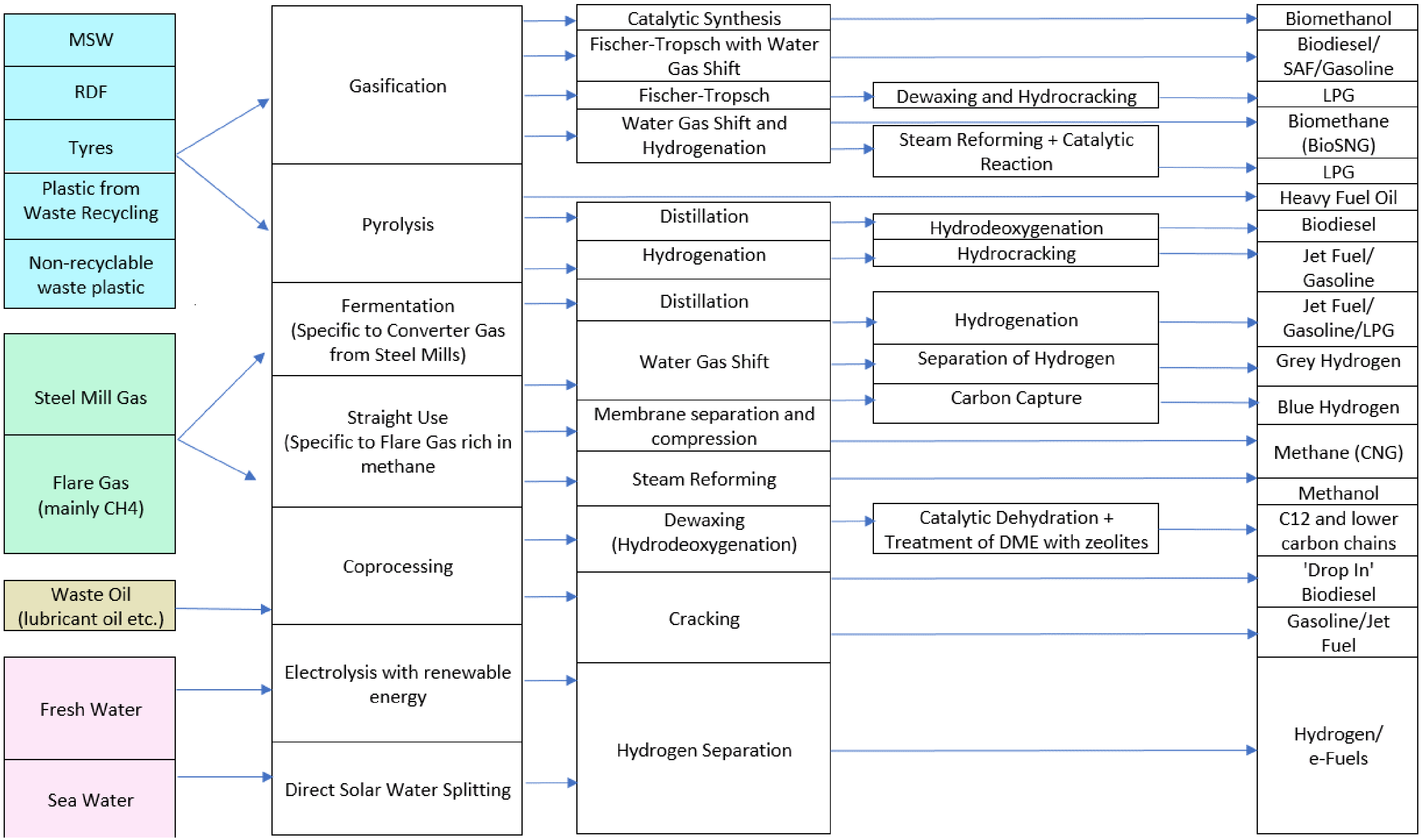

Figure 5 – Overview of prevalent RCF and RFNBO production pathways for low carbon fuels (not exhaustive)

Trade patterns

62. In 2020, 12% of feedstocks used in the production of LCFs came from the UK, with the remaining share originating from 90 different countries. The top 5 feedstock supplying countries accounted for nearly 50% of all renewable fuels in 2020. However, countries of origin for different feedstocks significantly vary year by year. Regional trends show that currently about a fifth (18% in 2020) of the feedstocks come from neighbouring EU countries, a decrease compared to previous years with more feedstocks (70%) coming from outside the EU, mainly Asia.[42]

63. Figure 6 displays trends in the trade of liquid biofuel supply. Over a five-year period the total supply of liquid biofuels has increased, reflecting the RFTO's increase in fuel obligation year on year. Data suggests that both domestic production (including both domestic supply and exports) and imports have increased over time, except in 2017, when domestic supply was at its highest and imports were at its lowest. Imports decreased during 2015-17 when RTFO targets were kept stable, but have risen significantly with increased RTFO targets from 2018 onwards.

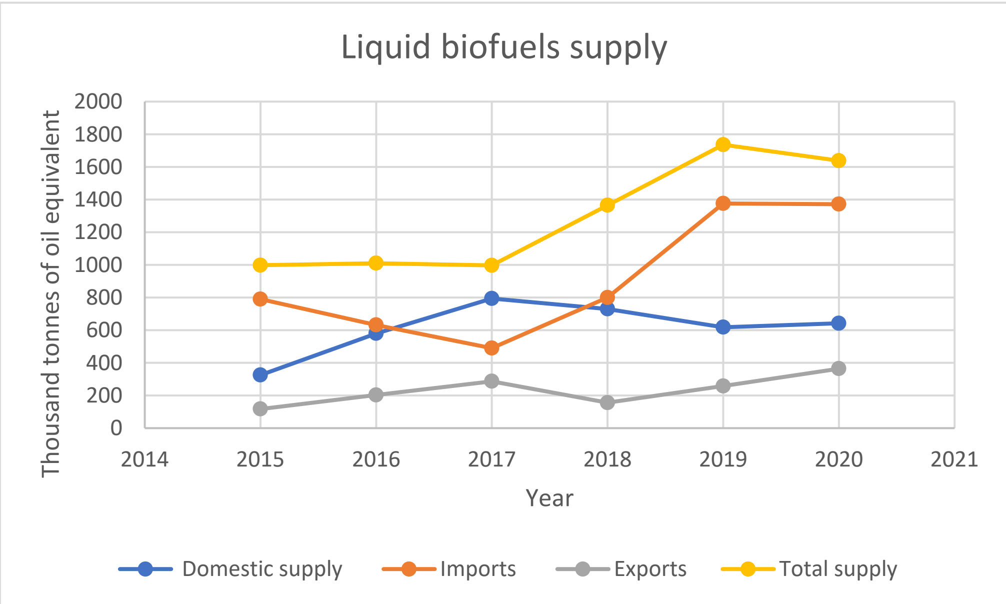

Figure 6: UK Liquid Biofuels Supply 2015-2020 (Source: DUKES).[42]

Sustainability requirements and greenhouse gas savings for low carbon fuels

64. To be eligible for support under the RTFO LCFs must meet strict sustainability criteria. These criteria establish protections for areas of high carbon stock and highly biodiverse areas. Biofuels will not be eligible for support if they are produced on these protected land types. The sustainability criteria also set minimum GHG saving thresholds, which fuels must exceed to be eligible for support.

[42] BEIS (2021), Digest of UK Energy Statistics. Annual data for UK, 2020, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1023276/DUKES_2021_Chapters_1_to_7.pdf

65. On average, the renewable fuels supplied to the UK in 2020 provided GHG savings of 82% when compared to fossil fuel use (78% when including the effects of indirect land use change). The graph below displays GHG savings delivered by renewable fuel supplied to the UK from 2008/09 to 2020.

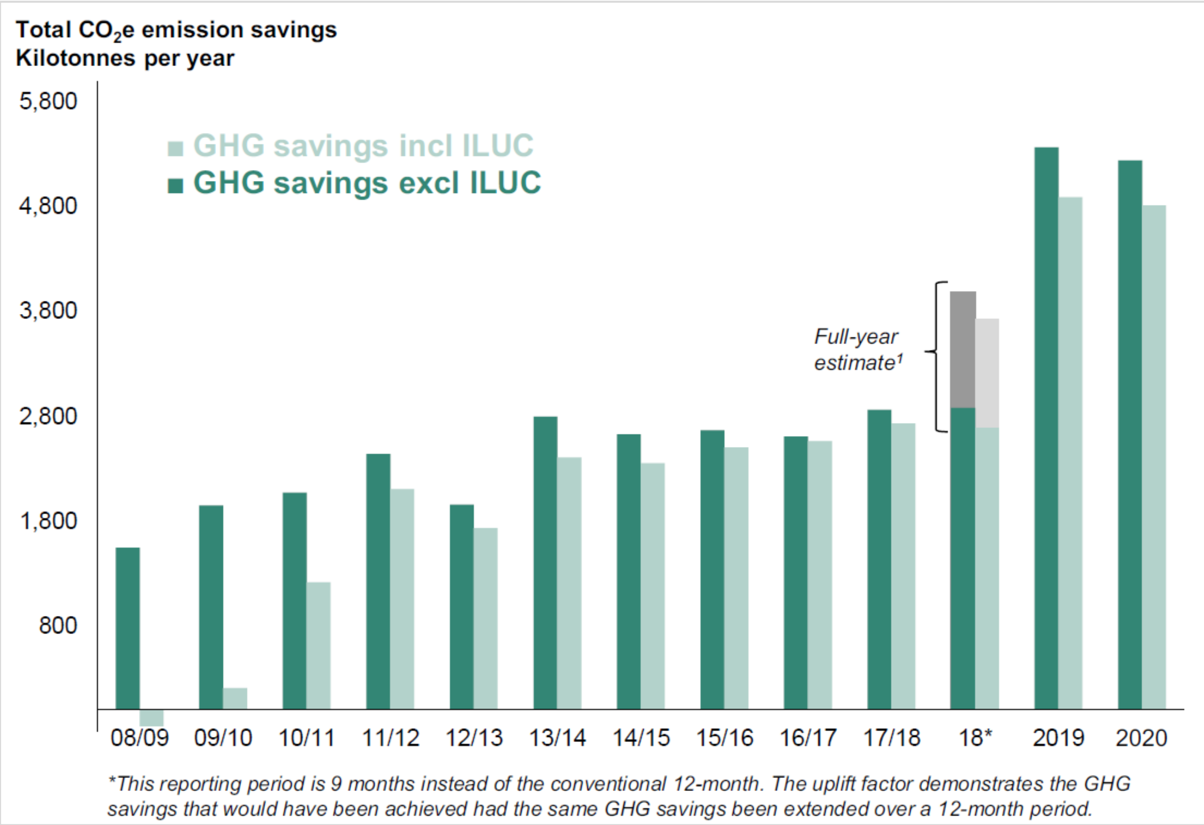

Figure 7: GHG savings by renewable fuels supplied to the UK, 2008/09-2020 (Source: Renewable Fuel Statistics 2020)

66. GHG savings vary depending on the feedstocks and processing technologies used. Average greenhouse gas emissions saved in 2020 for each fuel type are outlined in Figure 8 below. Generally, fuels predominantly produced from waste feedstocks have higher GHG savings.[43] Among the fuels supplied in 2020, renewable hydrogen provided the greatest GHG saving per unit, whereas methanol provided the smallest in comparison with the other fuel types. The high average GHG savings for renewable hydrogen reflect the fact that hydrogen only emits water when used in a fuel cell and can be made using renewable energy, resulting in zero CO2 emissions.

[43] Waste feedstocks tend to provide higher GHG savings as there are no emissions associated with the production of the raw material. Use of waste feedstocks can also bring additional benefits such as avoiding methane emissions to the atmosphere from manure.

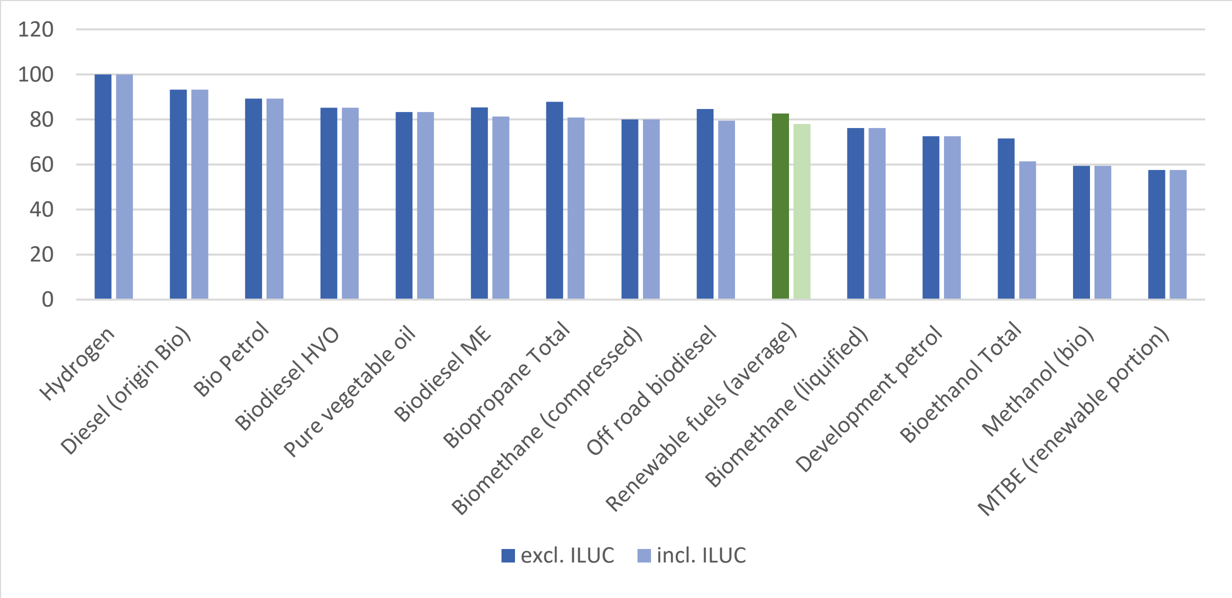

Figure 8: Average GHG savings (in %, compared to fossil fuels) by fuel type in 2020 (Source: Renewable Fuel Statistics 2020)

Future opportunities and challenges

67. Future changes to the LCFs landscape will have an impact on the fuels supplied and the wider supply chain, including feedstocks and conversion technologies used. With demand shifting to harder to decarbonise sectors, as outlined in Chapter 1, there will likely be an increased focus on diesel and kerosene replacements.

68. As we move to net zero, further reductions in GHG emissions from LCFs are likely to be required, which means combining their production with carbon capture and storage where possible and improving conversion efficiencies, especially where additional processing steps are required. There will also be continued pressures to expand the range of waste materials that LCFs can be produced from, taking into account waste reduction policies and demand from other sectors, as well as exploring other feedstocks (such as algae).

69. The sections below outline some of the specific challenges and opportunities for different categories of LCFs, including both biofuels and other LCFs (see Table 3 below).

Renewable fuels of non-biological origin (RFNBO)	Rather than from biomass, the energy content of a RFNBO typically comes from renewable energy sources that include wind, solar, geothermal, hydrothermal and ocean energy, or hydropower
Power-to-liquid (PtL)	A fuel produced using renewable energy and sources of hydrogen and carbon to produce fuels through synthesis. The term can also be used to describe the process.
Recycled carbon fuels	Recycled carbon fuels (RCFs) are fuels produced from fossil wastes that cannot be avoided, reused or recycled and have the potential to reduce GHG emissions relative

	to conventional transport fuels. Feedstocks include industrial waste gases and the fossil-derived fraction of municipal solid waste (e.g. non-recyclable plastic). Some feedstocks can be considered part renewable and part RCF when combined with biogenic material such as food waste.
Sustainable aviation fuels	A term that describes low carbon alternatives to fossil-derived aviation fuel, which can be blended into conventional jet fuel without requiring significant aircraft or engine modifications.

Table 2: Overview of terminology of low carbon fuels other than biofuels

Biofuels used in surface transport

70. As liquid biofuels are mainly blended into standard petrol and diesel used by road vehicles, the expected decline in petrol and diesel will also impact on their current market. This may affect petrol substitutes earlier than diesel, as petrol is mainly used in lighter vehicles where battery electric vehicles are already readily available. This will also lead to changes in how biofuels are supplied and to their production pathways, offering both new opportunities and challenges.

71. One potential way to maintain volumes of biofuels in road transport is the use of higher blends of biofuels and drop-in fuels. Given additional costs (e.g. for adapting vehicles and fuel bunkering infrastructure), this option is more suitable for heavier vehicles which are likely to require liquid fuels for a longer period of time – some even into the 2040s. As outlined in Chapter 2, there are still some barriers to the deployment of higher blends. Drop-in fuels like HVO are easier to deploy at higher levels, but come with a cost premium and supply is still more limited (there is currently no HVO production in the UK).

72. With increasing demand from the aviation sector, feedstocks for biofuel production will also need to be increasingly redirected to the production of sustainable aviation fuels. This will either require adding processing steps to existing pathways or deploying new production pathways (see also Figures 4 and 5 above). During the transition, it will be important to ensure that feedstocks are directed to the most efficient production pathways to capture maximum GHG savings. As detailed above there will also be continued pressure to improve GHG performance of fuels, which is likely to continue to support the move towards waste feedstocks and advanced conversion technologies.

73. As the transition progresses, it is ultimately also possible that certain production pathways may be adapted to supply alternative products or into alternative markets (e.g. biochemicals), especially should these markets provide higher revenues. Where any such changes occur, it will be important to ensure that these still provide cost-effective carbon savings for the economy as a whole, in line with the priority use principles as being developed for the Biomass Strategy (see Figure 13 in Chapter 6).

74. For gaseous biofuels (e.g. biomethane), demand in transport is closely linked to the number of gas vehicles. Recent trends show significant increases in gas

vehicles used by commercial fleet operators, supported also by a fuel duty differential. Anaerobic digestion of manure already offers the potential to achieve net zero carbon emissions over the lifecycle of biomethane. Small-scale biomethane production is also emerging (for instance, incorporating its capture or production into farming practices), which could provide additional revenue streams and, in some cases, fuel for local vehicles. There are case studies of biomethane being used in road and non-road mobile machinery fleets near anaerobic digestion plants which exploit some of the benefits of a circular economy.[44] However, as with any biofuel, biomethane is considered a transitional technology for road vehicles as it cannot offer zero emissions at the tailpipe. For its supply, biomethane also often relies on the existing gas grid for natural gas, which may also see changes as we move to net zero.

Other renewable and low carbon fuels used in surface transport

75. The supply of renewable fuels other than biofuels is currently limited. Small shares of renewable fuels of non-biological origin (RFNBOs), e.g. hydrogen and methanol, were supplied under the RTFO in 2020. Other LCFs such as hydrogen produced from non-renewable sources or recycled carbon fuels are currently not subject to support schemes like the RTFO. However, we are taking steps so that recycled carbon fuels are eligible for RTFO support. Recycled carbon fuels and hydrogen from other low carbon non-renewable are being considered outside the RTFO such as under a future SAF mandate (see also Chapter 5).

76. Infrastructure provision for the supply of other renewable fuels is limited. In the case of renewable hydrogen this is under development but not yet available at scale. According to an industry report there is some potential for use of existing logistics and distribution processes in the downstream oil sector for supply of renewable fuels such as hydrogen or synthetic fuels.[45] This could be a key factor in scaling up the supply and distribution networks.

77. Compressed renewable hydrogen is considered an attractive transport decarbonisation option as it produces zero emissions at the tailpipe when used in a fuel cell, and has high energy to mass density. However, it has a low energy to volume in comparison to fossil fuel equivalents, making it less viable as an aviation fuel and alternative hydrogen propulsion systems, such as cryogenic hydrogen, are currently underdeveloped. Hydrogen can also be produced through use of fossil feedstocks. This pathway is not supported through the RTFO as it is not renewable and currently emits carbon dioxide in the process. Another alternative that is not supported under the RTFO is hydrogen produced using nuclear energy because, while it is zero carbon at the point of production, it is not from a renewable source. Alongside many other uses set out in the BEIS Hydrogen Strategy, it is expected that hydrogen could be a key component on

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[44] Zemo (2021), Market opportunities to decarbonise heavy duty vehicles using high blend renewable fuels, available at: https://www.zemo.org.uk/work-with-us/fuels/projects/2020-high-blend-biofuels.htm

[45] UKPIA (2021), The Future of Mobility in the UK, available at: https://www.ukpia.com/media/2579/ukpia-future-mobility-2021-low-res.pdf

the path to net zero for multiple heavier transport modes, including maritime, aviation and road freight.

78. Recycled carbon fuels (RCF) are of particular interest as their use in the transport sector can offer greater energy recovery than other uses of waste and can also avoid the environmental impacts of conventional means of disposal, such as landfill or incineration. Recycled carbon fuels have the potential to make an important contribution to the path to net zero through applications such as SAF and 'drop in' fuels suitable for road vehicles that are difficult to decarbonise, such as heavy goods vehicles. There is also an opportunity for the UK to become a global leader in the development of associated technology, such as becoming specialists in the advanced conversion technologies required to produce them, including pyrolysis and gasification. There could also be wider potential benefits, e.g. supporting improved waste management practices. Further details on proposals for RCF support under the RTFO are planned to be published in early 2022 as well as the government response to outstanding issues relating to RFNBOs under the RTFO.

79. The future low carbon transport fuel mix is expected to include more significant amounts of these fuels. Although the proportion of each are difficult to predict at this stage, we expect certain fuels or particular feedstocks to be particularly important for the aviation and maritime sectors.

Sustainable aviation fuels

80. There is likely to be a market for liquid aviation fuels well past 2050 so demand for low carbon kerosene equivalents will be high. Meeting this demand requires rapid commercialisation of these advanced fuels, predominantly from waste feedstocks, during the 2020s to ensure supply can meet this need in the future. This provides opportunities for UK supply chains as detailed in the next chapter. The government set out an approach to reaching net zero aviation by 2050 in our Jet Zero Consultation in 2021 which included consideration of the role SAF and hydrogen aviation could play. The government will publish a Jet Zero Strategy in 2022, alongside a second consultation on a mandate to support a market for SAF.

81. Compared to road fuels, aviation fuels need to comply with a different set of specifications and standards, which typically require additional processing steps in their production. They are also overseen by different regulatory bodies, such as the UK Civil Aviation Authority (CAA) whose recent publication on net zero aviation discussed progress in terms of SAF production.[46] At present, SAF production is limited to one type of process known as hydroprocessed esters and fatty acids (HEFA), with existing facilities already supplying SAF to the UK and globally. All other approved pathways still face significant challenges and high production costs.[47] There are also less commercially developed pathways that

[46] CAA and UKRI (2021), Towards Net Zero Aviation: UK Legislative Framework, available at: https://publicapps.caa.co.uk/docs/33/CAP2284_20211020%20%20Legislative%20NZ%20document%20FIN%20(002).pdf

[47] Approved by the American Society for Testing and Materials (ASTM) - one of the most common and used aviation fuel standards for commercial jet fuel

show potential such as include power-to-liquid and biomass gasification. A number of development and demonstration projects are underway to test the use of hydrogen in aviation. In addition, the Aerospace Technology Institute's FlyZero project, funded by £15m of government support, will report on the potential use of hydrogen as a zero emission aviation fuel early in 2022.

82. As policy mechanisms are being developed to support supply of SAF and other advanced fuels, we will consider the types of feedstocks and production pathways that should be prioritised. SAF from nuclear origin or recycled carbon fuels are under consideration alongside waste-derived biofuels and RFNBOs. These fuels have the potential to deliver high carbon savings without being associated with significant direct or indirect land use or wider environmental impacts.

The winning proposals for the Green Fuels, Green Skies (GFGS) competition were announced in December 2021, receiving a share of £15 million for the development of SAF production plants in the UK.[48] British Airways, LanzaJet and Nova Pangaea Technologies have partnered to conduct a feasibility project that could produce more than 100 million litres of SAF a year. The project successfully secured £484,201 from the competition and will involve working on the feasibility study for the construction of facilities processing domestically sourced woody residues combining ethanol production and LanzaJetTM's alcohol-to-jet fuel technology. This builds on a project by Nova Pangaea Technologies completed under the Advanced Biofuels Demonstration Competition (ABDC).

Image 3: Nova Pangaea Technologies' management team at their demonstration plant in Humberside, which was supported under the ABDC.

Maritime fuels

83. As outlined in Chapter 2, the maritime sector is likely to require alternative low and zero emission fuels (such as ammonia, methanol and hydrogen) which could form the bulk of the energy supplied to vessels in the 2050s and beyond. However, significant uncertainty remains about the proportions of different types of fuel that will be required, although any hydrogen used must be low carbon hydrogen (e.g. produced using low carbon electricity or with the use of carbon capture and storage) to provide sufficient GHG savings. The mix of hydrogen, ammonia and methanol supplied will depend on a range of factors, including their potential to be integrated into existing refuelling infrastructure at ports as well as

[48] DfT (2021), Green Fuels, Green Skies competition: winners, available at: https://www.gov.uk/government/publications/green-fuels-green-skies-gfgs-competition/green-fuels-green-skies-gfgs-competition-winners

the relative demand from different types of vessels. As outlined in the Clean Maritime Plan, fuel prices remain a significant barrier to commercialisation of marine fuels.

84. At a global level, there may also be some increasing demand for biofuel solutions in the maritime sector. However, in the UK biomass-derived marine fuels are currently not seen as a long-term decarbonisation option, based on advice about the best uses of available biomass across the economy, such as scenarios developed by the CCC.[49]

The HySeasIII Project in the Orkney Isles is an example of a developed project using energy from renewable sources to produce hydrogen to fuel passenger ferries. The renewable energy produced often exceeds existing demand, so the project provides a way of utilising the energy alongside a zero emission ferry journeys. Funded in part through the European Union Horizon 2020 programme, HySeas is now in its third stage of development and is now being linked to other trials of hydrogen in ferries such as the Innovate UK Hydime project also based in Orkney.[50]

Image 4: Ship design first look from the HySeasIII project

Next steps and questions

85. As part of developing the LCFs strategy, we will need to determine what different demand scenarios (see Chapter 2) will mean for supply, including the fuel types, conversion technologies and feedstocks required.

86. As a first step, we are therefore commissioning a comprehensive overview of potential feedstocks for LCFs supplied in the UK. This is to gain a better understanding of the range to which feedstocks will be sustainably available to

[49] Committee on Climate Change (2020), The Sixth Climate Budget, available at: https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf
[50] 50 HySeas (2022), The Project, available at: https://www.hyseas3.eu/the-project/

the UK, including the particular risks and opportunities associated with different feedstocks. Where possible, this research will also include information on production pathways those feedstocks could be used for and associated emission savings. We will seek to combine this research with the demand scenarios referred to in Chapter 2 to gain insights into how different demand scenarios may influence which feedstocks and type of fuels would be more likely required.

87. This workstream will be closely coordinated with work undertaken as part of the Biomass Strategy development to identify the role of biomass in achieving net zero, in line with the priority use principles outlined in the recently published Biomass Policy Statement (see Figure 13 in Chapter 6), and compare different production pathways in terms of their contribution to net zero targets.

88. To support the strategy development in this area, we would invite views and ideas on the following questions:

viii. Does this chapter capture key trends, opportunities, and risks in terms of low carbon fuels supply? If no, please expand on any aspects that you think are missing or require further exploration.

ix. In your view, what are the key challenges and opportunities as relates to supply in the future transition of the sector?

x. Are there any other actions the government should consider as part of the strategy development to address uncertainties and identify opportunities on the supply side?

xi. Are there particular actions the government should prioritise as part of the strategy development?

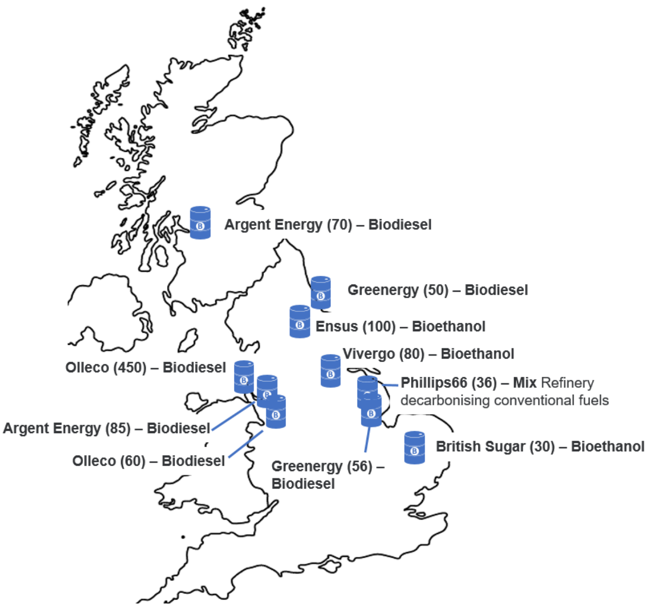
xii. Do you have any views on how to best capture interdependencies with the global supply chain?

4. The UK low carbon fuel industry

UK low carbon fuels industry today

89. LCFs are often the product of global supply chains, with both feedstocks and finished fuels traded across borders. Against this backdrop, the UK has established domestic production capacities which can offer significant opportunities in terms of growth in green technologies and jobs, particularly in areas in need of regeneration.

90. The LCFs industry encompasses a range of different market participants, including producers of the different fuels (e.g. liquid and gaseous biofuels, renewable hydrogen). Their supply chain may extend to agricultural production, the collection of waste, as well as fuel suppliers that blend LCFs with fossil fuels and arrange for distribution. The wider sector also includes services such as sustainability certification, research and innovation, and consultancy services.



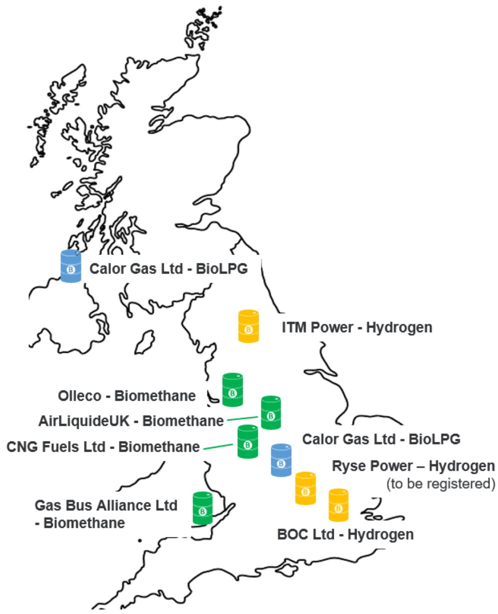


Figure 9: Overview of main UK low carbon fuel production sites (Source: RTFA, DfT)

91. There are currently three bioethanol production plants in the UK. The two biggest, operated by Ensus UK and Vivergo Fuels Limited are located in North East England and Yorkshire. They have a production capacity of around 410 – 420 million litres of fuel per annum using (feed) wheat as the primary feedstock.[51] The final producer, British Sugar plc, can produce up to 80 million litres of bioethanol per annum as a co-product of refining sugar beet at its largest refinery in Wissington, Norfolk.[52] In recent years, some production facilities were mothballed or operated at reduced capacity due to lower bioethanol demand than originally expected. However, following the introduction of E10 petrol, manufacturers are now planning to increase the output of their operations. At full capacity, these three plants can support a total of 6,000 UK jobs and produce 900 million litres of sustainable bioethanol.[53]

92. There are three significant biodiesel producers in the UK. Greenergy operates two production facilities in Teesside and North East Lincolnshire which respectively can produce 250 million and 220 million litres of biodiesel per annum from used cooking oil (UCO). Argent Energy operates two production facilities with a combined capacity of 150 million litres per year. The facility in Motherwell, Scotland, utilises UCO and the second facility in Cheshire utilises a range of waste feedstocks such as tallow and sewer grease. Finally, Olleco operates a facility in Liverpool with a production capacity of 40 million litres of biodiesel from UCO per annum.[54] This combined production capacity of 660 million litres would represent approximately 39% of the 1.7 billion litres of biodiesel verified under the RTFO in the UK in 2019.[55]

93. Owing to a range of production technoques, biomethane produced through anaerobic digestion allows for different sizes of manufacturer, from industrial scale producers through to smaller units on individual farms. Consequently, there were over 600 operational anaerobic digestion plants in the UK as of March 2021, with around 90 producing biomethane which is injected directly into the national gas grid. The use of biomethane as a renewable transport fuel is currently limited by the number of gas vehicles. Additionally, competition from other sectors could place constraints on the availability of biomethane supplies.[56]

94. Green hydrogen produced from electrolysis is the only form of hydrogen currently eligible for RTFCs. Hydrogen production processes are both energy and carbon intensive, meaning either renewable/low carbon energy or carbon capture

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[51] House of Comons Library (2019), The future of the British Bioethanol industry, available at: https://researchbriefings.files.parliament.uk/documents/CDP-2019-0004/CDP-2019-0004.pdf

[52] British Sugar (2018), A Homegrown Success Story, available at: https://www.britishsugar.co.uk/perch/resources/17503-socio-economic-report-brochuredigital-002.pdf

[53] Based on 2020 industry data provided by the RTFA to DfT

[54] Based on 2020 industry data provided by the RTFA to DfT

[55] See also DfT (2020), Renewable fuel statistics 2019: Final Report, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/932933/renewable-fuel-statistics-2019-final-report.pdf

[56] DEFRA (2021), Area of crops grown for bioenergy in England and the UK: 2008-2020, available at: https://www.gov.uk/government/statistics/area-of-crops-grown-for-bioenergy-in-england-and-the-uk-2008-2020

storage (CCS), are required to achieve genuine lifecycle GHG reductions. Current UK hydrogen production facilities are concentrated in refineries and chemical production facilities without CCS. However, there are efforts to establish low carbon hydrogen production facilities utilising CCS and the projects are at various stages of development. For example, SSE Thermal and Equinor have submitted a planning application to construct a 1,200MW carbon capture power station in Lincolnshire that would encompass one of the world's largest hydrogen production facilities.[57] Similarly, BP have announced plans to construct a 60MW electrolytic hydrogen production facility in Teesside by 2025 which could scale up to 500MW by 2030.[58]

95. Blending LCFs into fossil fuels and using existing distribution infrastructure is a more cost-effective way of bringing these fuels to markets and consumers than constructing parallel infrastructure. Consequently, many LCF production facilities are already located on fossil fuel refinery sites, with other market participants exploring how co-processing technologies can be used to reduce their carbon footprints and explore additional markets. The UK currently hosts six oil refineries and 651 miles of pipeline for the transportation of crude oil.[59]

96. Much as the refining processes for fossil fuels yield more than one product, many of the processes used in the production of LCFs also deliver valuable by-products, linking businesses and production facilities to other markets. Ethanol production processes can result in co-products such as high protein animal feed andstored CO_2, provided the production plant is suitably equipped. Similarly, biomethane produced from anaerobic digestion results in residual undigested biomass that has a variety of applications such as livestock bedding, or as an additional fuel source if pelletised. The most noteworthy by-products of biodiesel production are glycerol and methanol which can in turn be used as fuels also.

Future opportunities and challenges

97. Between now and 2050 there will be significant changes to where LCFs will be utilised across the transport sector and the wider economy. As a result, domestic industry in terms of current infrastructure, supply chains and future investments will be impacted. Business models of existing industry players may change and there will also be new market entrants. While these structural changes come with some uncertainties and challenges, they also offer substantial opportunities in terms of jobs, green growth and reducing GHG emissions. For example, a

[57] Planning Inspectorate (2021), Keadby 3 Low Carbon Gas Power Station Development Consent Order Application, available at: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010114/EN010114-000221-K3%20-%20Document%201.1%20-%20Application%20Cover%20Letter.pdf

[58] BP (2021), 'BP plans major green hydrogen project in Teesside' (press release), available at: https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-plans-major-green-hydrogen-project-in-teesside.html

[59] BEIS (2019), Digest of United Kingdom Energy Statistics 2019, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/840015/DUKES_2019_MASTER_COPY.pdf

feasibility study commissioned by the Department for Transport for the Future Fuels for Freight and Flight Competition (F4C) foundthat up to 21 new advanced commercial fuel plants could be established in the UK by 2030, with a gross value added of up to £400 million.[60]

98. A similar study on sustainable aviation fuels has highlighted that the development of a sustainable aviation fuels industry in the UK could support between 4,900 and 11,500 UK jobs, of which up to 5,100 jobs would be associated with domestic SAF production.[61]

99. Building on existing industries and expanding the domestic LCFs sector to include types of fuels and uses offers clear benefits, however these changes will require sizeable investments.

100. As the demand for fossil fuels diminish, investments in existing fossil fuel distribution and refuelling infrastructure may no longer be maintained in the same way. This raises questions of how far existing infrastructure can be adapted or repurposed and who will make these investments.

101. Many of the technologies and underpinning supply chains involved in low carbon fuel production are novel or used in volumes not previously supplied, so scaling up will be another challenge. As we move to net zero, it will also be necessary to build flexibility into systems and business models to help manage uncertainties; e.g. new installations may want to avoid being locked in to using a single feedstock or category of feedstock.

Questions and next steps

102. Changes in demand and supply patterns will offer both challenges and opportunities for domestic production. As part of the strategy development, we plan to work further with stakeholders to understand what adaptations to production sites and distribution infrastructure may be required in the future. This also includes how to make the best use of the existing infrastructure and whether any additional policy interventions are required in the transition (see also Chapter 5). This includes measures to provide more certainty as to the industry's trajectory to help encourage investments.

103. The scenarios referred to in the previous chapters will provide a useful framework for further discussions. However, we would welcome any views and ideas for further actions that could be taken in advance of the scenarios becoming available, including research.

[60] E4tech (2017), Future Fuels for Flight and Freight Competition – Feasibility Study, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/637662/dft_f4c-feasibility_final_report.pdf

[61] E4Tech (2020), Targeted Aviation Advanced Biofuels Demonstration Competition – Feasibility Study, available at: https://www.e4tech.com/uploads/files/final-report-aviation-abdc-feasibility-study-issue-v1-0.pdf

104. To support work in this area, we would like to invite responses to the following questions:

xiii. Does this chapter capture key trends, opportunities, and risks in terms of UK industry? If no, please expand on any aspects that you think are missing or require further exploration.

xiv. In your view, what are the key challenges and opportunities for the UK industry in the lead up to 2050?

xv. What are key actions the government should consider as part of the strategy development to address uncertainties and identify opportunities for UK industry?

xvi. Are there any production pathways or adaptations to production pathways and infrastructure that are most likely to benefit the UK economy?

xvii. If applicable, how does your organisation plan to adapt to the expected changes in low carbon fuel demand and supply?

5. The policy framework

The policy framework today

105. The main support mechanism for LCFs in the UK is the Renewable Transport Fuel Obligation (RTFO), a certificate trading scheme, which helps create a market for renewable fuels. In addition, demonstration competitions for advanced fuels have been supporting the commercialisation of new technologies and development of production plants in the UK. Measures such as fuel duty incentives (for biomethane), fuel standards and labelling, introduction of E10 petrol, and additional GHG reduction targets have also supported the market for LCF.

The Renewable Transport Fuel Obligation

106. The RTFO has been in place since 2008 and obligates fuel suppliers to supply a certain share of renewable fuels on a volume basis. Targets under the RTFO are set to rise from 11.9% in 2022 to 17.4% in 2032 and will remain at that level beyond that date. To demonstrate compliance with the requirement, fuel suppliers need to submit for each obligation year an amount of Renewable Transport Fuel Certificates (RTFCs) equivalent to their obligation. RTFCs are tradeable and they can be obtained by producing renewable fuel, purchasing renewable fuel together with a certificate or just purchasing the certificate. Fuel suppliers also have the opportunity to buy out of their obligation at a set price (e.g. should insufficient certificates be available at viable costs on the market).

107. The RTFO supports a market for renewable fuels. This encompasses biofuels and RFNBOs used in road vehicles and NRMM (which also includes rail and inland shipping). Since 2018, renewable fuels used in aviation can also receive support and recent amendments extend the RTFO’s scope further to RFNBOs used in maritime. DfT recently consulted on whether to expand the scope of the scheme to include recycled carbon fuels, i.e. fuels produced from fossil wastes.

108. To ensure the RTFO supports LCFs with the highest possible savings and promotes sustainable feedstocks and fuels of strategic importance, various additional incentives and safeguards have been built into the RTFO over the years.

109. In 2011, the RTFO was amended to include sustainability criteria that all fuels supported under the scheme need to comply with. These include land criteria that ensure feedstocks, in particular those for biofuels, are not grown in areas subject to environmental protections, including forests and peatland. Fuels also need to meet a minimum GHG savings threshold, which has been increased over time. The criteria ensure that all fuels supported deliver genuine GHG savings compared to fossil fuels and minimise the risk that the production of feedstocks leads – directly or indirectly – to land use change, such as deforestation, which would significantly undermine the fuel's contribution to reducing carbon emissions.

110. To prove compliance with sustainability criteria to UK regulators, the vast majority of fuel suppliers use recognised international voluntary schemes. Waste-derived biofuels, which generally achieve higher GHG savings receive double the reward compared to crop-based biofuels, which carry a higher risk of competition with food and feed production that could lead to land use change. Feedstocks need to undergo an assessment to ensure they are genuine wastes and that there are no other economic uses for the feedstocks (including reuse and recycling) in line with the waste hierarchy. More recent changes such as extending the land criteria to protect more habitats and introducing specific criteria for forest biomass also strengthen the existing sustainability criteria.

111. Since 2018, the RTFO includes a decreasing cap on crop-based biofuels and a specific sub-target for so-called development fuels, i.e. novel fuels of strategic importance, including renewable hydrogen and aviation fuels. Figure 10 gives an overview of the RTFO targets, including the development fuels target and crop cap.

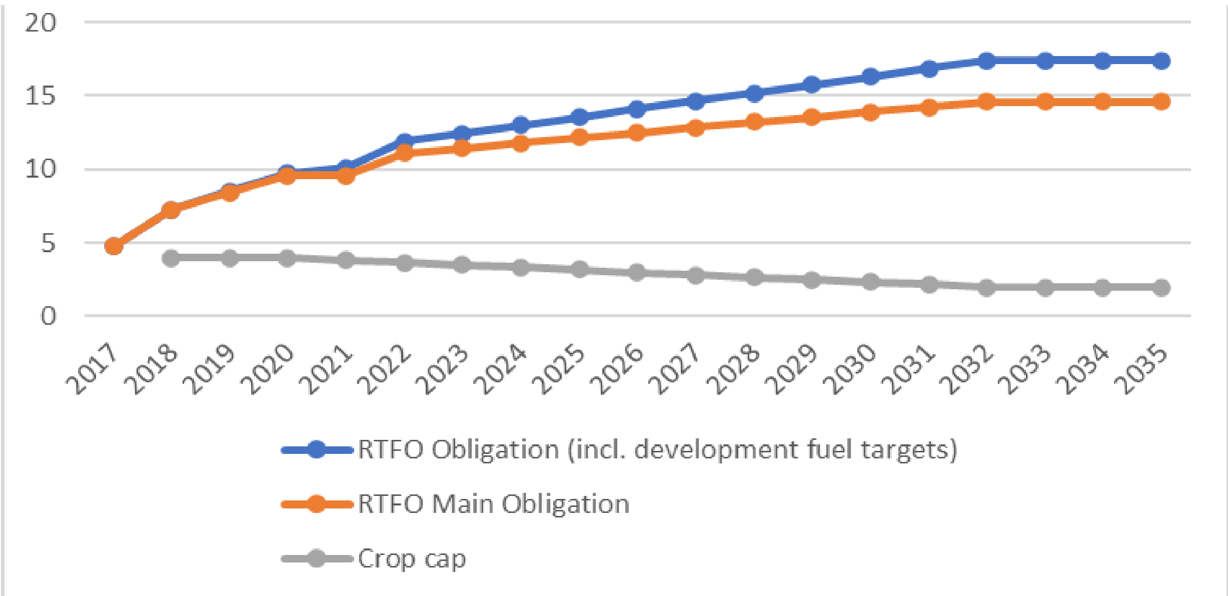

Figure 10: Obligation levels and the crop cap under the Renewable Transport Fuel Obligation (RTFO) to 2035

112. Detailed data on the fuels supplied under the RTFO are published on a quarterly basis, including GHG emission savings of the fuels supplied. GHG emissions

savings under the RTFO are calculated on the basis of a lifecycle approach, taking all the emissions from the production of the original feedstock of the fuel into account and comparing it with the standard emissions associated with fossil fuels. The approach differs to the simplified one used in UK carbon budget accounting, which generally considers emissions associated with biofuels as zero.The RTFO approach allows a clearer distinction between different fuels based on their GHG performance. Data under the RTFO include indirect land use change (ILUC) factors. These help highlight risks associated with the use of food and feed crops in biofuel production which could lead to increased demand for land, an effect that is observable but difficult to measure in individual cases and therefore not included in standard emission accounting.

Advanced fuel competitions

113. The commercialisation of new technologies to produce advanced fuels and the development of demonstration plants in the UK has been supported by three funding competitions.

- **Advanced Biofuel Demonstration Competition (ABDC**): Launched in 2014, the ABDC was designed to demonstrate the viability of a UK advanced biofuel industry and contribute to the de-risking of investment in future projects. The ABDC successfully led to the construction of two advanced LCFs plants: Nova Pangaea Technologies in Teesside (awarded £4.5 million for ethanol production) and Advanced Biofuels Solutions in Swindon (£11 million in grants for a synthetic natural gas plant).

- **The Future Fuels for Flight and Freight Competition (F4C):** The F4C was launched in 2017 and makes up to £20 million of capital funding available to projects for the production of low carbon waste-derived fuels to be used in aeroplanes and lorries. The objective of the F4C is to stimulate UK development and deployment of advanced, sustainable low carbon aviation and HGV fuels to help realise our long-term decarbonisation obligations, deliver economic benefits, and position the UK at forefront of the global advanced low carbon fuel industry.[63]

- **The Green Fuels, Green Skies Competition (GFGS):** The GFGS is providing up to £15 million in grant funding to UK SAF projects during the 2021/22 financial year. The competition aims to enable the SAF sector to deploy new technologies at a commercial scale that can reduce aviation emissions in the near-term and to try and help de-risk the future scale-up of projects. All projects were selected based on their potential to produce SAF capable of reducing emissions by more than 70% on a lifecycle basis when compared with conventional jet fuel.[64]

114. As announced in the Net Zero Strategy, there will be a new multi-year competition to continue accelerating the UKs commercialisation of SAF.Building upon the progress made during the ABDC, F4C and GFGS, the new £168m competition will provide capital funding to advance the construction of first-of-a-kind (FOAK) plants capable of producing SAF, in addition to supporting the emergence of new technologies. A further £12m has been allocated for the

continuation of the SAF clearing house project to accelerate bringing new SAF to the market.

Measures to promote sustainable aviation fuels

115. To generate demand for SAF, the government has proposed a SAF mandate to provide an incentive to SAF producers andsignal to investors the vital role that government believes the technology will play in the UK. A 2021 consultation proposed requirements for SAF to adhere to strict sustainability criteria such as preventing the loss of biodiversity, deforestation, and the clearance of land with high carbon stock (e.g. dry peatland) that could be associated with the cultivation of raw materials used in certain SAF production.[62]

116. The consultation also proposed that only waste-derived biofuels, RFNBOs, SAF from nuclear origin and recycled carbon fuels can contribute towards the SAF mandate obligation, as these fuels can deliver high carbon savings and do not typically present significant direct or indirect land use or wider environmental impacts. It is not envisaged that crop-derived biofuels will be permitted.

Other measures to promote low carbon fuels in transport

117. Before the RTFO was introduced in 2008, biofuels were mainly supported through reductions in fuel duties. While these have been mainly replaced by the RTFO, a duty incentive is in place for natural gas, which – in conjunction with the RTFO – supports the deployment of biomethane in the transport sector.

118. The deployment of LCFs has also been supported through the development of industry fuel standards. These standards provide reassurance that blends of fossil fuels and biofuels can be safely used in vehicles and equipment, as well as labelling requirementson fuel pumps and vehicles to make it easier for motorists to identify relevant fuels.[63]

119. In the Transport Decarbonisation Plan, thegovernment also committed to explore potential additional measures to help overcome market barriers for fuel blends with a higher than average biocontent in compatible vehicles. In contrast to E10, these may not be compatible with a majority of vehicles, so measures may need to be more focussed on sections of the fleet, such as heavy duty vehicles, that are likely to require liquid fuels for a longer period for additional investments in regards to infrastructure to pay off.

120. Between 2018 and 2020, a GHG reduction scheme also ran in parallel to the RTFO to implement an EU target of reducing the carbon intensity of fuels by 6%,

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[62] For more information see DfT (2021), Sustainable aviation fuels mandate. A consultation on reducing the greenhouse gas emissions of aviation fuels in the UK, available at: https://www.gov.uk/government/consultations/mandating-the-use-of-sustainable-aviation-fuels-in-the-uk

[63] For more information see also the Alternative Fuel Labelling and Greenhouse Gas Emissions (Miscellaneous Amendments) Regulations 2019, available at The Alternative Fuel Labelling and Greenhouse Gas Emissions (Miscellaneous Amendments) Regulations 2019 (legislation.gov.uk) and guidance published by the Office for Product Safety and Standards (2020): Regulations: Alternative fuel labelling, available at: https://www.gov.uk/guidance/regulations-alternative-fuel-labelling

awarding tradeable credits for the use of renewable fuels and other alternatives to standard fossil fuels. The mechanism was discontinued after 2020, though reporting on the carbon intensity remains in place.

Future opportunities and challenges

121. Over the last fourteen years, the RTFO has proven to be successful in creating a market for LCFs in a cost-effective manner. It stimulates demand for these fuels by setting targets and compensating for the higher costs of these fuels through a market-based scheme. The application of strict sustainability criteria and the promotion of waste-derived and advanced renewable fuels have also ensured that fuels supported deliver genuine GHG savings. In addition, demonstration competitions for advanced fuels have helped establish new production sites in the UK.

122. As highlighted in earlier chapters, the sector is expected to go through significant changes in the period to 2050 and the regulatory framework will need to adapt. Currently, increasing targets under the RTFO are set to 2032 but suppliers will remain obligated beyond this date as the RTFO has no end date in legislation (see Figure 10 above). In the absence of any further amendments the target will remain at the 2032 level in subsequent years. Its targets and its role – in combination with other mechanisms –will need to continue to be kept under review to ensure the regulatory regime remains fit for purpose in view of the changes and challenges set out in this chapter.

Maximising carbon savings and coordinating different policy interventions

123. Increases in RTFO targets and strengthening sustainability criteria have been to date the main mechanisms to achieve additional greenhouse gas savings from LCFs, raising the amount of sustainable, renewable fuels being deployed. However, as the demand for liquid and gaseous fuels in the road sector is expected to decline, increasing targets (and consequently the share of renewable fuels in total fuels supplied) may no longer be sufficient on its own to increase or even maintain current volumes of LCFs deployment.

124. Recent policy developments already highlight a trend towards additional measures parallel to the RTFO, targeted to address specific challenges related to transport mode, fuels or technology, such as the SAF mandate or the introduction of E10. Coordination of different policy interventions will be key in the future to ensure the measures complement each other rather than compete.

125. The idea of turning the RTFO from a scheme with volume-based renewable fuel targets to a scheme with GHG savings targets (as exist in California and Germany) has been raised by stakeholders over the years. Such a scheme would allow us to support GHG savings directly (rather than indirectly through rewarding volumes of fuels supplied). Stakeholders argue that this would incentivise the switch to lower carbon fuels and feedstocks and allow investments in more efficient processes. However, care is needed due to challenges of accounting for ILUC impacts in such schemes and differentiating between fuels, e.g. by setting additional incentives for waste-derived fuels. There is therefore a risk that a

switch could have unintended consequences and even risk market disruptions. As new evidence emerges and the wider regulatory framework evolves (see also below), further assessment of this option may become necessary again in the future.

126. Another approach could be to employ a hybrid system, with a GHG scheme running in parallel to the RTFO, as existed previously in the UK. The post implementation review of the RTFO beginning this year will also review the former GHG scheme, the scope of which extended beyond fuel, including an opt-in for electricity used in road vehicles.

Inclusion of new feedstocks, technologies and types of fuels

127. The development of new technologies, the need to achieve ever higher GHG savings across the economy (potentially leading also to competition for the same feedstocks and fuels by different sectors) and changes in demand (see Chapter 2) continually drive innovation and further diversification of feedstocks and fuels. Although the RTFO was originally created to support renewable fuels, we have recently consulted on the potential expansion of the RTFO's scope to include recycled carbon fuels. In the case of a SAF mandate, eligibility for fuels from nuclear electricity is also being considered. Any such changes to policy come with their own challenges, ranging from procedural, such as ensuring primary powers are in place to allow for necessary legislative changes, to technical questions on how to assess GHG savings compared to fossil fuels. Sustainability criteria and GHG accounting methodologies must also be fit for purpose, as they may need to be adapted to these new feedstocks and fuel types. Furthermore, interactions with other support schemes needs to be considered.

128. In the medium- to long-term, fuel production will also need to be combined with carbon capture and storage, where possible, to ensure the fuels deliver the highest possible greenhouse gas savings and to help reach the UK's net zero targets. How to incentivise the use of these technologies and account for them in the system will also pose a challenge to future policy design. Low carbon fuel plants using gasification or pyrolysis for the conversion of wastes may be eligible to apply for support under the Industrial CCS business model support, as part of Phase 2 of the CCUS Cluster Sequencing Process, subject to meeting the specific eligibility criteria.[64]

Promoting the use of low carbon fuels in different transport modes

129. A consultation on a separate mandate for SAF was carried out in 2021, setting out the challenges of SAF deployment.[65] Despite the potential that SAF offers in terms of GHG savings, and support offered under the RTFO and the advanced

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[64] For more information see BEIS (2021), Cluster Sequencing for Carbon Capture Usage and Storage Deployment: Phase-2, Background and Guidance for Submissions, available at:https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1031856/ccus-phase-2-guidance.pdf.

[65] DfT (2021), Sustainable aviation fuels mandate. A consultation on reducing the greenhouse gas emissions of aviation fuels in the UK, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005382/sustainable-aviation-fuels-mandate-consultation-on-reducing-the-greenhouse-gas-emissions-of-aviation-fuels-in-the-uk.pdf

fuel competitions, its production in the UK is still very limited. This is due to high capital costs for first-of-a-kind production plants, which impacts on the costs for the fuel as well as technology, and supply chain risks that disincentivise investments. A SAF-specific mandate in turn can generate demand, incentivise production and provide a signal to investors. Its design however needs to carefully consider specific targets, obligated parties, fuel eligibility, compliance, how to scale up new technologies and interactions with other policies.

Infrastructure and other market barriers

130. Support mechanisms like the RTFO or the SAF mandate are designed to create demand for and stimulate supply of LCFs. However, the incentives they provide may not be sufficient to also drive changes to vehicles and infrastructure,[66] particularly modes such as freight or aviation. Additional interventions beyond mandates may therefore be necessary to encourage investments in this area. For example, DfT has commissioned research on the infrastructure requirements at airports of hydrogen and electric aircraft through £3m of funding.[67] Apart from financial support (e.g. competitions or grants), such interventions may also relate to the permitting regime or industry standards.

131. When it comes to infrastructure, a particular challenge for regulatory intervention is the fact that production plants may deliver more than one product and not all of these may go into the transport sector. Equally, the infrastructure may not only be used for LCFs but also for fossil fuels or any other alternative fuels. This may require additional coordination and collaboration across policy areas and involve e.g. local authorities and devolved administrations, with responsibility for the planning regime.

Encouraging new investments

132. While market-based systems like the RTFO ensure targets are delivered as cost-efficiently as possible, prices for certificates naturally fluctuate. This can be a particular challenge for attracting investments in new technologies and production plants as it adds to uncertainty as to investment returns. For this reason, to guarantee a minimum price for the fuel produced, stakeholders have suggested in the past amendments such as a floor price, in particular for development fuels, or a contract for difference (CfD) for SAF. However, a straightforward price floor may not drive investment in UK production, as such a price floor would also apply to imported fuels. In the case of CfD, the competitive tendering process could be challenging in a SAF industry with a limited number of prospective market entrants and careful consideration is needed in calculating strike prices. The UK government remains keen to support the development of a domestic industry, and will continue looking at these issues carefully.

[66] The term infrastructure in this context may relate to fuel production site and distribution networks, including pipelines, tankers or refilling stations.

[67] DfT (2021), 'Jet Zero Council keeps up momentum with £3 million government funding for zero emission flight infrastructure as UK pioneers first-ever net zero carbon freighter flights' (press release), available at: https://www.gov.uk/government/news/jet-zero-council-keeps-up-momentum-with-3-million-government-funding-for-zero-emission-flight-infrastructure-as-uk-pioneers-first-ever-net-zero-carbo

Changes to the wider regulatory framework and harmonisation with other schemes

133. Policies to promote LCFs also interact with wider decarbonisation policies, which are expanding and evolving as we move to net zero, consequently regulatory regimes for LCFs will need to adapt. Mechanisms like carbon taxation and emissions trading promote GHG savings across different sectors – and should any such mechanism apply to LCFs used in transport in the future, this will significantly impact on the dynamics of existing support mechanisms. Similarly, any changes to regulatory regimes like fuel duty may have wider implications.

134. It is also important to bear in mind potential competition with other sectoral mechanisms and support schemes. For example, eligibility criteria (including sustainability criteria) for biomass currently differ under the different support schemes in place for heat, electricity and transport in the UK – and some industrial applications may not rely on support schemes that require its use to be subject to sustainability criteria. The government's Biomass Strategy will assess the existing sustainability criteria and how these may be improved to address any gaps. The strategy will also set out a priority use framework to identify the role of biomass across the economy in achieving net zero, while meeting wider environmental targets. Similar challenges may also apply to other feedstocks and inputs, and the regulatory regime needs to take this into consideration to such interactions.

135. A particular challenge also relates to GHG accounting. As highlighted earlier, to allow for differentiation between different fuels, the RTFO currently uses a life-cycle approach comparing the LCFs' GHG emission performance against the one of fossil fuels. The RTFO also takes ILUC impacts into consideration as part of its policy design and by publishing carbon savings including ILUC impacts. Any comparison across sectors, however, may rely on a simplified approach and will require careful handling.

Interactions with international level and local and regional approaches

136. Supply chains for LCFs tend to be international, as both feedstocks and fuels may cross several borders. To ensure that the fuels deliver genuine GHG savings, fuels supported in the UK need to comply with strict sustainability criteria. Similar criteria may be in place across Europe but are not the standard globally. The sustainability characteristics of different feedstocks therefore need to be traced across borders. This is done with the help of international voluntary standards.

137. However, there remain challenges to tracing sustainability across borders, given the complexity of the supply chains involved. Differences in regulatory environments and environmental standards may determine whether a certain feedstock can be considered a waste – or could be used e.g. in other products or as animal feed. For logistical reasons alone, compliance checks will be more difficult in some regions than others. Where these challenges can be addressed through the voluntary schemes, we will continue to work with international voluntary schemes to keep improving the system.

138. Challenges may also arise should the UK deviate from existing sustainability standards by imposing stricter requirements than elsewhere. In these cases, the assurance provided through third parties such as voluntary schemes may be diminished and additional information may be required from industry to ensure compliance with UK standards.

139. To promote GHG savings and create a level playing field, it is also in the UK's interest to engage in international initiatives to harmonise standards where possible. Approaches to supporting LCFs may differ significantly across countries, depending e.g. to what degree they are considered a transport decarbonisation measure or a boost to domestic agricultural production and industry. This may influence what specific incentives and subsidies are in place, including what type of fuels are supported and the particular value awarded to their GHG saving characteristics, and may make agreement on common global standards difficult. As LCFs are often more expensive than traditional fossil fuels, the market for them is heavily influenced by such regulatory intervention. Tariffs and trade remedies (in combination also with environmental regulations) can be some of the tools to even out the playing field but cannot address underlying issues in the same way as common standards. Regional collaboration and sectoral agreements may provide another way forward where no global standards are in place.

140. International initiatives are especially relevant for aviation and shipping. Consequently, stricter environmental requirements in one country may impact on refuelling location choices, making minimum requirements even more relevant. Both under the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO) there is ongoing work to coordinate decarbonisation efforts across jurisdictions, and in the case of ICAO to establish minimum sustainability standards for low carbon aviation fuels.[68] Future policy development will need to consider interactions with such initiatives, which can offer substantial benefits, while also making sure that the UK's high-level protections are maintained and promoted.

141. Within the UK, interactions with subnational policies and strategies may also need to be considered. While fuels policy tends to be reserved matter, there are important interactions with decisions that are taken at local or devolved level (relating e.g. to planning decisions, waste policy etc.).

Next steps and key questions

142. As we develop deployment scenarios and assess opportunities and risks for the low carbon fuel industry, we will also use the development of the strategy to assess potential gaps in our policy framework in so far there is not already

[68] See ICAO (2021), CORSIA Sustainability Criteria for CORSIA Eligible Fuels, available at: https://www.icao.int/environmental-protection/CORSIA/Documents/ICAO%20document%2005%20-%20Sustainability%20Criteria%20-%20November%202021.pdf

ongoing policy work (e.g. on the SAF mandate or the post implementation review of the RTFO in 2023, which will look again at development fuel targets).

143. To support this workstream we would like to invite views and ideas on:

xviii. Does this chapter capture key trends, opportunities, and risks in terms of policy framework? If no, please expand on any aspects that you think are missing or require further exploration.

xix. In your view, how should the government best deliver its aims of using LCFs to maximise environmental and economic benefits and are there specific measures the government should take to support the sector's transition?

xx. In view of the different challenges and opportunities, are there specific policy measures the government should prioritise and why?

xxi. Are there any key actions the government should consider as part of the strategy development to identify policy gaps and opportunities?

6. Low carbon fuels in the wider context

144. LCFs can be produced from a wide range of raw materials via different processing technologies for different uses, while also competing with alternative decarbonisation options. This means that the production and use of LCFs in transport is influenced by developments in different markets, policies and technology. Previous chapters highlighted some of these interactions, which can also contribute to uncertainties in the sector. On the supply side, markets for different agricultural products and waste may determine what feedstocks are available at what prices in any given period; and available processing technologies will further determine what type of fuels can be produced cost-effectively in comparison with other decarbonisation options. On the demand side, the infrastructure and vehicles in place will be determinant.

145. This chapter therefore looks in more detail at wider factors and developments impacting on LCF demand and supply, highlighting some of the complexities that need to be considered when developing the LCFs strategy.

Availability of sustainable resources including biomass

146. Given the main objective of supporting LCFs is to achieve carbon savings, sustainability is essential. If the use of biomass for biofuels production results directly or indirectly in the destruction of carbon sinks such as forests or biodiverse lands, any positive impacts compared to fossil fuels are effectively negated. Similarly, if support for LCFs diverts valuable resources (including electricity) from other uses which could have achieved higher overall carbon savings, this undermines the basic rationale for supporting LCFs.

147. What resources may be available sustainably now and in the future is difficult to determine precisely, given the wide range of potential resources and links between the LCF and other markets. Looking at historic data on feedstocks for biofuels supported under the RTFO, the respective share of different feedstocks has been changing annually (see Figure 11).

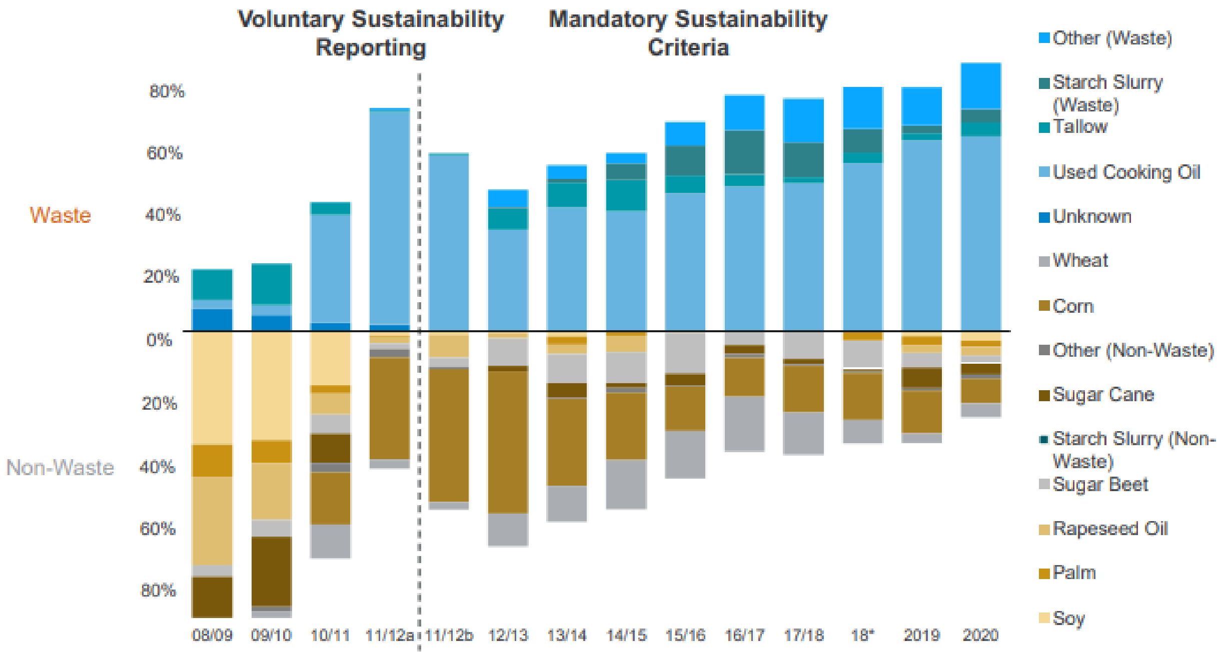


Figure 11: Supply of renewable fuel to the UK by feedstock, 2008/09 to 2020 (Source: Renewable Fuel Statistics 2020).

Feedstocks and finished products are traded on international markets, with countries and regions of origin being subject to significant variations each year (see Figure 12).

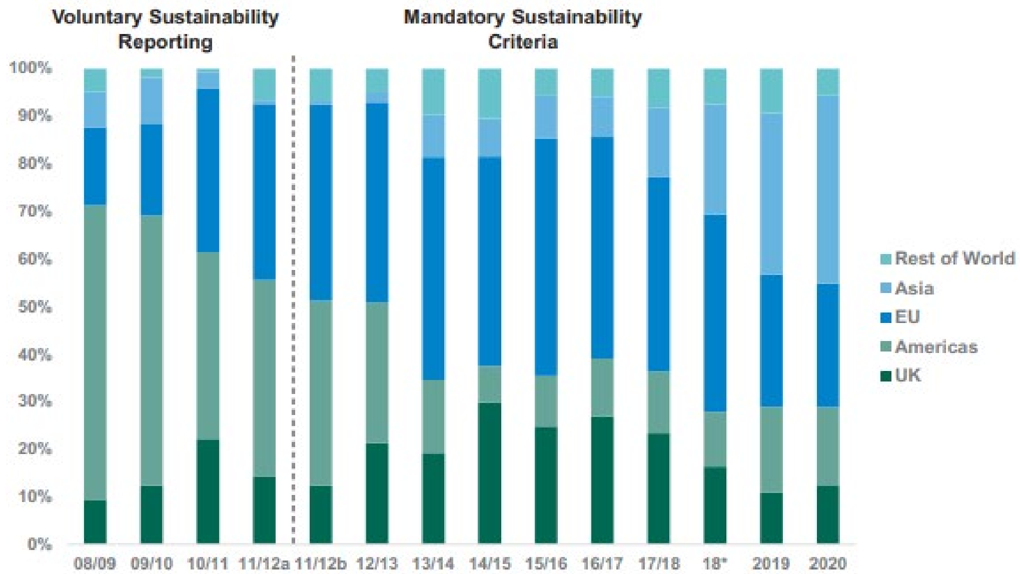


Figure 12: Proportion of renewable fuel supplied to the UK by region, 2008/09 to 2020 (Source: Renewable Fuel Statistics 2020)

case of a residue or waste, the original product) may also influence business decisions and market prices.

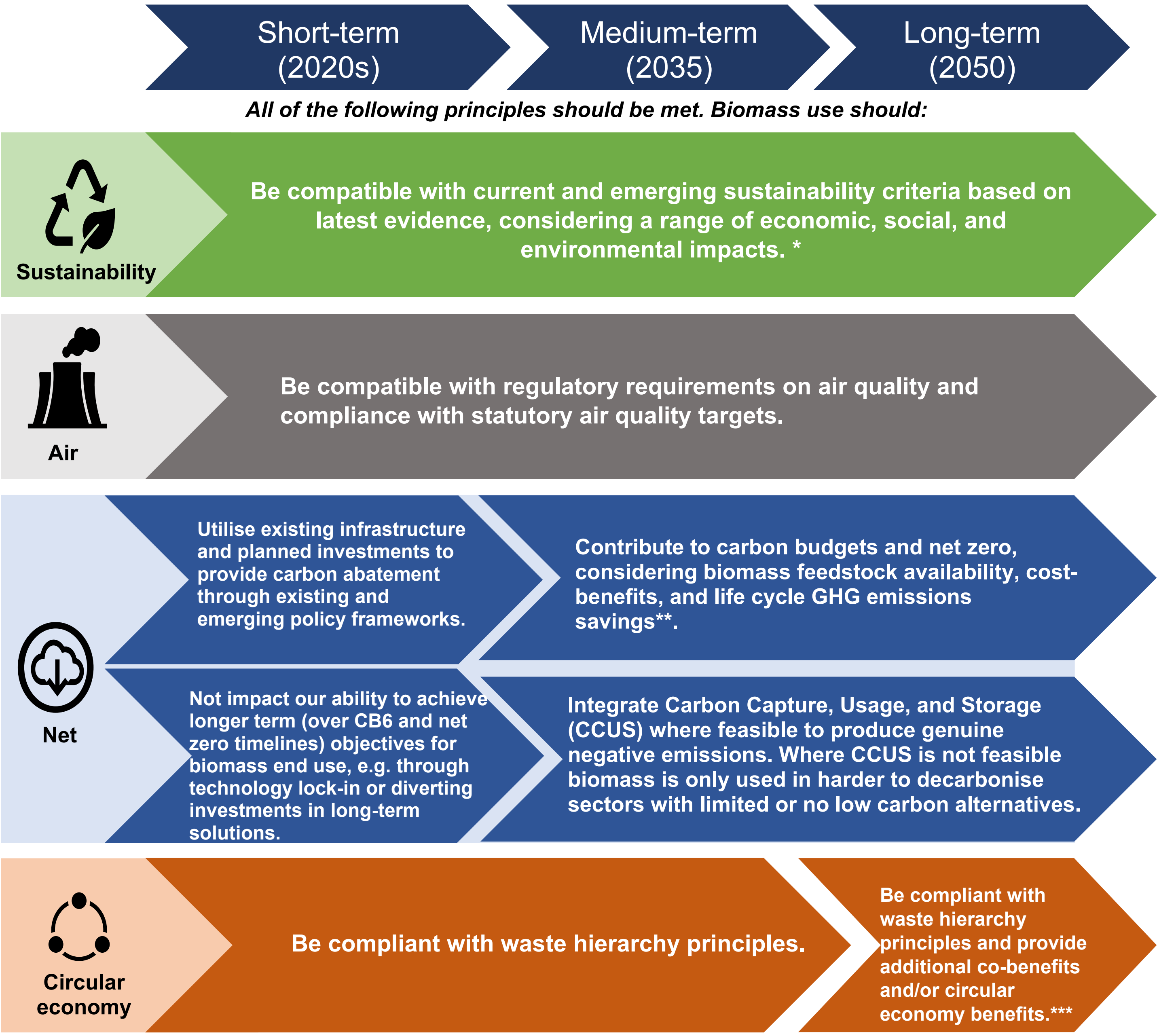
149. In a 2020 report, the Supergen Bioenergy Hub reviewed various biomass availability models for the Department for Transport.[69] The report outlined that estimates for biomass availability and demand by 2050 can vary quite significantly across different models. While at a global level these estimates range between 80,500 petajoule (PJ) and 261,000 PJ, at UK level they range between 606 PJ (close to current levels) and 3243 PJ. In part, this reflects differences in biomass definition and scope, but it also highlights that the specific purpose of each model and the assumptions it makes need to be carefully considered.

150. While it may be difficult to quantify available resources, understanding potential availability is important both for setting the regulatory framework and making investment decisions. Policies to promote LCFs need not to involuntarily distort other, existing markets and steer resources away from alternative uses that could provide even higher GHG savings. In practice, this often leads to incremental changes that allow for evaluation of the impacts before further measures are taken. However, this has the potential disadvantage of not providing investors with long-term certainty.

151. Even if the total amount of available feedstocks were to be reliably determined, there would still remain questions as to what share of any feedstocks can be considered sustainable and what might be a 'fair share' both for the UK but also for specific sectors, taking into account where this resource could make the most cost-effective contribution to GHG savings and wider environmental targets. The government's 'Biomass Policy Statement' set out overarching priority use principles for the use of biomass across the economy in the short- (2020s), medium- (to 2035) and long-term (to 2050), which are to be further developed as part of the Biomass Strategy due to be published in 2022 (see Figure 13 below).[70] This strategy will set out a priority use framework and will provide an assessment of the decarbonisation potential of biomass use in various sectors of the economy. The same questions equally apply to non-biomass feedstocks.

[69] Welfle, A., Holland, R.A., Donnison, I., Thornley, P. (2020), UK Biomass Availability Modelling Scoping Report. Supergen Bioenergy Hub Report No. 02/2020, available at: https://www.supergen-bioenergy.net/wp-content/uploads/2020/10/Supergen-Bioenergy-HubUK-Biomass-Availability-Modelling-Scoping-Report-Published-Final

[70] BEIS (2021), Biomass Policy Statement, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1031057/biomass-policy-statement.pdf



* Further work is being carried out to review the UK's existing sustainability criteria, including exploring ways to harmonise the criteria across sectors to promote fair competition. Details to follow in the Biomass Strategy.

** Compared to GHG emissions of appropriate counterfactuals.

*** e.g. by-products are used to make other high value products which can be utilised elsewhere in the economy.

Figure 13: Overarching priority use principles for biomass use over three timescales: 2020s, up to 2035 and to 2050 (Source: BEIS Biomass Policy Statement)

152. To help address some of the questions and uncertainties, we expect to commission further research into feedstocks that might be used over the coming decades to produce transport fuels.

Development and commercialisation of key technologies

153. Development and commercialisation of key technologies may also significantly impact on future demand and supply for LCFs. Their development and

commercialisation may allow for the collection and use of a wider range of feedstocks, impact on processing costs and accordingly the fuel's competitiveness, or enable higher greenhouse gas savings.

154. Most of these technologies have been referred to throughout this document. They can be broadly categorised as technologies that can be directly used to produce LCFs, enabling and competing technologies.

Technologies to produce low carbon fuels

155. Various emerging technologies will impact on LCF supply. These include technologies that enable the conversion of new feedstocks or the production of new type of fuels. This also relates to commercialising technologies that can produce sustainable aviation fuels (SAF).

156. The extent to which different technologies under development can be demonstrated, optimised, commercialised and ultimately compete with other technologies will influence demand for feedstocks and supply of different fuels.

157. We will continue to fund proof-of-concept LCFs innovation projects via the annual Transport Research and Innovation Grants (TRIG) scheme. TRIG competitions typically open each Autumn and offer innovators 100% funded grants of up to £30k to try out new transport technology ideas.[76]

Enabling technologies

158. There are also various technologies that may not be directly related to low carbon fuel production but which will influence their carbon savings. This includes technologies used to produce, collect or prepare feedstocks for processing, or waste management and segregation technologies (allowing e.g. easier access to biogenic waste). These may in turn influence supply (e.g. by expanding supply to new waste feedstocks or other resources such as algae), costs and emissions (e.g. by maximising process efficiency). It also covers the commercial development of carbon capture and storage technologies that will enable the delivery of higher carbon savings, or technology developments in other sectors.

159. Technologies to remove carbon provide the potential to make fuels emission-negative, supporting net zero transport by 2050. Carbon removal technologies can be broadly split into two categories. Some remove emissions from fuel production by capturing, using or storing CO2 that would have been otherwise emitted, including bioenergy with carbon capture and storage (BECCS). Direct air carbon capture and sequestration (DACCS) technologies capture atmospheric CO2 directly and can be integrated e.g. in power to liquid fuels production.

160. Wider technology developments may also influence what resources are available to LCFs production. For example, increasing electrification and decarbonisation of the grid could potentially increase the amount of biomass available to produce LCFs. At the same time, it could also reduce GHG emissions associated with production of LCFs, which can be energy intensive. Advances in the low carbon hydrogen production sector have the potential to reduce these lifecycle emissions

further, as many LCFs require hydrogen input to maximise the efficiency of the production process.

Competing technologies

161. As highlighted previously, the development, commercialisation and widespread deployment of technologies offering alternative decarbonisation pathways (e.g. electric vehicles or other uses of biomass) will also affect relative costs for LCFs.

Interactions with vehicle fleet and infrastructure developments

162. Demand and supply for LCFs are also shaped by the wider infrastructure and vehicle fleet in place, as highlighted in Chapters 2 and 3. Costs for adapting these need to be considered when looking at any future deployment as they may make the use of LCFs more or less cost-competitive compared to other low carbon solutions.

Vehicle fleet

163. For all transport modes, the mix of vehicles with an internal combustion engine, electric vehicles, fuel cell vehicles or any other technology (including gas vehicles) will impact on the demand for liquid and gaseous fuels.

164. Low carbon fuel deployment will also be influenced by the specific fuel blends the vehicle fleet is approved for, especially any limits to the biofuel content that vehicles can use, depending on fuel standards and the vehicle manufacturers' warranties. High shares of bioethanol replacing fossil petrol, as seen in Brazil, are only possible with car fleets containing high shares of flex-fuel vehicles – or if a substantial share of motorists would be willing to invest to adapt their vehicles.

Distribution infrastructure

165. Distribution and transport options for fuel (such as pipelines and tankers, filling stations and storage facilities as well as blending facilities) will also impact on deployment. They impact how many different fuels and grades of fuels can be offered widely to motorists or other fuel consumers. Current UK infrastructure for road fuels is optimised to provide two grades of petrol and diesel each (standard 'premium' and 'super') at public filling stations. Adding another fuel or blend comes therefore with significant costs, with consequences for fuel delivery, storage and refineries. In introducing petrol with up to 10% ethanol (E10), adding it as a third grade was judged cost-prohibitive and it was decided to make E10 the standard grade of petrol. For E10 this was possible given 95% of vehicles were approved for its use, which may not be the case for other options.

166. With any new fuel plants coming online (e.g. SAF production), distribution infrastructure will also need to be considered, including whether existing infrastructure can be used or new infrastructure might need to be built. Proximity and access to carbon capture and storage clusters will also need to be considered in the future.

167. With demand for petrol and diesel expected to fall for road vehicles, substantial investments in this infrastructure which is currently mainly used for fossil fuels might also be decreasingly profitable. However, this might also offer opportunities to rethink and adapt this infrastructure.

The impact of wider policies

168. Chapter 5 set out the regulatory framework for LCFs and the measures that may directly impact on the deployment of LCFs, outlining also some of the links to wider government policies.

169. For example, waste reduction, recycling and diversion from landfill policies will influence what wastes may be available as a feedstock for the LCF sector. The specific options that current and future policies (e.g. on electricity, heat, construction, chemical industry) choose to promote or discourage to decarbonise their sector will also have an impact on low carbon deployment. Measures to improve air quality and reduce CO2 and other emissions at the tailpipe will impact where and how LCFs may be used. Similarly, as set out in Chapter 5 the wider regulatory framework to decarbonise the economy as a whole is of relevance.

170. Further examples of how LCF policy overlap and interact with other government departments or with devolved administrations and local authorities include:

- **Climate policies**, including for example policies related to the UK carbon budgets, the net zero strategy or emission trading;
- **Energy policies**, covering renewable energy, biomass, security of supply or the decarbonisation of other energy sectors such as electricity and heat;
- **Industrial policies**, including R&D support, bioeconomy or CCUS;
- **Fiscal policies,** such as fuel duty, taxation;
- **Trade policies**, including trade agreements, trade remedies;
- **Transport decarbonisation** and **modal transport policies** for road, freight, rail, maritime, aviation;
- **Environmental policies**, covering also biodiversity or the environmental permitting regime;
- **Waste reduction, recycling and diversion from landfill policies;**
- **Agricultural policies;** and
- **Planning policies.**

171. Other regulation may also influence deployment of and investments into LCFs. These include, environmental and planning permits, industry standards, in particular fuel standards, or warranties offered by vehicle manufacturers for using fuels complying with specific standards.

172. As is the case in the domestic context, global climate, environmental or trade policies not necessarily directly connected to LCFs will also influence the markets for them.

Next steps and questions

173. We invite views and ideas on the following:

xxii. Does this chapter capture key interdependencies and interactions with other policy areas or markets? If no, please expand on any aspects that you think are missing or require further exploration.

xxiii. In your view, are there any specific actions government needs to take as part of the strategy development to address these interactions? If yes, what would those be?

7. What will happen next

The responses to this call for ideas will be taken into account when drafting the final strategy, which is to be published in late 2022. Paper copies will be available on request.

If you have questions about his call for ideas please contact LCFstrategy@dft.gov.uk

Annex A: Full list of questions

Chapter 1 – Introduction

i. How can the low carbon fuels strategy best improve certainty about the deployment of low carbon fuels to support the decarbonisation of the transport sector and the growth of this industry in the UK?

ii. Are there specific examples or best practices, the government should take into account when drafting the strategy?

Chapter 2 - Demand

iii. Does this chapter accurately capture key trends, opportunities and risks in terms of low carbon fuels demand? If no, please expand on any aspects that you think are missing or inaccurate, or require further exploration.

iv. In your view, what are the key challenges relating to demand in the future transition of the sector?

v. Apart from developing demand scenarios, are there any other actions the government should consider as part of the strategy development to address uncertainties and identify opportunities on the demand side?

vi. For the development of the demand scenarios, are there any key sources of information or data the government should consider?

vii. For the development of the demand scenarios, are there any specific aspects that government should consider (e.g. niche uses of low carbon fuels, competing demand from other sectors or technology development) and if so, do you have a view on how best to incorporate them?

Chapter 3 - Supply

viii. Does this chapter capture key trends, opportunities, and risks in terms of low carbon fuels supply? If no, please expand on any aspects that you think are missing or require further exploration.

ix. In your view, what are the key challenges and opportunities as relates to supply in the future transition of the sector?

x. Are there any other actions the government should consider as part of the strategy development to address uncertainties and identify opportunities on the supply side?

xi. Are there particular actions the government should prioritise as part of the strategy development?

xii. Do you have any views on how to best capture interdependencies with the global supply chain?

Chapter 4 - Industry

xiii. Does this chapter capture key trends, opportunities, and risks in terms of UK industry? If no, please expand on any aspects that you think are missing or require further exploration.

xiv. In your view, what are the key challenges and opportunities for the UK industry in the lead up to 2050?

xv. What are key actions the government should consider as part of the strategy development to address uncertainties and identify opportunities for UK industry?

xvi. Are there any production pathways or adaptations to production pathways and infrastructure that are most likely to benefit the UK economy?

xvii. If applicable, how does your organisation plan to adapt to the expected changes in low carbon fuel demand and supply?

Chapter 5 – Policy framework

xviii. Does this chapter capture key trends, opportunities, and risks in terms of policy framework? If no, please expand on any aspects that you think are missing or require further exploration.

xix. In your view, how should the government best deliver its aims of using LCFs to maximise environmental and economic benefits and are there specific measures the government should take to support the sector's transition?

xx. In view of the different challenges and opportunities, are there specific policy measures the government should prioritise and why?

xxi. Are there any key actions the Government should consider as part of the strategy development to identify policy gaps and opportunities?

Chapter 6 - Interdependencies

xxii. Does this chapter capture key interdependencies and interactions with other policy areas or markets? If no, please expand on any aspects that you think are missing or require further exploration.

xxiii. In your view, are there any specific actions the government needs to take as part of the strategy development to address these interactions? If yes, what would those be?

Annex B: Glossary and abbreviations

ABDC	Advanced Biofuels Demonstration Competition	-
BEIS	Department for Business, Energy and Industrial Strategy	-
BECCS	Bioenergy uses combined with Carbon Capture Usage and Storage	-
-	Blend wall	The maximum limit to which biofuels can be blended into a fuel and comply with the fuel standard that most vehicles are approved to use.
-	Biofuels	A liquid or gaseous fuel used in transport that is produced wholly from biomass.
-	Biomass	Any material of biological origin (including biodegradable fraction of products, wastes and residues).
-	Biogenic waste	A term that covers all waste of biological origin.
CCC	Committee on Climate Change	-
CC(U)S	Carbon Capture (Use) and Storage	A term covering a range of technologies that capture waste carbon (usually in the form of carbon dioxide) and convert it into commercial products, including fuels, or transport it to storage so it cannot enter the atmosphere.
CfD	Contract for Difference	A type of support scheme to ensure a minimum price for particular product.
CO2	Carbon dioxide	-
DACCS	Direct Air Carbon Capture and Sequestration	-
Defra	Department for Environment, Food and Rural Affairs	-

DfT	Department for Transport	-
DIT	Department for International Trade	-
DLUHC	Department for Levelling Up, Housing and Communities	-
	Development fuels	Advanced renewable fuels made from sustainable wastes or residues (excluding segregated oils and fats such as used cooking oils and tallow) or RFNBOs that are also of a specified fuel type (i.e. hydrogen, aviation fuel, substitute natural gas or a fuel that can be blended at at least 25% and still comply with relevant fuel standard)
-	Drop-in fuel	Drop in fuels are alternatives to liquid fuels that can be blended at higher than average levels into standard fuels without requiring changes to vehicles or infrastructure.
FAME	Fatty Acid Methyl Ester	A type of biodiesel
-	Feedstock	Raw material used to produce transport fuels including biofuels.
FCDO	Foreign, Commonwealth and Development Office	-
F4C	Future Fuels for Flight and Freight Competition	-
GFGS	Green Fuels, Green Skies Competition	-
GHG	Greenhouse Gas (savings/emissions)	A gas which in the atmosphere absorbs and emits radiation causing the 'greenhouse effect' whereby heat is trapped in the atmosphere, making the earth warmer and leading to climate change.
HMT	Her Majesty's Treasury	
HVO	Hydrotreated Vegetable Oil	A type of biodiesel. To distinguish it from FAME (see above) sometimes referred to as renewable diesel.
ICAO	International Civil Aviation Organization	-
ILUC	Indirect land use change	Land-use change where the cause is at least a step removed from the effects - the knock-on effects on expansion of agricultural land use resulting from the cultivation of biofuel feedstocks.
IMO	International Maritime Organization	-
LCFs	Low carbon fuels	Fuels that can provide GHG savings compared to fossil fuels on a life-cycle basis
LPG	Liquefied Petroleum Gas	-
	Life-cycle	Pertaining to all stages in the production and use of a fuel.
MTBE	Methyl Tert-Butyl Ether	-

NRMM	Non road mobile machinery	The term covers a wide range of machinery used in manufacturing, construction and quarrying industries. It includes agricultural and forestry tractors, and inland waterway vessels or recreational craft when not at sea.
PJ	Petajoule	A unit of energy equal to 1015 joules or 278 gigawatt hours.
PtL	Power to liquid fuels	A fuel produced using renewable energy and sources of hydrogen and carbon to produce fuels through synthesis.
	Renewable fuels	A fuel used from a source that is either inexhaustible or can be indefinitely replenished at the rate at which it is used. Such as a biofuel or other fuels produced from a renewable energy source i.e. renewable fuels of non biological origin .
RCF	Recycled carbon fuels	Recycled carbon fuels (RCFs) are fuels produced from fossil wastes that cannot be avoided, reused or recycled and have the potential to reduce GHG emissions relative to conventional transport fuels. Feedstocks include industrial waste gases and the fossil-derived fraction of municipal solid waste (e.g. non-recyclable plastic). Some feedstocks can be considered part renewable and part RCF when combined with biogenic material such as food waste.
RFNBOs	Renewable fuels of non-biological origin	Rather than from biomass, the energy content of a RFNBO typically comes from renewable energy sources that include wind, solar, geothermal, hydrothermal and ocean energy, or hydropower
RTFO	Renewable Transport Fuel Obligation	-
SAF	Sustainable Aviation Fuels	Low carbon alternatives to fossil-derived aviation fuel, which can be blended into conventional jet fuel without requiring significant aircraft or engine modifications.
-	Synthetic fuel	A fuel which is produced from a mix of hydrogen and a nitrogen or carbon source (e.g. carbon monoxide or carbon dioxide). A synthetic fuel can also be classed as a renewable fuel if the hydrogen is produced from a renewable source and any carbon source used is from a renewable or unavoidable carbon stream, for example an industrial process where carbon dioxide would otherwise be vented into the atmosphere.
TRA	Trade Remedies Authority	-
	Waste-derived	In relation to the current RTFO ‘waste-derived’ refers exclusively to biogenic wastes and residues. In relation to recycled carbon fuels, the term may also refer to wastes from fossil sources but where that is

		the case, this document will typically use the term “fossil wastes”.
	Voluntary scheme	Where appropriate, renewable fuel suppliers can use ‘voluntary schemes’ for the purpose of providing evidence to demonstrate that a consignment of fuel complies with the required sustainability criteria.

Annex C: Overview of current low carbon fuels deployed in the UK[71]

Bioethanol	**Overview**	Bioethanol is typically blended into petrol. UK standard petrol contains up to 10%, (E10), with E5 available in the 'super' petrol grade. Higher blends (up to 85%) are possible but require adaptations to vehicles and are therefore not widely deployed in the UK.
	Feedstocks	Typically starch-rich crops (such as wheat and corn) or sugars (sugar beet, sugar cane). In UK supply, corn (31% of bioethanol supply in 2020) has overtaken feed wheat and sugar beet as the main feedstock in recent years and the share of bioethanol from sugar cane has increased. UK supply from waste and residues, in particular low-grade starch slurry food waste, has also increased. In total, 13 different feedstocks for bioethanol were reported under the RTFO for 2020.
	Conversion technologies	Fermentation is an established process to produce bioethanol at scale. Co-products of the process may include digestates for animal feed or (provided the plant is equipped accordingly) stored CO_2 for the beverage or nuclear industry. Advanced technologies also allow the production of bioethanol from agricultural and forestry residues by breaking lignocellulosic biomass down into component sugars which can then be fermented into sugars. However, these processes are not yet widely deployed at commercial scale.
	Countries of Origin	In 2020, UK and Ukraine were the largest suppliers of feedstocks for bioethanol supplied in the UK, with feedstocks originating from 23 countries different countries.

[71] DfT (2021). Renewable fuel statistics (online). Available at: https://www.gov.uk/government/collections/renewable-fuel-statistics

		In terms of finished fuels, data shows the Netherlands was the largest supplier to the UK in 2020, followed by Germany and France, with fuels originating from 12 countries. The total volume imported in 2020 was 128 million litres compared to 3 million litres exported to 54 different countries, with Ireland, Thailand and Germany being prominent destinations.[72]
	Average GHG savings	72% excluding ILUC, and 61% including ILUC. Depending on feedstocks used, GHG savings in 2020 ranged from 53-92% (excluding ILUC) and 3% to 90% (with ILUC).
Biodiesel (FAME)	**Overview**	Biodiesel (FAME) is typically blended in diesel. Diesel blends sold at UK filling stations contain up to 7% FAME (B7). Higher blends with up to 30% biodiesel or even 100% biodiesel are also available though not approved for use in all vehicles and therefore used in dedicated fleets only.
	Feedstocks	Traditional feedstocks include oilseed crops such as rapeseed, soya, palm and sunflower. UK supply is mainly produced from waste feedstocks, including used cooking oil (75% of biodiesel supply in 2020, with supply having grown by 45% within the last 5 years), tallow and sewage sludge. 16 different feedstocks were reported for biodiesel supply in in 2020.
	Conversion technologies	Transesterification with glycerine as a co-product.
	Countries of Origin	Feedstocks originated from 90 countries, with China the top country of origin in 2020 (predominantly used cooking oil), followed by the UK. Fuels originated from 11 countries in 2020, with the Netherlands supplying the greatest amount, followed by Belgium and Spain. According to trade data, the total volume imported in 2020 was 1,187 million litres compared to 49 million litres exported to 15 countries, with the Netherlands, Spain and Belgium receiving the greatest volumes.[73]
	Average GHG savings	85% excluding ILUC, and 81% including ILUC. Depending on feedstocks used, GHG savings in 2020 ranged from 53-93% (excluding ILUC) and -12-93% (with ILUC).
Biodiesel HVO	**Overview**	Hydrotreated Vegetable Oil (HVO) is a drop-in biofuel that can be used as a direct replacement for diesel at higher levels without requiring adaptations. Accounting for 1% of renewable fuels supplied in the

[72] UNCOM trade data. Extracted November 2021 (online). Available at: https://comtrade.un.org/
[73] UNCOM trade data. Extracted November 2021 (online). Available at: https://comtrade.un.org/

		UK in 2020, it currently is a niche fuel in the UK market.
	Feedstocks	See also FAME biodiesel above. RTFO statistics for 2020 reported only two feedstocks for HVO supplied in the UK, used cooking oil and spent bleaching earth.
	Conversion process	HVO is produced by hydrogenation and hydrocracking of different types of oils and animal fats using hydrogen as a catalyst.
	Countries of Origin	Feedstocks were supplied from 10 countries in 2020 all outside of Europe, with Venezuela the largest supplier of feedstocks of used cooking oil for HVO production (80%). There is no domestic production of HVO, therefore all HVO is currently imported.
	Average GHG savings	94% excluding ILUC, and 94% including ILUC (2020 figures). Depending on feedstocks used, GHG savings ranged from 77% to 94% (with and without with ILUC) in 2020.
Biomethane	**Overview**	Biomethane is mainly used to replace natural gas and can be used in dedicated gas vehicles. It accounted for 2% of total supply in 2020 seeing a 1% increase from 2019.
	Feedstocks	In 2020, biomethane supplied under the RTFO was produced from 11 different feedstocks, up from 7 in 2019. These include food waste, sewage sludge, waste pressing, wet and dry manure, and straw.
	Conversion technologies	Anaerobic digestion using bacteria to break down organic matter such as organic waste, sewage, manure, dead animal and plant material in the absence of oxygen. Gasification and methanation can also be used using a nickel catalyst.
	Country Origin	Feedstocks for biomethane supply originated from 7 countries, with municipal organic waste from Spain accounting for half of these in 2020. Majority of biomethane for use in transport was imported in 2020.
	Average GHG savings	80% (with and without ILUC) in 2020. Depending on feedstocks used GHG emissions ranged from 71% to 92% (excluding ILUC) or 5% to 92% (with ILUC) in 2020.
Biomethanol, renewable methanol and methyl tert-butyl ether	**Overview**	Biomethanol and renewable methanol can be blended into petrol; methyl tert-butyl ether (MTBE) can be used as an additive for both petrol and diesel. Biomethanol accounted for 2% of total supply of renewable fuels in 2020, up 1% from 2019. MTBE accounted for less than 1% of total renewable supply in 2020. No renewable methanol was supplied under the RTFO in 2020.

	Feedstocks/ Inputs	In 2020 there were eight different feedstocks for the biomethanol supplied, including food waste, municipal organic waste, sewage sludge, starch slurry, waste pressings from production of vegetable oils, crude glycerine, dry manure, and organic municipal solid waste. In the same period, there were two different feedstocks for MTBE, municipal organic waste and sewage sludge. Renewable methanol is typically produced from carbon dioxide, hydrogen using renewable electricity.
	Conversion technologies	Biomethanol is typically produced from gasification of lignocellulosic materials, renewable methanol by using a process which combines carbon capture and electrolysis. MTBE is produced via catalytic distillation of methanol.
	Countries of Origin	Feedstocks for biomethanol originated from 3 different countries, with the United States the largest feedstock supplier accounting for half of the fuels supplied. MTBE feedstocks in 2020 were derived solely from the United States. There is limited data as to the trade of the finished fuel and additive respectively.
	Average GHG savings	On average biomethanol can provide GHG savings of 59% both including and excluding ILUC (2020 figures). Depending on feedstocks used GHG emissions ranged from 54% to 90% (excluding ILUC) or -12% to 90% (with ILUC) in 2020.
Biopropane	**Overview**	Biopropane or BioLPG describes a type of liquid petroleum gas (LPG) derived from biomass. It accounted for less than 1% of all fuel supplied in the UK in 2020.
	Feedstocks	2020 RTFO statistics list for feedstocks for biopropane: Palm (accounting for over half of the biopropane supplied), soapstock acid oil contaminated with sulphur, used cooking oil and palm fatty acid distillate.
	Conversion technologies	Variety of thermal or chemical processes, with the most common the coproduction of biopropane and renewable (HVO) diesel from vegetable oils.
	Country Origin	Feedstocks for biopropane were imported from 37 different countries, with palm oil from Indonesia accounting for the highest share (50%). There is limited data as to the trade of the finished fuel.
	Average GHG savings	89% excluding ILUC, and 84% including ILUC (2020 figures). Depending on feedstocks used GHG emissions ranged from 71% to 94% (excluding ILUC) or 5% to 92% (with ILUC) in 2020.

Renewable hydrogen	**Overview**	Renewable hydrogen is a renewable fuel of non-biological origin (RFNBOs), fuels which derive their energy content from input processes powered by renewable sources, rather than energy from feedstocks. It accounted for less than 1% of total renewable fuels supplied in the UK.
	Feedstock origin/ Inputs	100% of renewable hydrogen supplied through the RTFO in 2020 was produced using wind power. Methane can also be used to produce hydrogen, if this is in the form of natural gas then it would not be considered renewable, however if it is produced from biomethane than it would be permissible under the RTFO.
	Conversion technologies	Electrolysis (with renewable energy required for maximum GHG reduction) and steam methane reformation (which requires carbon capture and storage for maximised GHG reduction).
	Countries of Origin	In 2020, the renewable hydrogen supplied originated exclusively from domestic production.
	Average GHG savings	All hydrogen supplied under the RTFO in 2020 was produced from wind power. This provided on average 100% GHG savings in comparison with fossil fuels.
Other	Other fuels supplied under the RTFO in 2020 included: • **Biopetrol** (1% of renewable fuels supplied): Produced by co-processing used cooking oil from 30 different countries in a refinery, average GHG savings from biopetrol supplied through the RTFO in 2020 was 89% (with and without ILUC). • **Pure vegetable oil** (less than 1% of renewable fuel supplied): used cooking oil that is used directly in place of diesel, with average GHG savings of 83% (with and without ILUC). There are other renewable fuels that may be supplied under the RTFO, such as sustainable aviation fuels.	