Zemo Partnership

Accelerating Transport to Zero Emissions

DfT Low Carbon Fuels Strategy Development

Stakeholder Workshop Engagement Report - February 2023

Prepared by Zemo Partnership

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This report has been prepared for the Department for Transport by Zemo Partnership, February 2023

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List of Acronyms

- AtJ — Alcohol to Jet
- B7 (B#) — Biodiesel with up to 7% (#%) renewable content
- BEIS — Department for Business, Energy & Industrial Strategy
- BtL — Biomass to Liquid
- CCS — Carbon Capture & Storage
- CCUS — Carbon Capture, Usage & Storage
- CfD — Contract for Difference
- CNG — Compressed Natural Gas
- Defra — Department for Environment, Food & Rural Affairs
- DfT — Department for Transport
- E10 — Petrol with up to 10% renewable ethanol
- E-fuel — Electrofuel
- EfW — Energy from Waste
- EV — Electric Vehicle
- FAME — Fatty Acid Methyl Esters
- FT — Fischer Tropsch
- GHG — Greenhouse Gas
- H2ICE — Hydrogen Internal Combustion Engine
- H&S — Health & Safety
- HDV — Heavy Duty Vehicle
- HEFA — Hydroprocessed Esters & Fatty Acids
- HFC — Hydrogen Fuel Cell
- HGV — Heavy Goods Vehicle
- HVO — Hydrotreated Vegetable Oil
- ICE — Internal Combustion Engine
- IMO — International Maritime Organization
- LCA — Life Cycle Analysis
- LCF — Low Carbon Fuels
- LDV — Light Duty Vehicle
- LPG — Liquefied Petroleum Gas
- MSW — Municipal Solid Waste
- NRMM — Non-Road Mobile Machinery
- OEM — Original Equipment Manufacturer
- PtL — Power to Liquid
- PtX — Power to 'X'
- RCF — Recycled Carbon Fuel
- rDME — Renewable Dimethyl Ether
- RED — Renewable Energy Directive
- RFNBO — Renewable Fuels of Non-Biological Origin
- RTFC — Renewable Transport Fuel Certificate
- RTFO — Renewable Transport Fuel Obligation
- SAF — Sustainable Aviation Fuel
- SME — Small & Medium-sized Enterprise
- UCO — Used Cooking Oil
- WTW — Well-to-Wheel

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LCF Strategy Workshops

Executive Summary

Introduction

- The Government's *Transport Decarbonisation Plan*, published in July 2021, recognises the need to maximise the benefits of sustainable low carbon fuels.
- The Plan sets out commitments to **develop a strategy for low carbon fuels (LCF), from now until 2050,** to set a clear signal about the Government's vision for the sector. The Plan covers a range of transport modes - road vehicles, rail, non-road mobile machinery, maritime and aviation.
- The Renewable Transport Fuel Obligation (RTFO) is the Government's key measure to incentivise the supply of LCF. The RTFO has set a 2032 target for 14.6% of road transport fuel to be LCF.
- Today, LCF are mainly blended into retail petrol and diesel, notably bioethanol (E10) and biodiesel (B7). LCF are additionally supplied as pure, or blended, products to heavy-duty vehicle fleets, and operators of non-road mobile machinery. Examples are biodiesel B20, hydrotreated vegetable oil and biomethane.
- LCF deliver a third of domestic transport greenhouse gas emission savings under current carbon budgets. Furthermore, they bring value to UK growth and job creation, directly through domestic production of LCF and their downstream supply chain.
- LCF will transition to sectors where alternative decarbonisation solutions are harder to achieve – like aviation and maritime. A variety of new types of LCF will be required by the market over the next decade, including renewable hydrogen and E-fuels.

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DfT LCF Strategy – Development

- The objectives of the planned LCF Strategy are to:
  - Provide certainty to industry and investors on the role of LCF to 2050.
  - Help to develop a common understanding and identify the risks and opportunities of the transition.
  - Ensure carbon savings from LCF are maximized in a sustainable manner
- As part of the development of the LCF Strategy, the DfT Low Carbon Fuels Team held a series of stakeholder workshops, between 30th May and 20th June 2022. These workshops followed on from their 'Call for Ideas' that closed in April 2022.
- The objectives of the workshops were to help support information gathering and build a common understanding of key challenges and how the LCF Strategy can help industry meet net zero targets.
- Zemo Partnership supported the DfT in the organisation and facilitation of 28 stakeholder workshops, covering seven themes.
- This report by Zemo Partnership, summarises the feedback given by stakeholders participating in the LCFS workshops.
- The views expressed in this report are from the workshop participants and do not reflect the DfT's policy position. DfT will consider all feedback from stakeholders as part of the strategy development.

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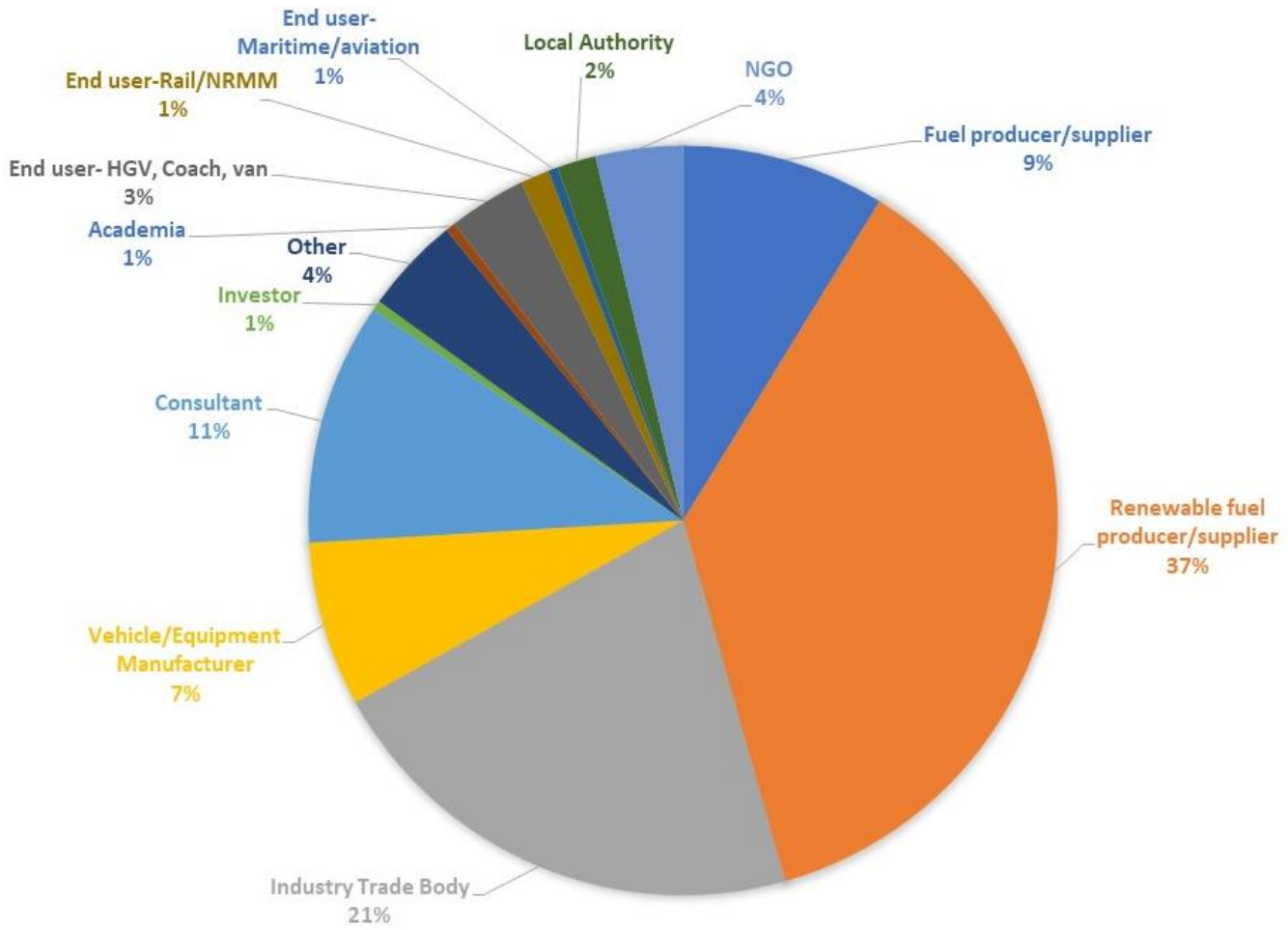
Stakeholder engagement

- The 28 LCF Strategy workshops were divided into 7 themes, with 4 workshop sessions per theme.
    1. Light vehicles and buses
    2. HGVs and coaches
    3. Shipping and aviation
    4. Rail and NRMM (Non-Road Mobile Machinery)
    5. New conversion technologies
    6. Maximising benefits of existing industry and infrastructure
    7. Local and international supply chains
- A total of 254 stakeholders, from 119 organisations, across 13 stakeholder groups, attended the workshops.
- A variety of stakeholders were invited to each workshop.
- There were 30-40 attendees per theme. A full list of the organisations that took part in the workshops is provided in the Appendix.



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Role of LCF over the next three decades

- The workshop participants expect a variety of liquid and gaseous LCF to play a role in decarbonising road transport, NRMM, rail, maritime and aviation over the next three decades. Most participants thought it likely that a diversity of fuel pathways (from feedstock generation to fuel production, distribution and combustion) will prevail. There was a view that technology innovation will be driven by appropriately shaped policy, to be set out by Government.
- Stakeholders in maritime and aviation consider these sectors challenging to decarbonise because they are subject to international markets and regulations, making it difficult for an individual country such as the UK to regulate.
- Participants stressed that accelerating GHG emission abatement over the next decade is vital for meeting net zero in 2050. A re-occurring point raised was that urgent action is required to scale up the adoption of LCF in the near term, with key opportunities present in road transport modes that will take longer to transition to electrification e.g. HGVs.
- Some participants thought that the use of liquid biofuels should be maximised in road transport, before shifting biomass feedstocks to 'harder to decarbonise' sectors such as aviation (in the form of SAF, Sustainable Aviation Fuel) from 2030 onwards.
- It was recommended that renewable fuels currently achieving high GHG emissions savings, such as biomethane, should be given greater recognition.
- A message arising from numerous workshops was that ramping up the adoption of LCF in the road transport sector could be a 'no regrets' opportunity, as the speed of electrification across a variety of transport modes is uncertain. Increasing the levels of LCF supplied to the existing vehicle fleet could deliver carbon savings immediately while waiting for electric propulsion technology to become more widely deployed. In the event of any delay in this transition to electrification, LCF would provide a route for continued GHG abatement.

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Role of LCF over the next three decades

- As the eventual demand for biomass feedstocks for the production of SAF (and maritime fuels) will exceed supply, it is unlikely that investment in building of feedstock supply chains will ever become a stranded asset.
- Increasing the pace of UK LCF production, especially SAF, was considered by participants to not only be imperative for meeting net zero, but also in maintaining the UK's competitive position internationally.
- Several stakeholders highlighted the importance of domestic drop-in renewable diesel production. Drop-in fuels can be directly substituted for petroleum fossil fuels, being chemically identical and meeting the same fuel quality standards as the fuels they replace.
- Participants asked Government to recognise the longevity of diesel ICE (Internal Combustion Engine) solutions for transport sectors which will find the transition to zero emission propulsion technology particularly challenging. This includes large/heavy NRMM, HGVs and rail freight, due to factors such as high power/energy density requirements, long operation life and hours, and operation in remote or rural locations.
- Recognition of the WTW (Well-to-Wheel) and life cycle GHG emissions of LCF was viewed as imperative by many workshop participants for providing a level playing field between different technologies and fuels. Different production routes for LCF save different amounts for carbon, depending on a wide range of factors such as energy used for processing the feedstock into fuel. Having accurate, and representative, GHG emission calculations for each type is the principal way to compare one fuel/technology to another. The GHG savings associated with a fuel may also stimulate innovation e.g. improve plant efficiency or the deployment CCS/CCUS (Carbon Capture & Storage/Carbon Capture, Usage & Storage).
- Providing assurance of supply chain life cycle GHG emission performance and feedstock sustainability was considered essential for LCF. Especially important for demonstrating to end-users that the production of LCF does not result in negative environmental impacts.

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Role of LCF over the next three decades

- In general, participants agreed that a ‘one size fits all’ technology/fuel approach will not be appropriate, and a variety of options should be supported. The deployment of LCF will be influenced by the end ‘use case’ as different applications have distinctly different duty cycles, payloads, journey profiles and refuelling models.*
- Participants deemed that the availability and affordability of suitable powertrain technologies for different use cases (e.g. hydrogen fuel cell HGVs, maritime ammonia engines) will impact the adoption rates of certain LCF. New infrastructure will also need to become available and scaled up over time. Several participants commented on the benefits of liquid LCF, which can make use of existing bunkering and refuelling infrastructure.

* The duty cycle defines how the vehicle is used e.g. hours of operation per day, average or peak load profile. Payload describes the carrying capacity of the vehicle and is the part of a vehicle's load from which revenue is derived e.g. cargo weight in an HGV, freight and passengers in an aircraft.

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Summary of mode specific LCF deployment

Participants of the workshops raised the following points on the deployment of LCF in different transportation modes.

Car, van, motorbike	• Whilst ICE phase-out dates have been set for cars and vans, there is a long-term role for liquid LCF in legacy fossil fuel vehicles which will still require decarbonisation (although the total volumes of fuel will reduce over time). • Certain van applications are considered difficult to electrify due to payload and duty cycle constraints, which is an opportunity for drop-in renewable diesel. For large van fleets, hydrogen is expected to offer medium to long-term solutions. • Motorcycles used for long journeys, and those ridden by owners with an affinity for the ICE, will be challenging to switch to electrification. There are opportunities for low carbon liquid fuels in this niche sector. • There was limited support for hydrogen use in cars and motorcycles.
Bus	• For buses, there is a near-term opportunity for biomethane. • High blends of biodiesel and drop-in renewable diesel provide a solution for decarbonising legacy diesel buses. • There are medium to long-term opportunities for hydrogen, especially where EV (Electric Vehicles) might be challenging e.g. for rural or long-distance routes.
Coach	• Drop-in renewable diesel is considered to have a near and long-term role for coaches. • There is potential for hydrogen to be used in the future. • A lack of fiscal support for this sector was raised as a key challenge for deploying LCF.

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Summary of mode specific LCF deployment

Participants of the workshops raised the following points on the deployment of LCF in different transportation modes.

HGV	• HGV covers a variety of use cases and duty cycles, requiring the right fuel to be matched with the right application. A range of LCF options are likely to be required. • The increasing electrification of light vehicles over the next decade is seen as an opportunity to liberate biodiesel/renewable diesel for use in decarbonising the HGV sector in the near-medium term. • Biomethane is highlighted to have an important near to medium-term role for articulated HGVs. • Higher blends of biodiesel and drop-in renewable diesel offer a route for 'harder to electrify' HGVs including those with the heaviest payloads and high mileages. There was a more frequent mention of drop-in renewable diesel e.g. HVO. • The medium to long-term role for hydrogen is dependent on vehicle and infrastructure deployment adoption rates. • Legacy diesel HGVs will require higher blends of biodiesel and drop-in renewable diesel in the long term.
NRMM	• NRMM is so diverse that different LCF will be suited to a specific use and machine type, based on location, proximity to infrastructure, energy demand, period of usage (long shifts, etc.) and urban setting (air quality). The asset life of the equipment can be up to 30yrs. • There is a common view, especially amongst end users, that the move to zero emission technologies will be challenging for the NRMM sector, resulting in the diesel ICE remaining in use up to, and potentially beyond, 2050. A long-term opportunity exists for drop-in renewable diesel. • Some applications could exploit H2ICE and biomethane (e.g. tractors) in the medium to long-term. • Unless new powertrain technology commercialises very quickly, given the long lifespan of rail and NRMM, the next investment cycle will still need a 'drop-in' renewable diesel.

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Summary of mode specific LCF deployment

Participants of the workshops raised the following points on the deployment of LCF in different transportation modes.

Rail	• The common view from end users is that rail will be challenging to fully electrify. • Various challenges were raised relating to the use of hydrogen in rail regarding storage, refuelling, & safety. • For both passenger and freight rail the lengthy asset life (up to 30 years) is perceived to require the continued use of diesel up to 2050. Particularly challenging routes include rural and remote lines. • Freight rail has demanding operational requirements, and drop-in renewable diesel in existing ICE is thought to be a long-term decarbonisation solution fro this application.
Aviation	• SAF offers clear benefits as a liquid drop-in fuel and is perceived to be the primary decarbonisation route for long-haul aviation. Near-term pathways for SAF include HEFA (Hydroprocessed Esters & Fatty Acids) and Gasification with FT (Fischer Tropsch) using MSW (Municipal Solid Waste) feedstocks. • There were mixed views on the role of hydrogen in HFC/H2ICE (Hydrogen Fuel Cell/Hydrogen Internal Combustion Engines) for aviation. • There was more commonality on the long-term role of e-kerosene.
Maritime	• Numerous LCF pathways were identified for the maritime sector. Like aviation, the significant energy demand of this sector requires substantial scale up of LCF. This is influenced by the international policy landscape. • Near-term opportunities were identified for biofuels (albeit incentives are absent in the UK). • Opportunities for the medium to long-term were identified as a combination of RFNBOs (e-ammonia/e-methanol) for international shipping, with the potential for hydrogen in domestic vessels. Hydrogen, ammonia and methanol require commercialisation of powertrain technologies and infrastructure development. • The long asset life of maritime vessels is an important consideration, as well as the duty cycle/use case.

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Factors influencing the deployment of LCF

Participants of the workshops raised the following points when asked about the factors influencing the deployment of LCF.

Financial

- For end users, there is common agreement that the cost of LCF is the primary influence regarding purchase behaviour. LCF are currently more expensive and some also require upfront investment for new fuel storage tanks and vehicle adaptations. Ensuring the business case exists for the lifetime of their asset is considered imperative. Linked to this is the availability, and duration, of fiscal incentives.
- For producers/suppliers and investors, the existence of market demand for LCF, and scalability, influences their business cases for investment. Price certainty for LCF was also identified as important, with the need for 'bankable' incentives.
- All stakeholder groups cited Government policy as having a critically important role in influencing the deployment of LCF. This relates to sending a signal of long-term support and commitment to the role of LCF in meeting net zero. This is necessary to provide confidence to the market to enable investment decisions in LCF. Certainty, transparency and longevity are seen as highly important from Government policy. The necessity for introducing a SAF mandate was repeatedly raised.

Fuel security/availability

- There needs to be certainty around the availability of feedstocks and LCF. There is increasing global competition for biogenic feedstocks, in particular UCO (Used Cooking Oil), this in turn could impact expected volumes of LCF supply. Furthermore, there is competition between the transport and industrial sectors for the economy for renewable electricity and hydrogen.

Sustainability

- Assurance of life cycle GHG emission performance and feedstock sustainability is considered highly influential.

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Factors influencing the deployment of LCF

Participants of the workshops raised the following points when asked about the factors influencing the deployment of LCF.

Availability of compatible vehicles/vessels and refuelling infrastructure

- The availability and accessibility of refuelling infrastructure were frequently raised as issues for the HGV, NRMM, rail and maritime sectors. This was most prominent for gaseous fuels such as biomethane, ammonia and hydrogen.
- For end users, the availability of new powertrain technologies (e.g. ammonia/hydrogen ICE, hydrogen fuel cells) is key.

International landscape

- Maritime and aviation are the most prominent sectors influenced by international markets and policies. Aligning the UK with international policy is considered important for avoiding market distortions. An example of this being whether the EU continues to double-count feedstocks – if they stop, this will have an impact on the price and therefore the supply of different renewable fuels to the UK.
- Geopolitics is mentioned as a key risk to LCF supply chains entering the UK.
- A further risk cited is that policy and incentives could make LCF more attractive in other countries, which could divert feedstocks and LCF to these regions rather than the UK. As world regions introduce LCF policies, this could result in the retention of biomass feedstocks in domestic markets, thereby restricting supply internationally. Participants highlighted that the UK needs to be a location attractive for investment to produce LCF, otherwise investors will look elsewhere.
- The EU Fit-for-55 proposal is proposing to move to a GHG target of 13% reduction by 2030. If the UK doesn't align with this, there is a risk of the UK becoming a ‘dumping ground’ for biofuels with the lowest GHG emission performance.

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Factors influencing the deployment of LCF

Air quality

- Some stakeholders highlight air quality as a relevant consideration, whilst others propose mitigation for air pollution emissions should be tackled separately.
- NRMM stakeholders working in the construction sector highlight the importance of air quality in cities. Specifically, policies which restrict certain vehicles and machines due to emission performance. A particular issue for NRMM is that the market for zero emission vehicles and machinery is in its infancy, with limited affordable products on the market. This could present a challenge with using LCF in regions which introduce Zero Emission Zones.

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Summary of deployment challenges and opportunities

The workshop participants raised the following points on the challenges and opportunities for the deployment of specific LCF.

Drop-in renewable diesel	Challenges: • The higher cost of HVO is a constraint for various end users in the HGV, rail and NRMM sectors. • Security of supply is a concern due to the lack of production in the UK. • Long-term availability of UCO is considered a risk due to competition for feedstocks with HEFA (SAF) production in the future. • Fuel bunkering sites have space constraints and installing new/additional tanks for HVO is challenging. Opportunities: • There are opportunities across all road transport modes, plus maritime, due to compatibility with existing ICE engine technology, storage and refuelling infrastructure.
Higher blends of biodiesel	Challenges: • Vehicle warranty for higher blends is limited and inconsistent across OEMs, especially for HDVs (Heavy Duty Vehicles). • NRMM equipment is typically warrantied for up to B20, with limited scope for increasing above 20% bio-content. • Fuel bunkering sites are frequently constrained on space, making it difficult to install new tanks for higher blends of biodiesel. • There is limited deployment of higher blends of biodiesel in rail and further demonstrations are required. Opportunities: • Bus, HGV, maritime, NRMM and rail offer on-going market opportunities for existing biodiesel producers/suppliers.

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Summary of deployment challenges and opportunities

The workshop participants raised the following points on the challenges and opportunities for the deployment of specific LCF.

Biomethane	Challenges: • Infrastructure deployment is challenging, with new sites being delayed by planning processes and land availability. Opportunities: • Using manure as a feedstock results in large GHG savings today. The resulting fuel is considered to have a negative carbon intensity as it captures methane (a GHG) that would otherwise have been released into the atmosphere. • Biomethane can be used in artic HGVs and NRMM e.g. tractors.
Recycled carbon fuels	Opportunities: • RCF are an efficient use of waste (non-recyclable) plastic to produce drop-in renewable diesel and SAF. • They have the potential for using low cost feedstocks.
Renewable dimethyl ether	Challenges: • rDME has yet to be commercialised in the UK (the first production plant is planned at Teesworks). Opportunities: • rDME is a drop-in replacement for LPG with potential markets including HGVs and NRMM.

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Summary of deployment challenges and opportunities

The workshop participants raised the following points on the challenges and opportunities for the deployment of specific LCF.

RFNBOs - hydrogen	Challenges: • There were differing opinions on the role of hydrogen in the rail, NRMM and aviation sectors. • In rail, there was less support for hydrogen from end users. Weight and speed demands of freight rail are considered key challenges due to hydrogen's lower volumetric energy density compared to diesel. On board storage of hydrogen will constrain passenger and cargo capacity. • The poor WTT (Well-To-Tank) energy efficiency of hydrogen was cited several times. • H&S considerations of hydrogen are a concern e.g. on board storage of compressed hydrogen and oxygen, the storage and handling of cryogenic liquids. • The challenges for infrastructure deployment include land availability, planning processes, H&S regulations, COMAH (Control of Major Accident Hazards) regulations restricting the capacity of hydrogen storage at depots and public refuelling sites. • Limitations on HGV tube trailer hydrogen storage capacity could present practical challenges for delivery of compressed hydrogen for HGV refuelling sites, especially artic fleets (i.e. several deliveries per day). • The current cost of hydrogen vehicles is high and financial support would be needed. • The availability and access to refuelling infrastructure is a challenge. • Innovation is required to reduce the cost of electrolysers and improve HFC technology and storage tanks. • New skills and training are required for hydrogen deployment. • Competition for low carbon hydrogen from other sectors may be a constraint for the transport sector. Opportunities: • H2ICE was highlighted frequently as an easier route for deploying hydrogen in road transport due to the lower purity grade requirements of the hydrogen. NOx emissions were cited as very low, and it was suggested that Government should class this technology as 'zero emission tailpipe'.

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Summary of deployment challenges and opportunities

The workshop participants raised the following points on the challenges and opportunities for the deployment of specific LCF.

RFNBO-E-fuels	Challenges: • The availability of renewable electricity is a key constraint for e-fuel production, plus competing demands for renewable electricity from multiple economic sectors. • Demands for renewable hydrogen across multiple sectors could constrain feedstock availability. • The significant cost of producing e-fuels is a key barrier, particularly in terms of SAF. Opportunities: • The production of e-kerosene could enable the co-production of (drop-in) e-diesel for road transport.
SAF	Challenges: • Regulatory intervention is urgently required to enable UK SAF production e.g. SAF mandate, CfD (Contract for Difference). • The availability of UCO for producing HEFA in the medium to long-term is a concern. • There is a risk that there will be insufficient biomass feedstocks for road biodiesel production as the SAF mandate increases over time. Opportunities: • SAF could be produced using waste feedstocks: MSW for gasification with FT, recycled carbon fuels. • Using CCS in SAF plants could reduce GHG emissions. • There is a potential for wider benefits from reduced non-CO_2 global warming impacts related to contrail formation.
Ammonia	Challenges: • H&S concerns around the toxicity of ammonia mean that there are challenges for storage and handling. • The development of dedicated infrastructure would be required at ports for use in maritime.

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How can the LCF Strategy, and wider policies, support industry in the transition to net zero?

Participants of the workshops raised the following points on the LCF strategy and wider policies.

Government must accelerate the implementation of policy interventions to address GHG reduction and send out the right messages to industry.

- It is important that Government delivers a strong signal of being committed to LCF over the long term.
- Government should identify the near, medium and long-term opportunities for decarbonisation across transport modes. A clear roadmap of the end goal and how to get there should be developed, with strategies for each mode. This should show what the LCF landscape will look like in 2050 – which fuels are still there, where do traditional biofuels end up e.g. SAF or move to other markets such as chemicals, or disappear all together?
- Government should acknowledge the long-term role that LCF will have in addressing 'hard to decarbonise' modes, including NRMM and HGVs, and in decarbonising legacy diesel ICE fleets.
- Policy and regulation should support the take-up of LCF over the next decade and provide a key opportunity for HDVs and NRMM during the transition to zero emission technologies.
- Government should address the perceived 'one size fits all' electrification approach and some departments' wariness towards bioenergy.
- Government should adopt a technology neutral approach based on WTW GHG emissions reduction. This will stimulate a level playing field for innovation and investment. The perceived ban on ICE sales by a certain date does not fit with this.
- It is important to ensure that the UK is an attractive location for investment and to stimulate domestic LCF production.
- The strategy should include educating and raising awareness on the lifecycle GHG credentials of biofuels to both the public and Government. The Zemo Renewable Fuels Assurance Scheme is a good example.

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How can the LCF Strategy, and wider policies, support industry in the transition to net zero?

Participants of the workshops raised the following points on the LCF strategy and wider policies.

LCF policy

- Either the GHG obligation should be reinstated or the RTFO should evolve into a GHG emission obligation. This will create a level playing field between different LCF, encouraging investment and innovation.
- The RTFO targets need to be more ambitious and extend beyond 2032 to provide long-term security.
- Recycled carbon fuels should be recognised under the RTFO, as should the value of other waste feedstocks such as MSW (biogenic/residual) and end of life tyres.
- A fit for purpose mechanism for addressing the buy-out price is required.

SAF policy

- The introduction of a SAF mandate is needed as soon as possible, in conjunction with a CfD support mechanism.
- Clarity is required on the SAF mandate structure, timing and administration.

International policy landscape

- Net zero depends on global LCF availability and regulations. This is especially important for shipping and aviation.
- The UK should keep abreast of the international policy landscape (especially the EU) and ideally align to avoid potential market distortions. The UK needs to be a location to attract investment to produce LCF, otherwise investors will look elsewhere.
- The UK needs to align with the IMO (International Maritime Organization), otherwise costs will be higher and there is a risk of carbon leakage (GHG emissions increase in one country as a result of an emissions reduction by a second country with a strict climate policy).
- Clarity is required on the definitions for the maritime sector, e.g. what does net zero mean for shipping? This also needs to consider international policy.

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How can the LCF Strategy, and wider policies, support industry in the transition to net zero?

Participants of the workshops raised the following points on the LCF strategy and wider policies.

Government incentives and funding are required to:

- Help innovative businesses with new technology to develop pilot plants and scale up LCF production.
- Support infrastructure deployment.
- Support commercial demonstration facilities by de-risking investment with government backed loans.
- Introduce a guarantee of carbon price, such as CfD.
- Improve the business case for the end-users through fiscal incentives, thus stimulating LCF demand. A discount on fuel duty linked to GHG emission performance would encourage higher blends of renewable diesel in HDVs and NRMM.
- Offer funding to support demonstration trials, e.g. using higher blend biodiesel in rail, LCF in maritime vessels.

Alignment with other Government departments

- Policies related to LCF and feedstocks (e.g. BEIS hydrogen strategy, BEIS biomass strategy, Defra waste hierarchy) should be harmonised.
- The planning process needs to be reviewed and improved to avoid hindering the pace of refuelling infrastructure deployment and scale-up (biomethane, hydrogen) e.g. National Planning Policy Framework.
- Government and industry need to work together to prevent a fragmented sector.
- Government should engage with operators more to understand their challenges and needs.
- Central and local government need to work together on placing LCF hubs in core locations.
- Government should set up a skills initiative for training and apprenticeships related to new types of LCF, thereby supporting the next generation of green jobs.

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How can the LCF Strategy, and wider policies, support industry in the transition to net zero?

Participants of the workshops raised the following points on the LCF strategy and wider policies.

Fuel security and sustainability

- Government should stimulate opportunities for sourcing local feedstocks, in particular waste. Examples of best practice include exploiting fugitive methane emissions from farm slurry to produce carbon negative biomethane and collecting used cooking oil from catering establishments.
- Government should support domestic LCF production facilities for feedstocks (particularly waste), whilst ensuring the timing and magnitude of incentives is aligned with international markets.
- Policy incentives need certainty to help encourage the development of LCF production plants and secure the feedstock supply chains.
- Regulations must ensure strict sustainability standards for LCF supply chains are maintained.

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LCF Strategy Workshops

Stakeholder Feedback Summary: Workshop Themes 1 to 7

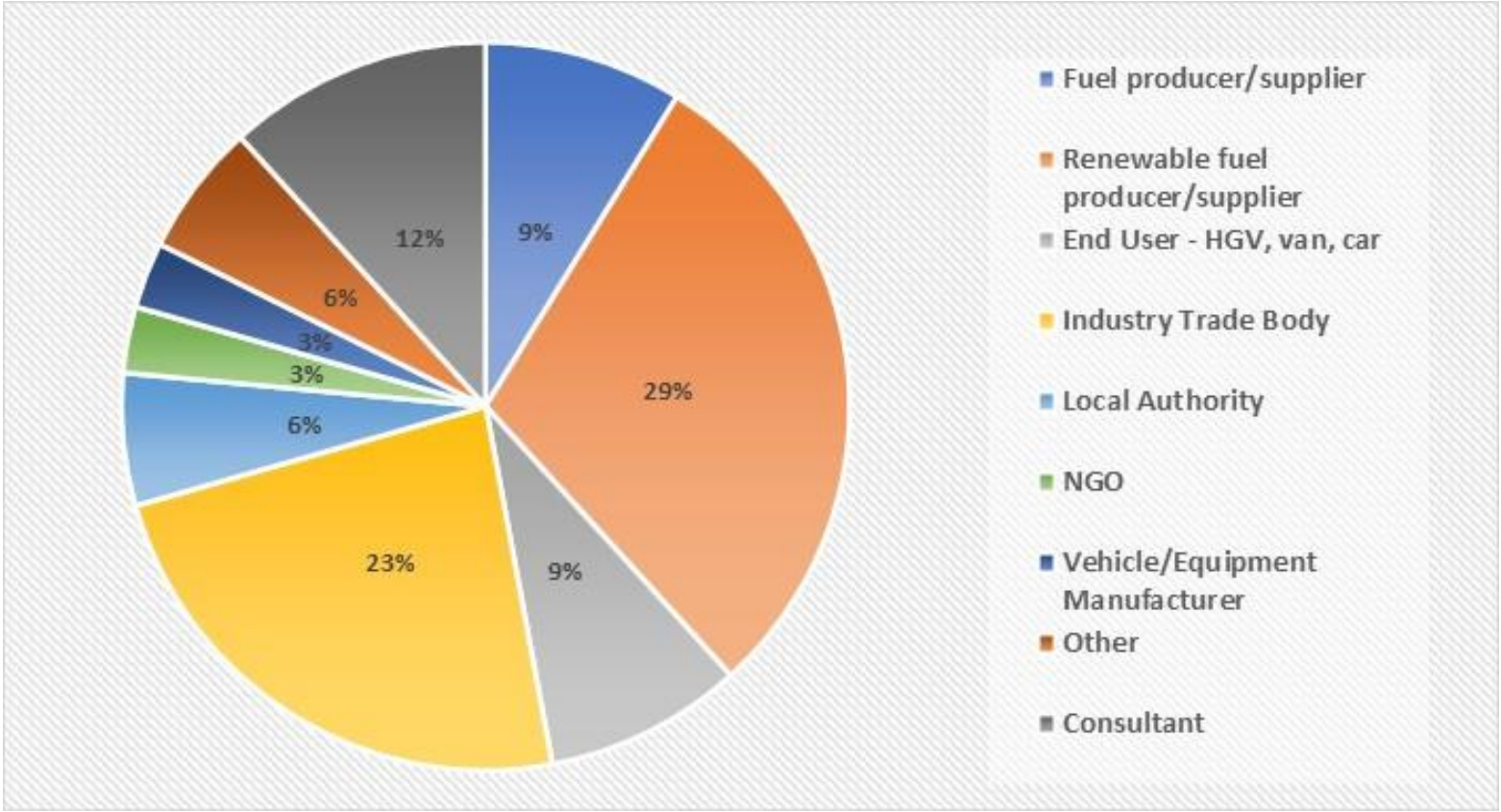
LCF Strategy Workshops

Theme 1:

Light Vehicles and Buses

Workshop stakeholder analysis

- Theme 1 had a total of 37 attendees.
- The stakeholder groups with the largest representation were ‘renewable fuel producer supplier’ and ‘industry trade body’.



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Q1: Role of different LCF 2022 – 2050

Participants suggested the following roles for LCF in the timeframes considered:

Sector	2022-2030	2030-2040	2040-2050
Light vehicles	E10, B7 and drop-in renewable fuels beyond the blend wall (retail).		Drop-in liquid fuels: biogenic and e-fuels (may be linked to SAF production).
Vans – captive fleets	Drop-in renewable diesel , higher blends biodiesel, especially those more challenging to electrify e.g. security vehicles with armouring, tow vehicle.	Hydrogen increasing over time, especially for those with longer range, and with refrigeration units.	
Motorbike leisure, long journeys, weight sensitive, adverse to electrification	E10 and drop-in fuel beyond the blend wall (retail).		
Bus	Higher biodiesel blends (B20, B30) and biomethane for the short term; hydrogen increasing over time, especially for rural fleets where battery electric is not an option yet.		

- Participants noted that the legacy ICE fleet will need liquid LCF. Drop-in renewable diesel (e.g. HVO) is generally preferred.
- It was suggested that the use of biomass feedstocks for biofuels in road transport should be maximized In the near-term. Incremental increases in the bio-content over time will bring further decarbonisation to light duty vehicles and buses.
- There was consensus among the participants that action to increase LCF deployment in the near-term is required urgently. The phrase “one tonne of carbon saved now is significantly more beneficial than one tonne saved in 2030” was voiced by several people.

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Q2: Influencing factors for deploying LCF

Participants proposed that the following factors would influence end-users and producers in LCF deployment in the light duty vehicle and bus sectors:

End-users

- Total cost of ownership, price volatility and the availability and duration of fiscal incentives .
- Infrastructure cost and availability, especially for hydrogen.
- Certainty and security of fuel supply.
- Convenience of use.
- Ability to fulfill vehicle duty cycle and range requirements.
- WTW lifecycle GHG performance.
- Supply chain sustainability.
- Compliance with Clean Air Zones and Zero Emission Zones.

Producers/suppliers

- Scale of deployment and market opportunities.
- Regulatory requirements.

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Q2: Influencing factors for deploying LCF

Participants proposed that the following factors would influence investors in LCF deployment in the light duty vehicle and bus sectors:

Investors

- Clear and consistent policy is required.
- Certainty of fiscal incentives.

Participants highlighted several key challenges and risks for LCF deployment in the light duty vehicle and bus sectors.

Challenges and risks

- Competition for feedstocks and hydrogen, including demand from multiple sectors.
- Potential constraints for HVO supply over time as feedstocks (UCO) move to SAF production (HEFA pathway).
- Access to land and the lengthy planning processes required to deploy LCF infrastructure.
- Safety concerns around hydrogen fuel storage and dispensing.

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Q3: Wider considerations when deploying LCF

Participants put forward the following considerations for the deployment of LCF in the light duty vehicle and bus sectors:

- Geopolitics significantly influences the trade of feedstocks and LCF supply chains e.g. the war in Ukraine has resulted in an increase in energy crop commodity prices.
- The cost of living crisis and inflation will impact affordability of lower carbon options.
- GHG emissions should be determined on a life cycle basis.
- Attitudes towards land use (food versus fuel) and sustainable agriculture will affect the quantity of crop-based feedstocks available for biofuels. Also, ILUC (Indirect Land Use Change) considerations can lead to complex regulations.
- Accounting for WTW energy efficiency was mentioned in the context of hydrogen.
- The availability of people with the necessary skills to develop LCF, vehicles and the required infrastructure.
- The relevance of air quality depends on the location e.g. it is more critical in city environments than in rural locations. There is a view that certain biofuels can burn cleaner than diesel. There is a perspective that air quality should be considered separately from climate change mitigation, and the deployment of LCF should focus on GHG reduction.
- Some LCF can offer noise benefits in urban areas e.g. gas engines are quieter than conventional diesel engines.
- International considerations: the UK should avoid being isolated economically, or in terms of infrastructure or fuel type.

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Q4: Technology innovation

Participants suggested the following innovations as potential 'game-changers' for LCF deployment in the light duty vehicle and bus sectors:

- If recycled carbon fuels, made from end-of-life tyres and unrecyclable plastics, could be scaled up affordably, they could provide an alternative drop-in fuel.
- Exploiting cover crops (grown to protect and enrich the soil) such as camelina to produce biofuels. This would also be beneficial in providing jobs in agriculture.
- Algae is a potential feedstock. It has lots of promise but has yet to deliver.
- Biomethane can be produced from farm slurry to produce a fuel with a negative carbon intensity. The biomethane can be used to fuel local vehicles, creating a circular economy.
- A cheap supply of green hydrogen could benefit a variety of technological solutions.
- Developments in CCS and CCUS could provide further GHG emissions savings.

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Q5: How can the LCF strategy, and wider policy, support your industry in achieving net zero?

The workshop participants' responses on strategy and policy were as follows:

- Government needs to provide a clear signal that they are committed to LCF.
- There is a need to promote education and awareness about the lifecycle GHG credentials of biofuels to both the public and Government.
- Policy should be technology neutral and not prevent technologies such as hydrogen ICE.
- The RTFO should reflect the GHG reductions by either reinstating the GHG obligation or reforming the RTFO to a GHG target.
- The RTFO target needs to be more ambitious and extended to 2050, without undermining supply.
- Some participants felt that the additionality rules in the RTFO and guidance for hydrogen are not fit for purpose.
- There needs to be consistent policy and improved cohesion across all government departments (DfT, BEIS, Defra, etc).
- Government needs to make it clear whether climate change or air quality is the main priority for transport. Bans on sales of new non-zero emission models is based on tailpipe emissions, but these vehicles may not have the lowest overall GHG emissions on a Well-to-Wheel or life cycle basis.
- Policy and standards should be related to net zero.
- The planning process needs to be improved to avoid hindering the pace of infrastructure deployment.
- Government should be a key enabler for skills and capacity to develop the next generation of green jobs.

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Q5: How can the LCF strategy, and wider policy, support your industry in achieving net zero?

The workshop participants suggested a range of financial incentives to support industry, including:

- The use of higher blends of renewable fuels should be encouraged by introducing a reduced fuel duty, linked to the GHG performance of the fuels.
- Purchase subsidies which would encourage LCF vehicles (e.g. hydrogen fuel cell vehicles) into the market.
- Enhanced capital allowances for vehicles and infrastructure.
- BSOG (Bus Service Operators Grant) should recognise LCF.
- Incentive-based approaches such as California's LCF standard.

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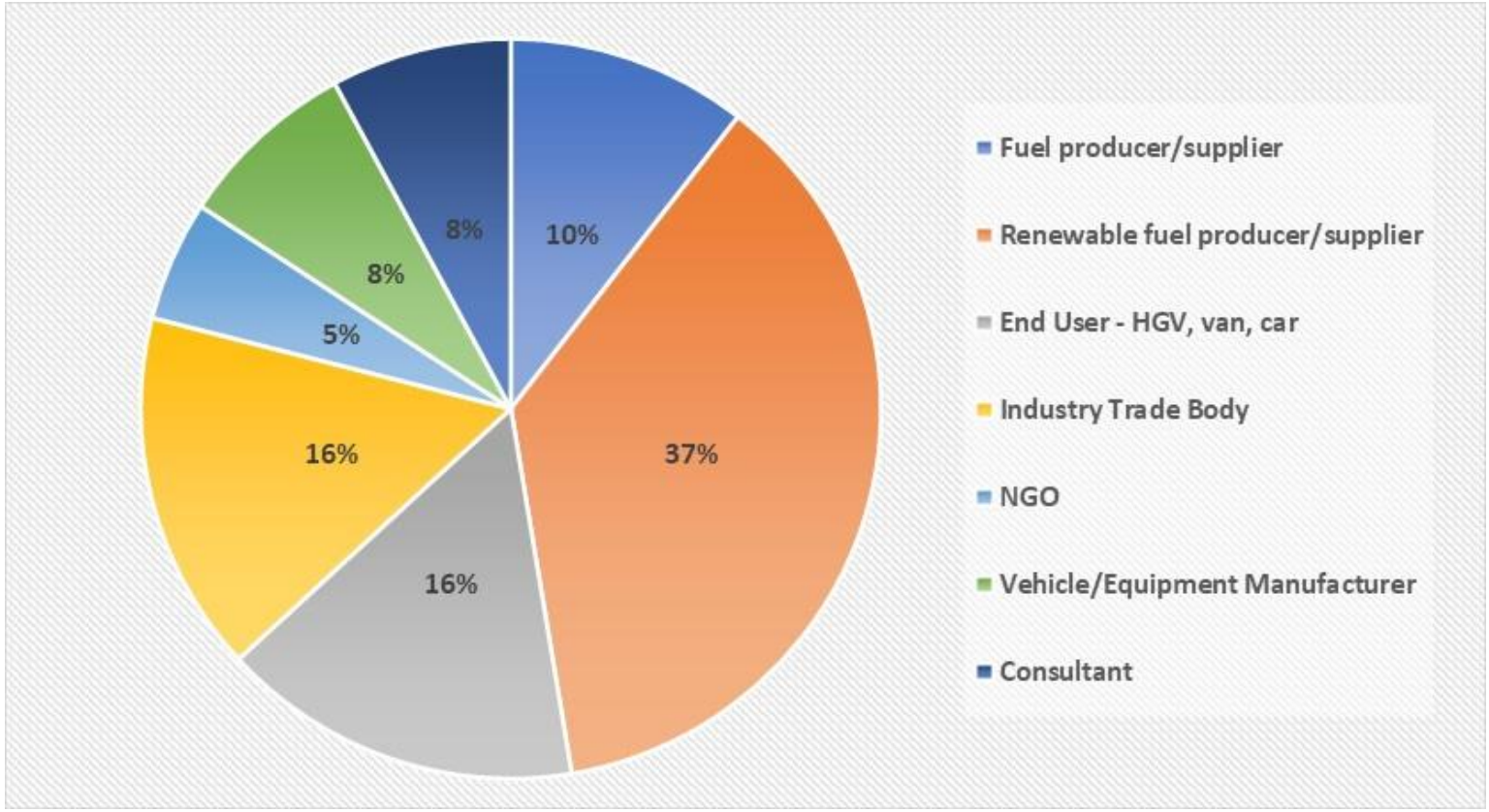
LCF Strategy Workshops

Theme 2:

HGVs and Coaches

Workshop stakeholder analysis

- Theme 2 had a total of 40 attendees.
- The stakeholder groups with the largest representation were ‘renewable fuel producer supplier’ followed jointly by ‘industry trade body’ and ‘end user’.



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Q1: Role of different LCF 2022 – 2050

Participants suggested the following roles for LCF in the timeframes considered:

Sector	2022-2030	2030-2040	2040-2050
HGV	• Retail B7, possible option for B10. • Captive fleets - ramping up of drop-in renewable diesel (e.g. HVO), higher blends (e.g. B20, B30) of biodiesel, biomethane (long-haul/heaviest HGV), rDME, hydrogen fleet demonstrators.	• Retail B7, possible option for B10. • Captive fleets - larger scale uptake of biomethane and HVO; higher blends of biodiesel (including advanced diesel fuels from waste), early market hydrogen.	• Retail B7 with possible option for B10 – reducing volumes. • Captive fleets - biomethane and drop-in renewable diesel in the heaviest/long-haul HGV; increased role of hydrogen (H2ICE/HFC).
Coach	• Follow similar fuel pathways to HGVs, excluding biomethane (no CNG coaches are available in the UK).		

- Participants noted that the legacy ICE fleets will need liquid LCF, with a preference for drop-in renewable diesel (e.g. HVO).
- The 2022-2030 timeframe is considered critical for increasing LCF adoption. LCF production must be scaled up to deliver GHG reduction over this decade, which is highly important for meeting net zero.
- Biomethane is an affordable near-term solution for long haul HGVs and can achieve zero/negative GHG emissions today.
- HVO can offer immediate GHG savings and production plants could be upgraded in the future to produce HEFA (SAF).
- There is possible deployment of rDME in diesel trucks but no commercial market for this at present.
- Electrification of the light duty vehicle fleet will release surplus biodiesel for the HGV and coach market.
- Biofuels can be used with range extender powertrains (plug-in hybrids), giving air quality and climate change benefits.
- Given the variety of HGV duty cycles and use cases, a variety of solutions are required.
- The operating life of coaches and HGVs often exceeds that of light duty vehicles (HGV 15yrs, coach 15-25yrs).

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Q2: Influencing factors for deploying LCF

Participants proposed that the following factors would influence end-users and producers in LCF deployment in the HGV and coach sectors:

End-users

- Total cost of ownership, fuel price, fuel price volatility and the availability of fiscal incentives. HGV fleets operate within very tight financial margins so the switch to LCF must be affordable. This is especially challenging for SMEs.
- Fuel availability and supply certainty, including access via public refuelling stations and bunkering.
- Ease of transition.
- Recognised accreditation of fuel sustainability and life cycle GHG emission savings.
- Deployment restrictions in cities related to vehicle emission performance e.g. Clean Air Zones, Zero Emission Zones, Low Emission Zones.
- Operation, maintenance and vehicle warranty implications e.g. tighter control of fuel storage and vehicle maintenance for higher blends of biodiesel.
- Vehicle cost (e.g. HFC, CNG).
- Vehicle availability and development e.g.
    - 6x2 CNG HGVs currently do not have sufficient range as the fuel tanks are too small.
    - The packaging of hydrogen fuel cell systems and batteries is a challenge for some applications, including coaches.

Producers/suppliers

- Feedstock availability.
- Clear roadmaps on the transitional use of LCF and clarity of interaction of LCF with CCUS clusters are needed.

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Q2: Influencing factors for deploying LCF

Participants proposed that the following factors would influence investors in LCF deployment in the HGV and coach sectors:

Investors

- Confidence in payback on investments in infrastructure.
- Certainty around the likely adoption rate.
- The provision of fiscal support, with clear guidance on how long this will continue to be available.

Participants highlighted several key challenges and risks for LCF deployment in the HGV and coach sectors.

Challenges and risks

- The policy landscape needs to provide certainty, stability and longevity.
- The UK needs to provide sufficient investment opportunities or investors will seek developments overseas.
- Competition for feedstocks and fuels (e.g. hydrogen) from other sectors and internationally.
- The need for refuelling infrastructure, especially hydrogen, was raised frequently.
    - This is considered difficult to plan as different solutions are required for different vehicles. Programs such as the Zero Emission Road Freight Trials are important for demonstrating viability.
    - The lengthy planning process and land availability are common barriers to infrastructure deployment.

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Q3: Wider factors to consider for deploying LCF

Participants put forward the following considerations for the deployment of LCF in the HGV and coach sectors:

- Sustainability
    - Life Cycle GHG Assessments and Well-to-Tank GHG emissions must be considered.
    - It is important to be mindful of, and audit for, indirect issues beyond certification and the supply chain. This would include issues overseas (e.g. deforestation) and issues related to waste feedstocks.
    - The geographic nature of feedstocks and use of renewable fuels where they are produced.
- Interdependencies of fuels and other materials and chemicals e.g. removing liquid fuels reduces the ability to further refine other chemicals.
- The energy efficiency of the LCF pathway on a Well-to-Tank basis e.g. producing hydrogen from electrolysis for use in a H2ICE/HFC vehicle versus using electricity in an electric vehicle.
- Health and safety considerations of volatile and flammable gases, in particular hydrogen.

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Q4: Technology innovation

When asked to suggest innovations that could be potential 'game-changers' for LCF deployment in the HGV and coach sectors, the responses from participants were limited (2 out of 4 workshops did not mention any innovations).

The following suggestions were made:

- The end of sales of ICE vehicles is seen as dampener on innovation. ICE in combination with other technologies could offer GHG and air quality benefits e.g. plug-in hybrid vehicles using LCF.
- Vehicle powertrain advancement and availability e.g. hydrogen fuel cells.
- Affordable green hydrogen from widespread renewable electricity production.

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Q5: How can the LCF strategy, and wider policy, support your industry in achieving net zero?

The workshop participants' responses on strategy and policy were as follows:

- Government should provide consistent policy relating to LCF with certainty, stability and longevity (required for the lifetime of the asset / 15 years).
- Government needs to give a clear signal that they are committed to LCF and support their use in HGVs. Government should promote the near-term benefits of renewable fuels such as biomethane and higher blends of renewable diesel.
- There should be harmonisation between Government departments and policy.
    - Policy frameworks for low carbon hydrogen (BEIS/DfT) should be aligned e.g. approach to 'additionality', carbon accounting boundary.
    - A holistic approach is needed for policies using the same feedstocks to avoid unintended consequences (e.g. chemical, industry, transport).
- Policy should be considered in an international context.
    - Standards should align with EU standards.
    - Domestic production of LCF should be supported to reduce imports.
    - The UK needs to be a location to attract investment to produce LCF, otherwise investors will look elsewhere.
- Government should also consider efficiency.
    - Vehicles that can't be decarbonised in other ways should be prioritised where supplies of renewable fuels are limited.
    - Vehicles and fleets should use fuel as efficiently as possible.
    - The most efficient solution should be adopted for each application e.g. EV rather than hydrogen for local deliveries.
    - Circular economy solutions may emerge e.g. linking LCF production to chemical recycling of fuel stocks.

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Q5: How can the LCF strategy, and wider policy, support your industry in achieving net zero?

The workshop participants' responses on strategy and policy were as follows:

- Policy should be technology neutral and based on WTW GHG emissions reduction (rather than a ban on ICE). This will stimulate a level playing field for investment.
- Policy should be based on life cycle GHG emissions, not tail-pipe emissions.
- Clarity is required on the ban of sales of ICE and the acceptable level of NOx for hydrogen combustion engines.
- LCF policy and RTFO
    - The GHG obligation should be reinstated in the RTFO.
    - The RTFO targets need to be more ambitious and extended after 2032.
    - Recycled carbon fuels should be added.
    - A fit for purpose mechanism for addressing the buy-out price is required.
- Collaboration
    - Government and industry need to work together to prevent a fragmented sector.
    - The lessons learnt by stakeholders decarbonising faster could be shared.
    - Government needs to engage more with operators to understand their challenges.
    - Central and local government need to work together on placing LCF hubs in core locations.

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Q5: How can the LCF strategy, and wider policy, support your industry in achieving net zero?

The workshop participants' responses on strategy and policy were as follows:

- Financial incentives
  - Fuel duty discounts, with long-term visibility, should be introduced for renewable diesel/biodiesel, and maintained for biomethane.
  - 1st year capital allowance should be extended to vehicles and infrastructure.
  - Support is needed for developing a national infrastructure network with open access refuelling stations for commercial fleets and private vehicles.
  - The coach sector needs its own financial incentive schemes.
  - Government funding processes need to be simpler and more reactive.
- Government should set up skills initiatives for training and apprenticeships.
- Government should encourage OEMs to include higher blends of biodiesel in their vehicle warranty provision.
- Stakeholders did not agree on commonality. It was proposed that the long-term goal should focus on delivering one solution to avoid a disjointed market, but others felt that businesses have individual needs and should find the best low carbon solution for them, without a hierarchical or prescriptive approach (especially HGV end-users).
- Government should consider opportunities for small businesses and rural use cases.

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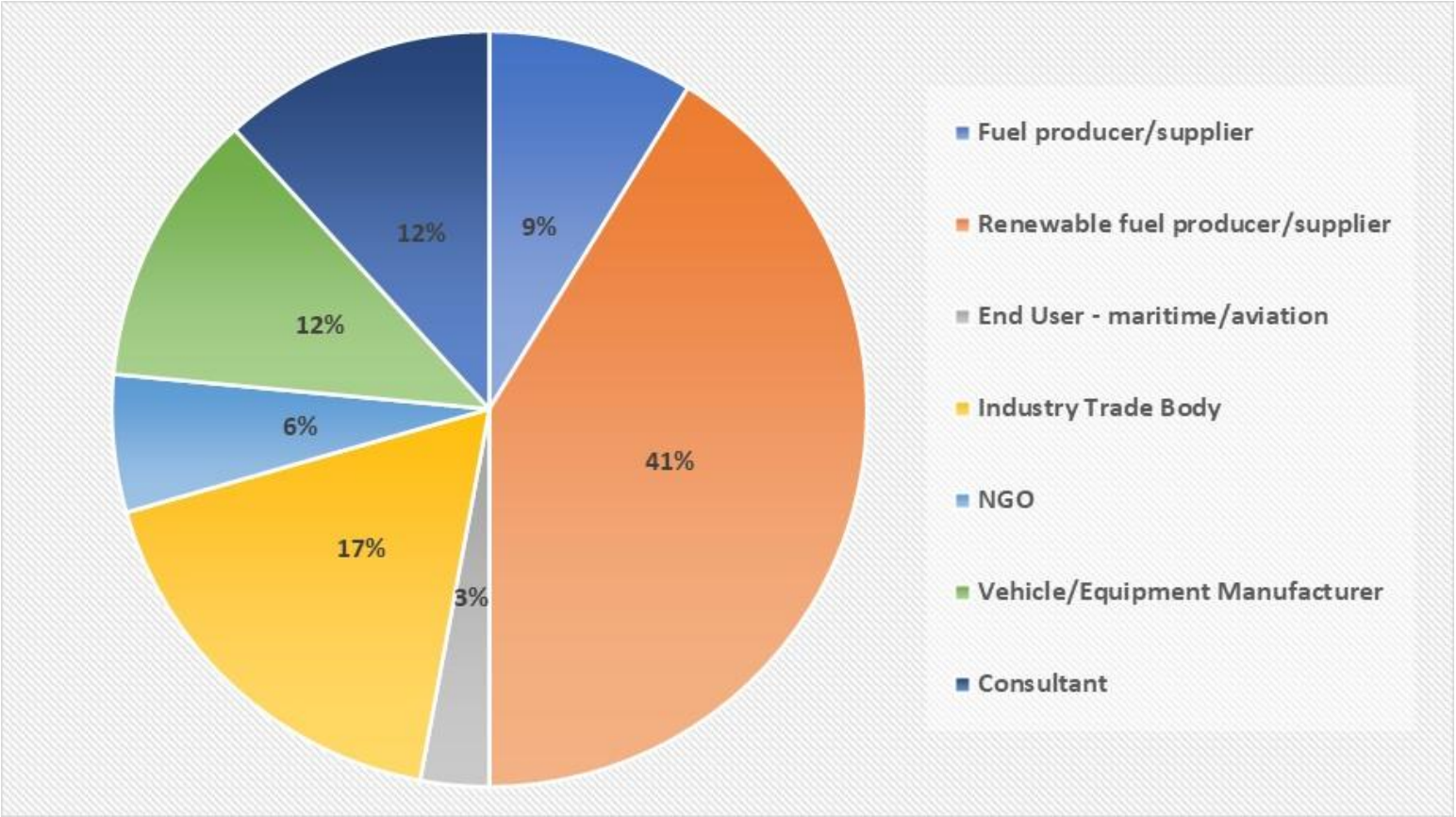
LCF Strategy Workshops

Theme 3:

Shipping and Aviation

Workshop stakeholder analysis

- Theme 3 had a total of 37 attendees.
- The stakeholder groups with the largest representation were ‘renewable fuel producer supplier’ followed by ‘industry trade body’.



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Q1: Role of different LCF 2022 – 2050

Participants suggested the following roles for LCF in the timeframes considered:

Sector	2022-2030	2030-2040	2040-2050
Maritime	Biodiesel blends, drop-in renewable diesel, waste biomass derived fuels, tyre pyrolysis oil, fossil LNG, RCF, bio-methanol, methanol and ammonia.	Biodiesel/renewable diesel, bio-LNG, ammonia, hydrogen, methanol and bio-methanol, potential for e-methanol.	Rise in e-ammonia, liquid e-fuels, green hydrogen, methanol and e-methanol.
Aviation	SAF - waste biomass derived including from HEFA, AtJ, RCF. Early e-Kerosene (PtX).	Increased use of HEFA as road biofuel demand declines. RCF, BtL, AtJ derived SAF. Small volumes of e-fuels including the use of DAC (Direct Air Capture). Hydrogen-electric for both fuel cell and combustion.	Larger volumes of e-kerosene as the primary SAF and increasing waste derived SAF. Use of CCS on SAF plants. Hydrogen. Use of DAC with green hydrogen. Potential developments in SAF, batteries and hydrogen combustion.

- It was agreed that drop-in low carbon liquid fuels will be important given the long lifetime of vessels and aircraft.
- Pathways for the maritime sector are difficult to predict as they are highly influenced by international market and regulations.
- SAF is expected to dominate long haul applications in aviation. There is scope to use other waste materials to produce SAF e.g. end of life tyres.
- There were reservations about the use of hydrogen in aviation. Range is limited due to its low volumetric energy density. There are also H&S concerns around the storage and handling of cryogenic liquids for liquified hydrogen.

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Q2: Influencing factors for deploying LCF

Participants proposed that the following factors would influence end-users in LCF deployment in the shipping and aviation sectors:

End-users

- The higher fuel price of renewable fuels requires incentivisation for the maritime sector.
- Fuel availability, quality and supply certainty.
- Fuel safety, standards and regulations.
- Confidence in life cycle GHG savings. There needs to be a mechanism in place to provide assurance.
- Powertrain technology on board the vessel and confidence of shipowners to make the right choice.
- Shipping companies' clients may have sustainable purchasing/procurement policies requiring a focus on GHG emissions reductions, to reduce the clients' Scope 3 emissions in company reporting.
- International requirements and restrictions.

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Q2: Influencing factors for deploying LCF

Participants proposed that the following factors would influence producers and investors in LCF deployment in the shipping and aviation sectors:

Producers/suppliers and investors

- SAF mandate details are required to focus investors e.g. whether low carbon hydrogen is allowed as a HEFA feedstock.
- Policy and regulatory certainty.
- Confidence in offtake agreement (i.e. knowledge that the fuel produced will continue to be in demand at the required price, commonly factored in at the time of financing). Potential plant funders need certainty that the legislation and guidance will be clear, consistent, and provide a level playing field. This in turn means that the customer for their fuel will be confident to put contracts in place for fuel offtake agreement.
- There is growing importance of ESG (Environmental, Social and Governance) and CSR (Corporate Social Responsibility).
- Government support is needed for CfDs, fiscal incentives and access to development funding for SMEs.
- Airlines committing to purchase SAF prior to implementation of the mandate.

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Q2: Influencing factors for deploying LCF

Participants highlighted several key challenges and risks for LCF deployment in the shipping and aviation sectors:

Challenges and risks

- Scale and development:
  - LCF need to be scaled up to supply huge volumes and many pathways are not yet commercialised.
  - For LCF deployment in the 2030s-40s timeline, production facilities need to be built by the late 2020s/early 2030s.
  - Biodiesel and other LCF should be developed for road transport now and then transition to aviation and maritime.
  - There was some agreement that green hydrogen and ammonia should first be used to decarbonise existing industrial applications requiring these products, before being used in transport applications.
- Competition for feedstocks and fuels from other sectors and internationally:
  - Sectors without other decarbonisation options should be prioritised.
  - E-fuels require cheap renewable electricity.
  - Gasification will be competing with electricity generation for waste feedstocks such as MSW, despite greater potential GHG savings in the transport sector. As a result of this feedstocks are more likely to be used for electricity generation due to the incentives on offer, than to produce transport fuel.
  - SAF will be competing with other sectors for ethanol and low carbon hydrogen.
  - The availability of some feedstocks depends on the rate of electric vehicle deployment in other transport sectors.

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Q2: Influencing factors for deploying LCF

Participants highlighted several key challenges and risks for LCF deployment in the shipping and aviation sectors:

Challenges and risks

- There is a need for infrastructure, especially for bunkering and dispensing hydrogen and ammonia.
    - Pilot fuels, required with LCF for maritime, need separate bunkering and infrastructure.
    - Infrastructure availability in different ports is an issue.
    - Hydrogen storage is challenging (H&S regulations, capacity, etc.).
- Safety and toxicity concerns for fuel on board vessels and aircraft, e.g. ammonia for shipping, hydrogen for aviation.
- There is a potential for carbon leakage/displacement (GHG emissions increase in one country as a result of an emissions reduction by a second country with a strict climate policy).

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Q3: Wider factors to consider for deploying LCF

Participants put forward the following considerations for the deployment of LCF in the shipping and aviation sectors:

- Several examples of international considerations were suggested.
  - Alignment of the SAF mandate with the EU.
  - Co-ordination and complementary targets to drive the uptake of LCF.
  - The national maritime authorities will play a key role in the approval of vessels with zero carbon fuel.
- There may be benefits from SAF in terms of contrail (aircraft vapour trail) formation and the impact of non-GHG emissions on the climate. It is important to consider and follow scientific evidence as it evolves.
- Water use will be relevant for some feedstocks (e.g. biofuels and hydrogen) in water stressed locations.
- There may be trade-offs emerging between the security of energy supplies and sustainability requirements.
- The price of rare earth materials (e.g. lithium, platinum) for hydrogen electrolysers and batteries.
- Waste feedstocks should be used locally.
- Duty cycles of vessels vary significantly depending on the application e.g. ferries are different from cargo transport.
- A strategic network of UK energy hubs could offer infrastructure advantages e.g. in ports.
- SMEs will be the most challenged in terms of making changes on their own.

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Q4: Technology innovation

Participants suggested the following innovations as potential ‘game-changers’ for LCF deployment in the shipping and aviation sectors:

- On-board CCS for maritime.
- Advancements in lithium batteries, in particular offering opportunities for scaling up energy storage for renewable electricity.

The discussions also raised the following points.

- To enable innovation, policy needs to be developed such that it is secure and well structured.
- Stakeholders agreed on the need to get things built, ahead of speculating about ‘game-changers’.
- There needs to be innovation in business models for energy hub integration e.g. a fuel production site also being a location for renewable electricity and hydrogen.

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Q5: How can the LCF strategy, and wider policy, support your industry in achieving net zero?

The workshop participants' responses on strategy and policy were as follows:

- Clear consistent policy across Government is required. This needs to provide certainty, stability and longevity (30 years).
    - Policy should consider the wider net zero agenda and carbon budgets.
    - Policy needs to provide as much long-term certainty as possible to enable investment.
    - Policies must be cohesive e.g. ETS (Emissions Trading System), SAF mandate and RTFO.
    - Clarity is required on definitions for the maritime sector e.g. what does net zero mean for shipping?
    - Clarity is required on the SAF mandate structure, timing and administration.
- Policy and standards should be based on life cycle GHG emissions.
    - Life cycle GHG emissions are essential for comparing technologies and fuels.
- Policy should be technology neutral.
- The international policy landscape is important for shipping and aviation.
    - Net zero depends on global LCF availability and regulations.
    - The UK needs to align with the IMO, otherwise costs will be higher and there is a risk of carbon leakage (GHG emissions increase in one country as a result of an emissions reduction by a second country with a strict climate policy).
    - Government should support domestic production facilities for feedstocks (particularly waste), whilst ensuring the timing and magnitude of incentives is aligned with international markets.

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Q5: How can the LCF strategy, and wider policy, support your industry in achieving net zero?

The workshop participants' responses on strategy and policy were as follows:

- Government needs to send a strong message on the role of LCF in UK decarbonisation and the importance of domestic production.
    - A clear roadmap of the end goal and how to get there, with strategies for each mode is needed.
- LCF policy
    - The RTFO targets need to be extended beyond 2032, with an increasing level of ambition.
    - It may be necessary to merge the RTFO into a combined system, which includes the SAF mandate.
    - The current dRTFC (development Renewable Transport Fuel Certificate) regime should be changed so that waste plastic is used as a feedstock for LCF, rather than EfW (Energy from Waste).
    - The crop-cap has hindered transport decarbonisation and bioethanol should be considered for SAF.
    - The SAF mandate should have an annual, rather than five-year, target.
- The time taken and the delay in confirming RED II was cited as a hurdle in EU LCF deployment. A simple target with simple regulations that everyone understands is needed.
- Fiscal support is needed for shipping demonstration trials.
- Support will be needed for both near-term and long-term solutions, and it is important to consider scalability.

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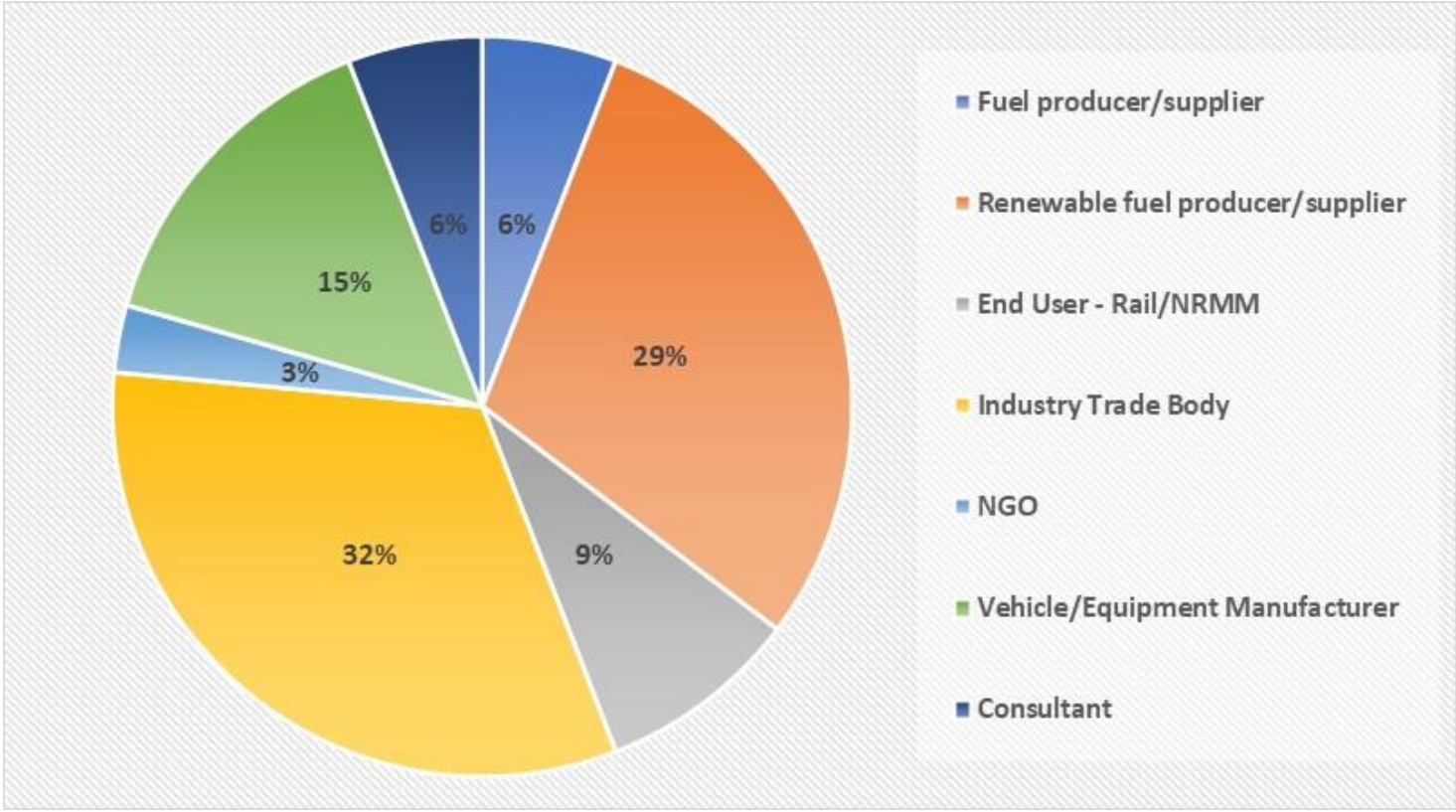
LCF Strategy Workshops

Theme 4:

Rail and NRMM

Workshop stakeholder analysis

- Theme 4 had a total of 39 attendees.
- The stakeholder groups with the largest representation were ‘industry trade body’ followed by ‘renewable fuel producer supplier’.



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Q1: Role of different LCF 2022 – 2050

Participants suggested the following roles for LCF in the timeframes considered:

Sector	2022-2030	2030-2040	2040-2050
Rail	B7, drop-in renewable diesel (e.g. HVO), higher blends of biodiesel, overhead electrification strategies in place (contingent on Government support).	B7, drop-in renewable diesel , biodiesel, dual fuel hydrogen with drop-in renewable diesel, increasing electrification, hydrogen (ICE and fuel cell) for some routes and shunting locomotives.	Wider electrification and hydrogen, drop-in renewable diesel, e-fuels.
NRMM	B7, higher blends of biodiesel (B20), drop-in renewable diesel (e.g. HVO), bioLPG, rDME, biomethane, hydrogen ICE. (Battery electric for certain use-cases.)	B7, higher blends of biodiesel, drop-in renewable diesel, rDME, biomethane, hydrogen ICE and fuel cell, retrofit dual fuel (hydrogen or ammonia with renewable diesel), e-fuels. (Battery electric for certain use-cases.)	Drop in renewable diesel, biomethane, hydrogen ICE and fuel cell, e-fuels. (Battery electric for certain use-cases.)

- Drop-in fuels will be required for a long period, as rail and NRMM equipment is in operation for several decades.
- The use of bioLPG and rDME is currently focused on mobile generators.

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Q1: Role of different LCF 2022 – 2050

In discussing the roles of different LCF in the rail and NRMM sectors, participants raised the following points:

Rail

- Electrification may not be economically viable for rail routes in remote locations or with low demand.
- Freight locomotives are much heavier, travelling at high speed, requiring higher power demand.
- Rail often runs in remote areas without mains electricity supply. Hydrogen supply may also be challenging in remote areas.
- Electrification assumptions need to be confirmed in the Whole Industry Strategic Plan being developed by the Great British Railways Transition Team. The pace of electrification is influenced by the speed of Government investment.
- The use of hydrogen would lead to space constraints on locomotives. Storing compressed hydrogen could require the equivalent of one carriage and make it uneconomic for passenger and freight rail operators.

NRMM

- Duty cycles, durability and size are diverse in this sector. Hence there will be a need for a wide range of fuels.
- NRMM electrification is expected to be limited to small low-power machines that operate on fixed/dedicated sites.
- For hydrogen there may be limited space for bunkering compressed hydrogen on construction sites, making mobile refuelling necessary.
- NRMM can operate in remote locations where supplying hydrogen may be challenging.

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Q2: Influencing factors for deploying LCF

Participants proposed that the following factors would influence end-users in LCF deployment in the rail and NRMM sectors:

End-users

- Economics including fuel price, availability of fiscal incentives and the cost of new equipment or converting existing equipment.
    - Passenger rail is mostly controlled and funded by Government whilst freight rail is run in the private sector, making financing considerations different for new assets. Like the HGV freight sector, rail freight works against tight financial margins, making any increased cost for LCF difficult to accommodate. The asset owner for freight rail varies and could be the freight operator and/or the financier. In a terminal, it could be the customer. Infrastructure networks could be shared with passenger railway or even highways.
    - The cost of biofuels (e.g. HVO) increased when the red diesel rebate was removed, making the adoption of renewable diesel difficult.
- Fuel availability and supply certainty e.g. there is only one small scale producer of HVO in the UK.
- Vehicle warranty implications for higher blends of biodiesel.
- Machine development and availability e.g. hydrogen ICE and fuel cell vehicles/equipment.
- Hydrogen distribution and storage e.g. space constraints on trains, bunkering of hydrogen on construction sites.

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Q2: Influencing factors for deploying LCF

Participants proposed that the following factors would influence producers and investors in LCF deployment in the rail and NRMM sectors:

Producers/suppliers

- Feedstock availability and cost.
- Fuel demand and scalability.

Investors

- There is a need to de-risk OEM and producer investments, support scale up and build confidence for investors.
- Demand side technology readiness. Will the fuel be available, legal and cost effective throughout the asset life?
- Availability of Government subsidies.
- There is a growing trend for finance lenders to be carbon sensitive, with ESG (Environmental, Social & Governance) becoming increasingly influential.

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Q2: Influencing factors for deploying LCF

Participants highlighted several key challenges and risks for LCF deployment in the rail and NRMM sectors:

Challenges and risks

- Availability of, and competition for, feedstocks and LCF:
  - Availability of HVO could be a blocker for rapid deployment due to competition for feedstocks (UCO).
  - Availability of green hydrogen is limited. There is also competition for green hydrogen from other sectors.
  - There is insufficient electricity generation capacity for producing power-to-liquid fuels (e-fuels).
  - Waste feedstocks for rDME may be channelled to SAF, due to incentives.
  - Waste should be used to make LCF rather than incinerated to make electricity. Waste incinerators generate high levels of pollution. Government incentives for energy from waste prohibit the synthetic fuel routes.
- Safety and toxicity aspects related to certain fuels e.g. hydrogen.
- There is a need for infrastructure, especially for hydrogen.
- Policy across Government needs to provide certainty, stability and longevity.
- Assurance of LCF supply chain life cycle GHG emissions and sustainability is needed, as provided by Zemo's Renewable Fuels Assurance Scheme (RFAS).

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Q3: Wider factors to consider for deploying LCF

Participants put forward the following considerations for the deployment of LCF in the rail and NRMM sectors:

- Producing biomethane on farms and using it for agricultural vehicles and generators eliminates transportation (efficiency and GHG improvements). It also provides economic opportunities for local rural communities.
- Fuel compatibility with existing vehicles, equipment and infrastructure.
- The volumetric energy density of the fuel. For example, hydrogen (either compressed or liquified) has a lower volumetric energy density than diesel and therefore requires an increased on-board storage volume for an equivalent vehicle range.
- Customer preferences and purchasing/procurement policies e.g. requirements for the use of low carbon equipment on construction projects, requirements to hire or lease low carbon NRMM equipment.
- Planning permission for hydrogen storage and refuelling takes considerable time and could be delayed by H&S regulations.
- Air quality should not be confused with decarbonisation. Zero Emission Zone deployment may be problematic for decarbonisation in the NRMM sector. Government should not be fixated on zero emissions: very low emissions with significant GHG savings should be acceptable. The best approach is to replace older equipment with that meeting Stage 5 and 6 emission standards. It should be recognised that this is less of an issue in more rural locations.
- The red diesel rebate is a disincentive for lower carbon technologies in rail and agriculture.
- There is a need to increase awareness about new types of drop-in renewable diesel: HVO is not the only product on the market.
- Green hydrogen and ammonia should be used in industry first, then transport.

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Q4: Technology innovation

Participants suggested the following innovations as potential 'game-changers' for LCF deployment in the rail and NRMM sectors:

- It was agreed that anaerobic digesters to produce biogases for fuels should be promoted.
    - There was some disagreement about the optimum use for biomethane produced from anaerobic digestor plants. It was suggested that this should be used for tractors and agricultural vehicles locally. This suggestion was countered with the argument that it may not be viable for smaller farms. Another suggestion was that the biomethane would be better suited for use in heavy long-haul trucks.
- Alternative biogenic waste feedstocks could be used to produce drop-in fuels.
- Improvements in battery technology.
- Advancements in hydrogen electrolysers, hydrogen storage tanks and hydrogen ICE technologies.
- There is an expectation that power-to-liquids will be game changers, however a lot of development is needed to get these fuels off the ground, and they are very expensive.

The discussions also raised the following points:

- There will be a mix of technologies in this sector: there is no 'silver bullet'.
- We should act now where possible, rather than wait for new technologies e.g. convert freight locomotives on rural lines to dual fuel.

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Q5: How can the LCF strategy, and wider policy, support your industry in achieving net zero?

The workshop participants' responses on strategy and policy were as follows:

- There is a need for clear consistent policy across Government, with certainty, stability and longevity.
  - This should provide long-term certainty for investment: assets have 40-60yr lifetimes.
  - Local and regional Government should work together e.g. Clean Air Zones, Zero Emission Zones.
- Policy and standards should use life cycle GHG emissions with a mechanism for assurance in LCF life cycle GHG emissions and sustainability.
- Government needs to communicate a clear message that LCF have a key role to play in decarbonisation.
- Government needs to provide direction, whilst allowing a wide variety of solutions for specific applications.
- Strategy and policy should be technology neutral.
- Clarity is required on the future of new ICE sales for NRMM. Ruling out ICE will not be practical in this sector.
- Strategy needs to consider European policy landscape, to ensure that fuels and feedstocks are not diverted overseas because incentives are better elsewhere.
- Government should foster domestic LCF production, particularly for drop-in renewable fuels.
- Government should provide guidance on LCF and sustainability for SMEs.
- DfT and the Dept for Education should work together on university and technical college training, to address the skills shortage.

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Q5: How can the LCF strategy, and wider policy, support your industry in achieving net zero?

The workshop participants' responses on strategy and policy were as follows:

- The RTFO targets need to be more ambitious and extended after 2032. Targets should be based on GHG emissions rather than volume.
- Policy writing should show an understanding of the scale of investment required to switch to green hydrogen.
- Financial incentives
  - Fuel duty discounts / incentives, with long-term visibility, are needed to encourage LCF uptake, drive demand and improve the business case for investment.
  - The UK needs a mechanism to fund R&D (Research and Development), up to and including pilot plant prove out.
  - Funding is required for trials to demonstrate that train engines can run on high blends of biodiesel.
  - Consortium funding is required for partners to develop regional hydrogen production.
  - Hydrogen vehicles should be supported with a scheme like the DfT ZEBRA (Zero Emission Bus Regional Areas).

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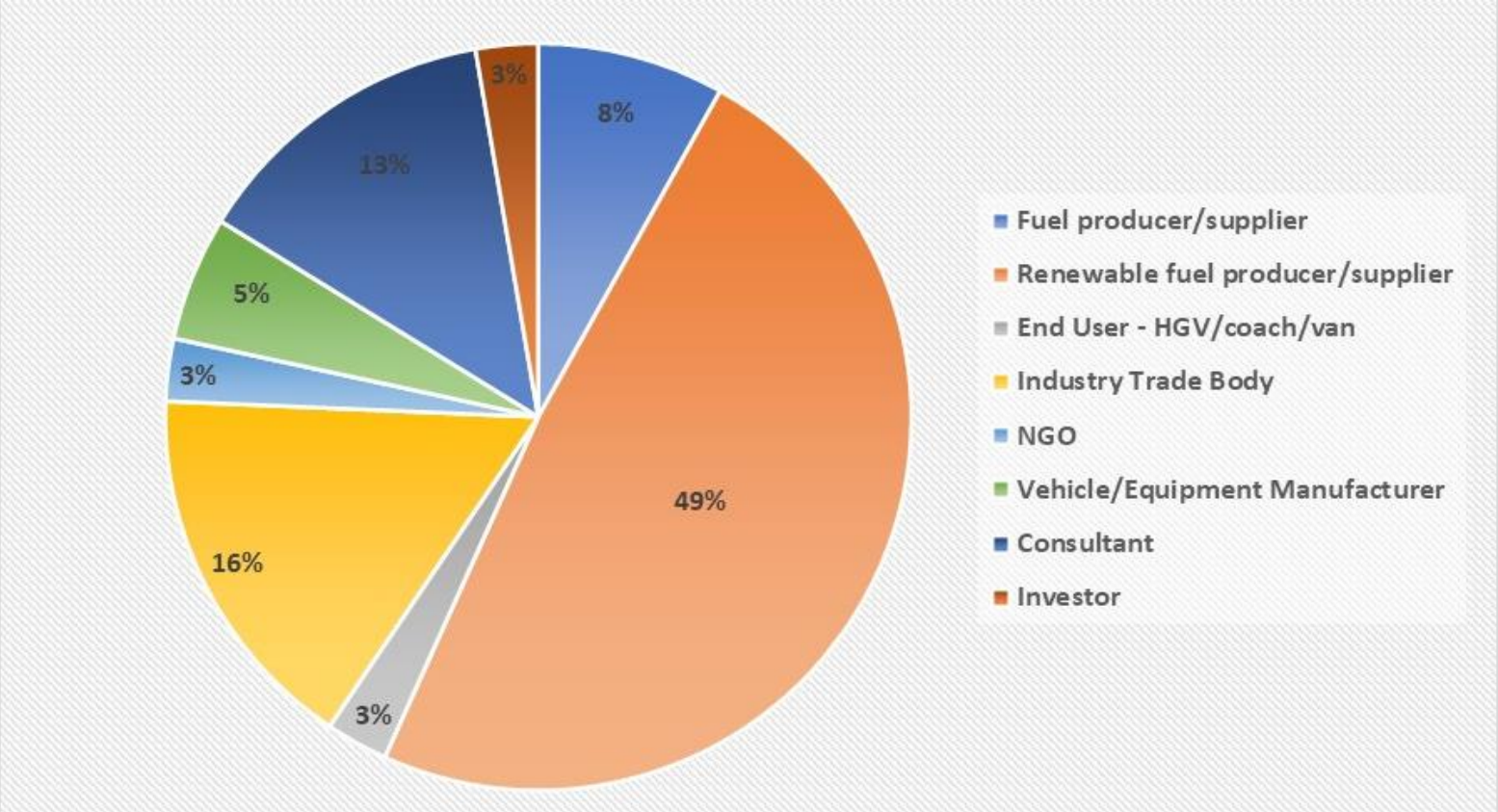
LCF Strategy Workshops

Theme 5:

New Conversion Technologies

Workshop stakeholder analysis

- Theme 5 had a total of 39 attendees.
- The stakeholder groups with the largest representation were ‘renewable fuel producer/ supplier’ and ‘industry trade body’.



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Q1a: Key pathways for LCF in the next 3 decades

Participants thought that a variety of fuels will be relevant. It was difficult to identify consensus on specific pathways as all will have a role to play.

2022-2030	2030-2040	2040-2050
HVO/HEFA (SAF), recycled carbon fuels, bio-hydrogen via waste gasification. MSW will be a key feedstock, the focus should not just be on biogenic feedstocks.	Advanced conversion processes with and without CCS, recycled carbon fuels, bio-hydrogen via waste gasification with CCS, ATT (Advanced Thermal Treatment) processes, fat pyrolysis and gasification.	PtX (e-fuels, including ammonia), recycled carbon fuels, advanced conversion processes with CCS. This requires electrolysis and green electricity costs to come down.

- Biomethane was mentioned as an important transitional low carbon gaseous fuel. The existing refuelling infrastructure could facilitate future deployment of hydrogen e.g. utilising existing CNG/LNG refuelling sites.
- Fugitive methane emissions from farm slurry can be captured and processed to produce biomethane with a negative carbon intensity.

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Q1b: Key technology and market innovations

This question was interpreted differently in each session, resulting in a wide-range of topics being discussed. Participants' suggestions for key technology and market innovations included the following:

- There needs to be a mechanism to support the supply of LCF to market at scale. There is high engineering complexity in assembling plants and early entry to market is proving very challenging due to the large capital costs. Funding is required to get plants built.
- Investment takes time and requires a market signal to move to commercialisation. Having price certainty is critical. CfD has been shown to be effective in the electricity market and could work for SAF.
- Increasing demand through a mandate/obligation will drive the investment for scaling up production.
- Regulation uncertainty is hindering developments. If the UK is not aligned with Europe in terms of the RTFO, this could result in low quality feedstocks and fuel entering the UK market. The EU is moving to a GHG-based policy mechanism and there are risks if the UK does not follow suit.
- Utilising existing infrastructure will save money and reduce the requirement for new steel production. Drop-in liquid fuels offer clear benefits in terms of using existing infrastructure.
- The use of recycled carbon feedstocks can allow comparatively low cost fuel production compared to other feedstocks. A mechanism is required to facilitate the growth of gasification and the advanced fuel industry.
- There is a need for new technology and innovation in the safe handling of ammonia.

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Q2: Challenges and opportunities

Participants suggested the following challenges and opportunities for LCF fuel pathway technologies:

Challenges – Fuel Pathways

Feedstock availability

- UCO availability could be constrained, especially for HEFA if an ambitious mandate is set for SAF (e.g. 10%).
- The demand for biomass for FT pathways is increasing worldwide.
- BTL (biomass to liquid) gasification and FT are very capex intensive and need sufficient feedstock for large scale.
- Processes which produce a variety of products from renewable feedstocks should be prioritised e.g. processes to produce SAF also produce co-products such as bioLPG.
- The eligibility of feedstocks may vary from country to country and will affect economic viability e.g. whether crop-based ethanol can be used for alcohol-to-jet pathways.

Investment

- Some pathways, especially for SAF, are 3-4 times more expensive than the fossil fuel equivalent. This could have a knock-on effect on consumers e.g. air travel. One participant believes that price parity will not materialise.
- There is difficulty in securing finance due to lack of confidence in first commercial projects and exposure to external price shocks. 'Bankable' fiscal support from Government is required e.g. CfD.
- For green hydrogen there is uncertainty around the costs of future electrolysers and low carbon electricity.
- Lack of education, 'bad press' and bias around different technologies are an issue.

Opportunities – Fuel Pathways

- Current ethanol production could be used in alcohol-to-jet pathways as gasoline demand reduces.
- Waste feedstocks such as non-recyclable plastics, tyres and refuse-derived fuel could result in further bio or partially renewable propane production through pyrolysis and gasification routes.

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Q2: Challenges and opportunities

Participants suggested the following challenges and opportunities for LCF infrastructure and supply chain technologies:

Challenges – Infrastructure and Supply Chain

- Strategic highway infrastructure (i.e. biomethane refuelling stations) requires a fast-track mechanism for acquiring planning permission, etc. This should also consider driver welfare facilities.
- The potential for establishing UK SAF plants could be undermined by cheap imports of SAF. This could materialise if regions like the US and Europe, develop their domestic SAF industry at a faster pace than the UK.
- Infrastructure needs to be rolled out in an equitable manner, ensuring there are solutions in place for rural areas.

Opportunities – Infrastructure and Supply Chains

- There may be opportunities to repurpose existing refineries or produce renewable fuel in the vicinity of the feedstock, to exploit local supply chains.
- Drop-in fuels can use existing infrastructure. Various markets will require low carbon liquid fuels for a long time and the renewable content could be increased incrementally. Progress now is imperative to allow time for production to scale up.
- A coordinated and timely job transition for workers with transferable skills, from the fossil fuel sector to UK-based technologies in gasification, CNG refuelling, hydrogen production, etc., could mitigate the risk of a skills shortage.
- Carbon capture capacity in the UK will contribute to producing LCF with the lowest GHG emissions.
- Production of fuel could be a stepping stone for other circular economy options in the future.

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Q3: Key factors guiding investment decisions

Participants proposed that the following factors would guide investment decisions in LCF:

- The international policy landscape. Government needs to encourage inward investment in the UK. The UK is a small market and must present itself as the best place for investment.
- Demand for LCF needs to be stimulated by Government thereby building confidence in long-term market opportunities for LCF in the UK. This will subsequently support the business case for investing in new plant.
- Revenue security for developers and risk allocation (de-risking) for investors and contractors are a big impediment at present, especially for SMEs.
- Policy needs to mitigate the risk to enable scale-up. Investors with the funding to support scale-up look for a steady income e.g. pension funds. The multiple risks in this sector deter them:
    - Market/supply demand risk,
    - Technology risk (this varies e.g. HVO is more mature than hydrogen),
    - Regulatory risk.
- Investment in hydrogen and renewable fuel production facilities requires visibility of the long-term revenue stream. Government must provide consistent policy, stable finance mechanisms and security for 30+ years to secure long-term investment.
- There is a need for a guarantee of carbon price, such as CfD, to drive adoption at scale. Government should let the market decide how to get there (i.e. policy should be technology neutral) with a supportive carbon price.
- Product selection and scale of production are very important, especially when using waste, which needs to be resourced locally.

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Q4: Wider factors affecting developments

Participants suggested the following wider factors and constraints affecting developments in LCF:

Public/Investor education

- We need to educate investors on the demand for LCF in different sectors, long-term policy and GHG performance.
- Government needs to be more vocal in backing LCF. Zero tailpipe vehicle deployment at scale is a long way off and LCF can deliver high GHG savings today.
- Stronger links between academia and industry are required e.g. Advanced Propulsion Centre. The Automotive Council does not include LCF.

Policy consistency between Government departments and Treasury

- Government needs to provide certainty that support mechanisms will not change after 3-4yrs, preventing a return on investment.
- The UK does not have a waste or biomass policy. It is more carbon efficient to use waste for LCF production than electricity generation. This presents challenges in building an industry where waste feedstocks are so important.

Compliance

- There is a lack of a UK 'one-stop shop' clearing house. Going through the ASTM (American Society for Testing & Materials) process for SAF to be accepted as a 10% drop-in, can include sending samples to the US for testing.
- Compliance is expensive, time consuming (e.g. supply chain verification) and will impact investment.

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Q4: Wider factors affecting developments

Participants suggested the following wider factors and constraints affecting developments in LCF:

Competition

- Electricity is required for the primary electricity market, the secondary hydrogen market and the tertiary synthetic fuels market.
- Competition for hydrogen between sectors is hard to preempt (e.g. refining, chemical, steel manufacturing). Additional demand will drive up prices in the short to medium-term. This makes it difficult to see e-fuels as a viable investment prospect in the near future.

Geopolitics

- The war in Ukraine has instigated a desire to move away from Russian natural gas as quickly as possible.
- The supply of rare earth materials e.g. for EVs.

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Q5: How can the LCF Strategy, and wider policy, support your industry in achieving net zero?

The workshop participants' responses on strategy and policy were as follows:

Policies across government need to be consistent, integrated and have longevity.

- All incentives, programmes and regulatory bodies should be in line with the wider Net Zero Strategy.
- It is essential to work with Defra to ensure the UK waste hierarchy accounts for carbon abatement from waste feedstocks. MSW will still be around in 2050 (waste policy).
- The UK planning system needs addressing. The Highways Authority should be linked with infrastructure development.

Policy should include life cycle GHG emissions and aim for technology neutrality. Innovation should be stimulated by a robust policy framework.

- The RTFO should incorporate carbon intensity as a metric ASAP. This will create a level playing field, encouraging investment and innovation. It should also be extended beyond 2032 to provide long-term security.
- Policies should be clear, consistent and consider the long term. There is a need to move with immediacy and pragmatism as the next decade is critical for action. There needs to be a focus on incremental changes that add up and have an impact in the long-term.
- Policy should feature the temporal dimension of carbon abatement: '1 tonne removed today is worth more than 1 tonne removed in 10 years time'.
- The RTFO should be expanded to recognise recycled carbon fuels and carbon capture.
- DfT should provide guidance on additionality and clarify what qualifies as green hydrogen.

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Q5: How can the LCF strategy, and wider policy, support your industry in achieving net zero?

The workshop participants' responses on strategy and policy were as follows:

Government cannot work in isolation from European regulations.

- Government should reduce the time it takes for companies adhering to EU regulations to bring proven technologies to the UK. For example, rCB (recovered carbon black) is covered in Europe under REACH (Registration, Evaluation, Authorisation & Restriction of Chemicals). It takes a lot of time and effort to go through UK processes, making the UK less attractive for companies looking to build subsequent plants.
- Biomethane could be imported from Europe, but the mass balancing requirements are difficult to understand.

Government needs to send out the right messages.

- The 'one size fits all' electrification approach and some departments' wariness towards bioenergy need to be addressed.
- Government needs to lead with a 'don't waste your waste' message to divert wastes to fuels, rather than incinerating them.
- Technology neutrality should be the aspiration. The ban on ICE sales by a certain date does not fit with this.
- Government should demonstrate what the LCF landscape will look like in 2050. Which fuels are still there? Where do traditional biofuels end up (e.g. SAF)? Do they move to other markets (e.g. chemicals) or disappear all together?

Government incentives and funding are required.

- Funding is needed to help innovative businesses with new technology, developing pilot plants and with scaling up.
- Support is needed for infrastructure deployment.
- Fuels that coproduce different types of bioenergy or biofuels should be supported.

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Q5: How can the LCF strategy, and wider policy, support your industry in achieving net zero?

The workshop participants' responses on strategy and policy were as follows:

Government can encourage investment by:

- Offering government-backed loans for commercial demonstration facilities to de-risk investment.
- Ensuring policy is consistent and credible.
- Providing security for long-term investment.
- Introducing a guarantee of carbon price, such as CfD.

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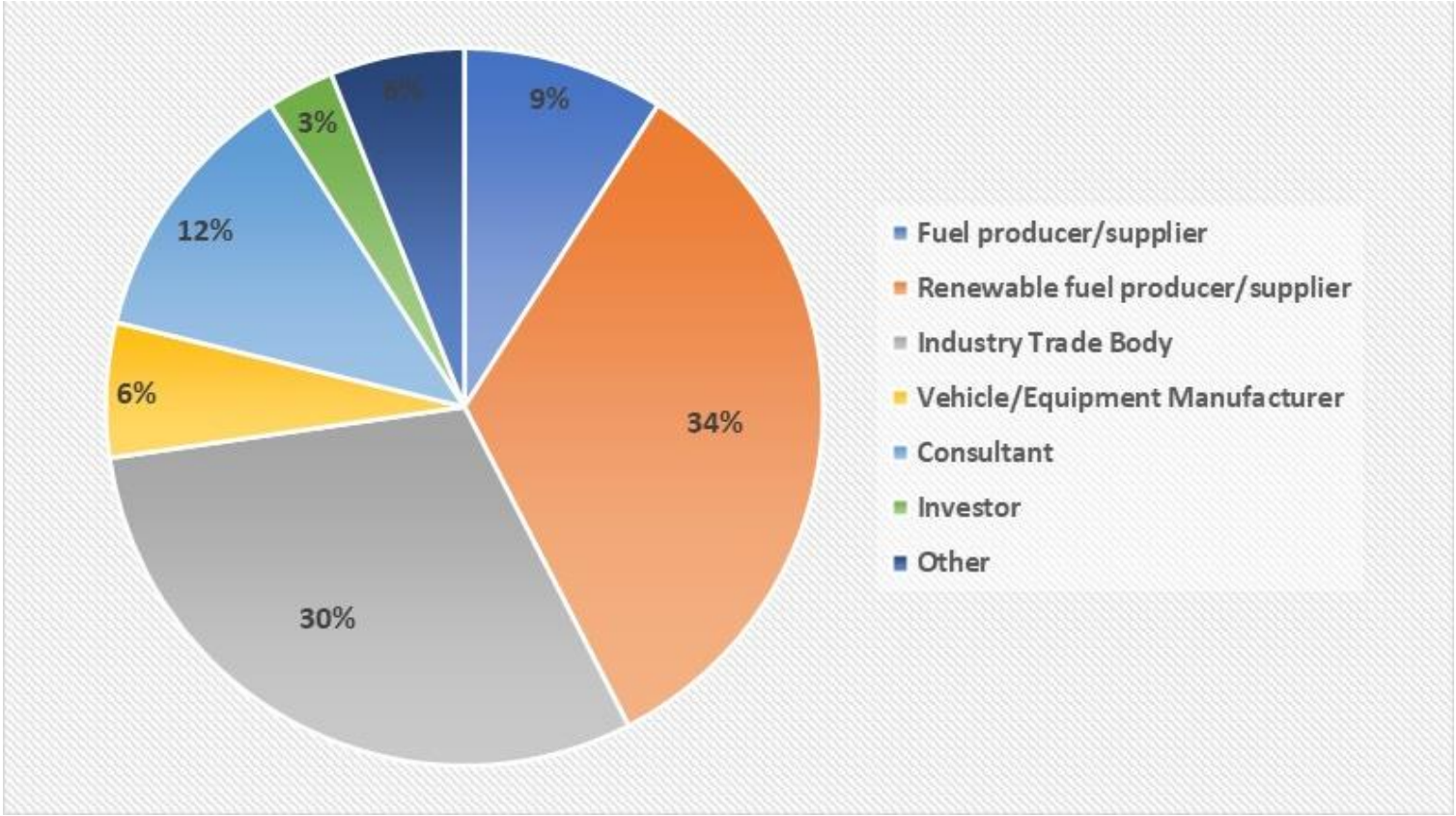
LCF Strategy Workshops

Theme 6:

Maximising Benefits of Existing Industry and Infrastructure

Workshop stakeholder analysis

- Theme 6 had a total of 32 attendees.
- The stakeholder groups with the largest representation were ‘renewable fuel producer/ supplier’ and ‘industry trade body’.



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Q1a: Challenges for adapting to future demand

Participants suggested the following challenges for adapting to future demand in the timeframes considered:

Challenges	2022-2030	2030-2040	2040-2050
Existing LCF production	• Competition for feedstock is discouraging investment. • There are limited volumes of green hydrogen meeting the low carbon hydrogen standard. • Domestic HVO production. • Demand and compatibility of new vehicles is not a UK priority.	• Competition from cheaper imports. • As the aviation mandate increases, SAF production will take the feedstock required for road biodiesel production. • Questions around the longevity of LCF: are they just transitional? • The ability of consumers to adapt to new energy vectors.	• The availability of low carbon electricity. • The availability of finite feedstock resources. • LCF will require continued Government support, so that any emissions from residual ICE vehicles can be reduced.
Storage, bunkering and distribution	• Creating storage infrastructure whilst maintaining existing commitments. • Heritage assets need investment to be fit for LCF e.g. tank linings. • Ease of import from international markets. Customers traditionally operate on a 'top up' basis with distributors sending regular tankers. A mindset change to be smarter and more efficient/green is needed.	• There is a need to standardise and streamline the LCF offering so that storage and distribution infrastructure can be developed to meet future demands. • The demand for hydrogen and ammonia is uncertain. • There is uncertainty around using pipelines to transport hydrogen with the purity required for PEM fuel cells (Polymer Electrolyte Membrane).	

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Q1a: Challenges for adapting to future demand

Participants suggested the following challenges for adapting to future demand in the timeframes considered:

Challenges	2022-2030	2030-2040	2040-2050
Wider supply chain (including refuelling)	• Refuelling infrastructure development is delayed by a dysfunctional planning system. • The lack of demand side guarantees creates a disadvantage for first movers in hydrogen refuelling stations. • LCF GHG lifecycle credibility. • Certain fat types should be promoted as feedstocks for transport fuels - where there is limited demand from animal feed and oleochemical producers, due to consumer preferences for vegetable oils.	• Loss of capacity due to lack of policy commitment. • Bans on ICE vehicles may deter investment and limit availability of LCF. • The cost of carbon capture, especially DAC (Direct Air Capture), is a barrier to PtL (e-fuels).	• Loss of relevance of legacy infrastructure could disrupt supply. Solutions requiring infrastructure change are inherently disruptive. • The availability of feedstocks. • Ensuring sufficient domestic production capacity. • Consideration of different sectoral uses of fuel when generating at scale.
Other	• There is a skills shortage in relation to gaseous fuels, such as biomethane and hydrogen. • The ICE phase-out means that investing in diesel alternatives may not be viable.	• There are inherent challenges for methanol as a transport fuel (e.g. energy density, cost base).	• There is a need to understand where LCF use sits within the wider debate on 'behavioural change' and if there will be continually growing service levels.

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Q1b: Opportunities for adapting to future demand

Participants suggested the following opportunities for adapting to future demand in the timeframes considered:

Opportunities	2022-2030	2030-2040	2040-2050
Existing LCF production	• Higher biofuel blends e.g. B10. • High blend biodiesel (FAME/HVO) can be introduced today, providing OEMs accept. • Expansion of Biomethane production. • Co-processing in existing UK production facilities. • Conversion of existing infrastructure may be more economic than new-build.	• Develop alternative renewable and sustainable feedstocks. • Significant potential for rapid scale-up of indigenous bioLPG production in UK: as a co-product of SAF, at new HVO plants or from establishing gasification and FT synthesis facilities.	• Global incentives for the rapid expansion of green hydrogen could deliver significant GHG reductions.
Storage, bunkering and distribution	• Drop-in fuels can use existing assets. • Installation of more telemetry or 'smart tanks' so deliveries are made as required.	• Production of fuels onsite via electrolysis from a network connection could solve storage problems. • Making LCF options available at retail sites e.g. motorway services.	

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Q1b: Opportunities for adapting to future demand

Participants suggested the following opportunities for adapting to future demand in the timeframes considered:

Opportunities	2022-2030	2030-2040	2040-2050
Wider supply chain (including refuelling)	• Recognise the role of the 6 UK refineries in decarbonisation. • Synergy between electricity networks and refuelling along the strategic road network (EV charging, overhead catenary and hydrogen production via electrolysis). • Encourage bunkering operators to allocate storage for high blend diesels across their networks. • rDME blended into existing LPG refuelling. • Higher blend biodiesel can use existing infrastructure.	• Hydrogen combustion has lower purity requirements than fuel cells. • Development of hydrogen fuel cells. • Green hydrogen supply costs may be reduced by the UK linking into the European hydrogen backbone.	• Niche e-fuel production through UK carbon capture technology. • Wholesale transition to cheap, low carbon electricity.
Other	• Jet demand will continue as there is little alternative to SAF. • CCS allows the production of carbon negative fuels using waste.	• Sustainable biomass feedstocks e.g. residues.	• PtL (e-fuels) can release feedstocks if the UK invests enough in renewable and/or nuclear electricity production.

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Q2: Key factors influencing LCF deployment decisions

Participants proposed that the following factors would influence decisions in LCF deployment:

- To avoid stranded assets, producers and investors need certainty of demand, such as offtake (a purchase agreement often negotiated before the construction of a facility to secure a market and revenue stream for its future output).
- Certainty of price, such as a CfD mechanism.
- Wider capital support e.g. the role of the UK Infrastructure Bank.
- Certainty around the availability of infrastructure. This requires an overhaul in planning permission processes. The lack of space and limited availability of tanks to offer multiple grades of fuel needs to be addressed.
- The availability and sustainability of feedstocks.
- There needs to be long-term policy demonstrating consistency and technology neutrality. A divergence from EU policy could limit the technical solutions supplied in the UK. Clarity is needed on:
    - The future of the RTFO.
    - The role of low carbon hydrogen.
    - The SAF mandate.
    - The wider UK ETS (Emissions Trading System) framework.

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Q3a: Wider factors affecting development and infrastructure

Participants suggested the following wider factors and constraints affecting developments in LCF and infrastructure:

- The planning framework needs to be fit for purpose.
- Life cycle GHG emissions, including the carbon embedded in new infrastructure and recycling vehicles at end-of-life.
- Public messaging is inconsistent: there is a lack of education on biomethane life cycle emissions and too much focus on new undeveloped technology.
- There is a mismatch in waste policy between DfT and Defra. Most waste is either landfilled or incinerated.
- Human factors, such as the cost of living crisis and inequality impacting on societal behavioral changes and increasing the reliance on cheaper fossil fuels.

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Q3b: Challenges and opportunities for fuel storage, bunkering and refuelling infrastructure

Participants suggested the following challenges and opportunities for fuel storage, bunkering and refueling infrastructure:

Challenges

- Lack of OEM warranties for higher blends of biodiesel and bioethanol.
- Multifuel depots (e.g. biomethane and biodiesel) are difficult as today's diesel HGVs can cover multiple use-cases. Ideally new technology would replace diesel, but this must be balanced with continued business operations.
- Avoiding stranded assets requires principled/joined up strategy, covering both vehicles and infrastructure.
- Depot-based infrastructure will happen by default but is capital inefficient, supplies a relatively small number of vehicles, and segregates the market. The alternative is open access infrastructure which is more efficient from a national/collective perspective. However, open access is a difficult investment proposition (who pays for it?).
- Forecourts shared with passenger vehicles cannot just consider trucks, as underground tanks are often shared.
- Driver behaviour will need to change to accommodate new refuelling practices (e.g. drivers will not drive 150 miles without a full fuel tank before leaving the depot).
- Large-scale storage and transportation of hydrogen, including safety considerations. There is a disjointed view of national highways on how to treat developments. There are cost/safety trade-offs in future proofing the gas grid for hydrogen.
- There are a limited number of supply routes for fuels e.g. two gasoline, one diesel, potentially one 10ppm gas oil.

Opportunities

- National road bunkering network mapping, showing stations with the capacity to take multiple grades of diesel, could also supply FAME/HVO.
- Hydrogen ICE could have a position in the transition period, to help build the demand for hydrogen and support the scale-up of production. These vehicles are not limited by shortages in the supply of minerals for fuel cells.

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Q4: How can the LCF strategy, and wider policy, support your industry in achieving net zero?

The workshop participants' responses on strategy and policy were as follows:

- Government policy needs to be implemented urgently. Price support frameworks must recognise the climate emergency and the limited time for competitive opportunity. Stakeholders acknowledged the Government ambition of the last two years but need to see delivery now.
- Strategy should be based on LCF life cycle GHG intensity with a balanced, timely approach to technological neutrality. It should take into consideration feedstock limitations and the unsustainable path dependency of current investable waste disposal means.
- Government needs to overhaul the planning framework for refuelling infrastructure, possibly allowing green-field sites to be developed. The DfT could support building up a landbank.
- Reinforcement of national electricity (and possibly gas) infrastructure needs to continue.
- Upskilling/training is required for engineers to work with biomethane and hydrogen as HGV transport fuels.
- There needs to be alignment between the Net Zero Strategy and incentives/regulation e.g. the RTFO targets are based on volume rather than a GHG obligation.

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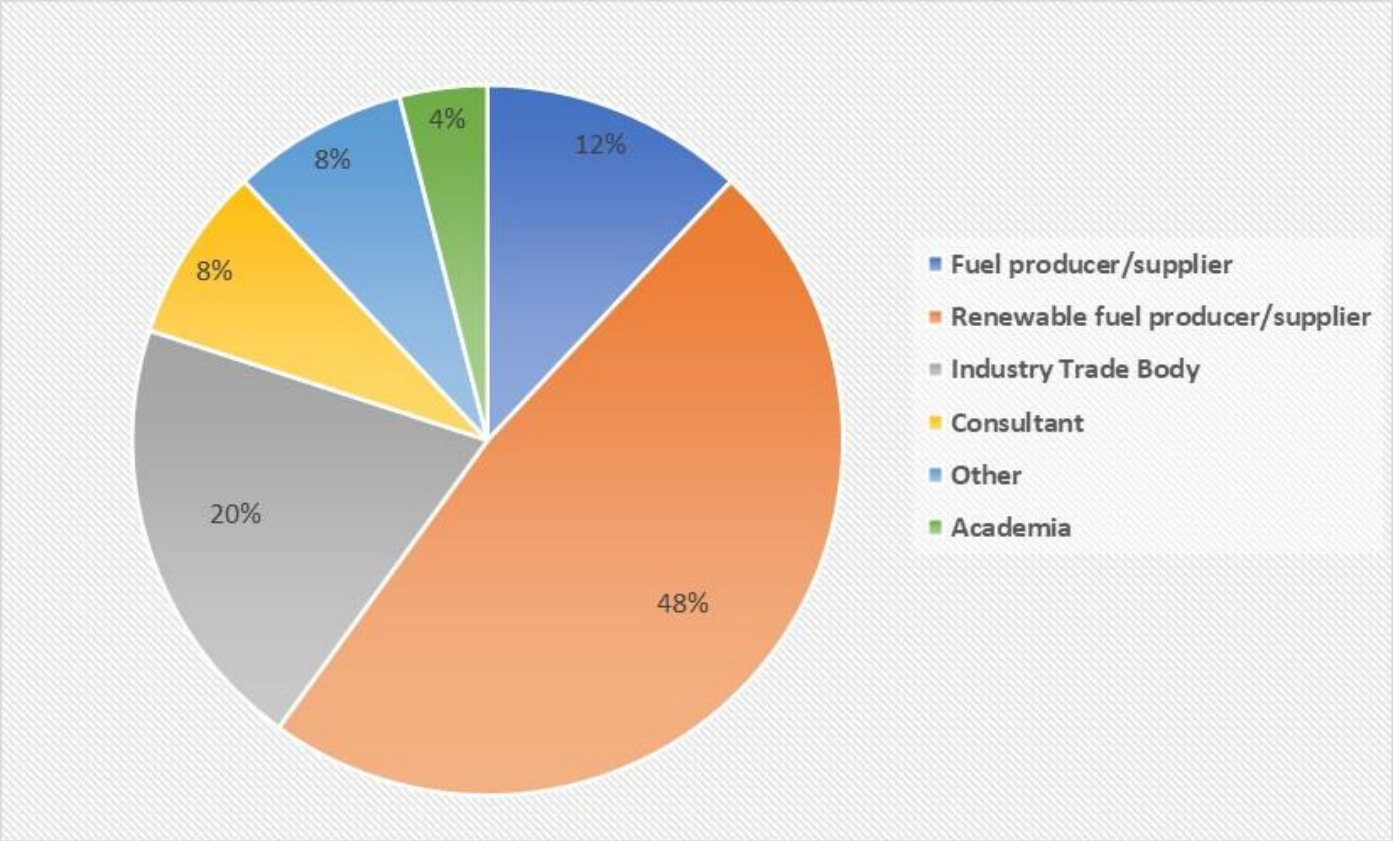
LCF Strategy Workshops

Theme 7:

Local and International Approaches and Supply Chains

Workshop stakeholder analysis

- Theme 7 had a total of 30 attendees.
- The stakeholder groups with the largest representation were ‘renewable fuel producer/ supplier’ and ‘industry trade body’.



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Q1a: Risks of current supply chains and trading arrangements

Participants highlighted a variety of risks associated with current supply chains and trading arrangements:

Sustainability

- Monitoring sustainability across complex supply chains (e.g. risk of UCO being blended with palm oil in S.E. Asia). RCFs, particularly MSW, need to ensure there is a clear traceability procedure that takes place during the filtering process.
- Transitioning from biofuels to more advanced fuels (e.g. aviation fuels) will increase competition and the risk of non-compliance.
- There are concerns about embedded carbon in the global transportation of feedstock and how this could be perceived by public.
- Feedstock availability limitations and high competition in the 2030s could exist between industries requiring the same feedstocks (e.g. biodiesel for HGV and SAF for the aviation industry). Ring-fencing may be required.
- A high degree of imports may make it more challenging to apply robust sustainability and GHG criteria.

International policy landscape

- Following Brexit, the UK is in danger of losing EU sources of feedstock (e.g. more feedstocks reaching Netherlands for HBE, hernieuwbare brandstofeenheden, scheme) and there is additional 'red tape' between EU and UK schemes (e.g. gas mass-balancing creates hurdles to bio-gas certified molecules entering the UK).
- Complexity between different UK, EU and international legislation (e.g. regulatory changes in countries of origin could lead to disruption of imports) creates supply chain uncertainty.
- UK fuel standards need to comply with international standards otherwise we risk restricting markets.
- A delay in UK policy could mean an opportunity is missed.

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Q1a: Risks of current supply chains and trading arrangements

Participants highlighted a variety of risks associated with current supply chains and trading arrangements:

RTFO

- Volume-based targets for transport (as opposed to GHG-based) impact incentives around certain feedstocks.
- A dual system of volume and GHG obligations, as was the case in 2019 and 2020, doubles the administrative burden for suppliers and may not increase total GHG savings.
- Clarity is needed around double counting biofuels.
- The RTFC (Renewable Transport Fuel Certificate) value is a variable that can go down.
- There is uncertainty about whether fuel duty is paid before or after blending.

Infrastructure

- Infrastructure may become stretched as novel fuels come to market (e.g. biodiesel grades may need to be segregated, using separate tanks and pumps).

Security of supply

- The absence of local production, and resources being directed to sub-optimal uses (e.g. EtW), increase supply risks.
- Competition from new plant development abroad is driving local production out of the market. Certainty from policy incentives is needed to encourage the development of plants and secure the feedstock supply chain.
- Feedstocks will generally move to the jurisdiction with the highest incentive, it is therefore crucial that UK incentives under the RTFO/LCF strategy are competitive with other jurisdictions.

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Q1b: Benefits of current supply chains and trading arrangements

Participants suggested the following benefits associated with current supply chains and trading arrangements:

Current supply chains

- LCF can decarbonise sectors which have no current alternatives.
- Drop-in fuels can use the current supply chains. Existing UK infrastructure assets and production facilities should be used.
- LCF create a demand/value/purpose for waste (e.g. biomethane, second generation biodiesel). More suppliers are now coming to market, thus improving the security of supply.
- There is a high availability of feedstock for innovative circular economy (e.g. local farm biomethane production and utilization).
- Robust voluntary sustainability schemes create a strong framework for LCF supply chain sustainability verification. ISCC (International Sustainability & Carbon Certification) and the Zemo Renewable Fuels Assurance Scheme examples identified.
- Supportive waste policy: the incineration tax is moving waste/biomass 'up the hierarchy'.

Trading arrangements

- Fungibility means that there is ability to send LCF to the most favourable markets. This offers benefits to producers and provides access to international feedstocks with common standards and prices.

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Q2: Examples of best practice

Participants suggested the following examples of best practice:

UK 'best practice' mentioned

- UK freeport status provides financial benefits and helped Calor to secure investment for their rDME plant in Teesworks.
- Collaboration between Olleco and McDonalds, to collect used cooking oil and produce B100 for use in delivery trucks.
- The Teesside hydrogen hub focuses on production, supply and usage in an isolated location. It is a good example of linking offshore wind, hydrogen supply and potential demand.
- Projects using tyre pyrolysis to produce recycled carbon fuels.
- The Bennamann 6 farm pilot with Cornwall Council for dairy farms shows good circular economy practice. Wet manure is used in producing biogas with potentially negative GHG. It also provides local economic benefits.
- Zemo's Renewable Fuels Assurance Scheme provides a simple mechanism to verify sustainable LCF supply chains to the end customer: Renewable Fuels Assurance Scheme | Fuels | Zemo Partnership.
- PR campaigns to inform the public about sustainability credentials of specific biofuels e.g. 2020 E10 campaign.

International 'best practice' mentioned

- Fuel duty reduction for HVO in Scandinavia drives demand and hence incentivises supply chain development.
- The Port of Rotterdam has support/funding from Government for CCS, new electrolysis development and hydrogen imports (via ammonia). The port provides all the interconnecting infrastructure.
- EU SAF sub-target for e-kerosene.
- Belgium collects 60% of UCO.

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Q3a: Ensuring availability of feedstocks and LCF

Participants proposed the following to make sure that LCF and feedstocks are available where needed:

Supportive policy

- Undertake a review of routes to compliance for RTFO, to support a mid-term switch of feedstocks e.g. to SAF.
- Review the mass-balancing rules, particularly with respect to Europe, to reduce 'red tape' and unnecessary transport.
- GHG-based incentives need to be competitive with other jurisdictions.
- Time UK Policy announcements, relative to EU and international ones, to ensure the UK attracts investment.
- Extend double counting to more 3rd generation biofuels to support UK projects.
- The RTFO puts a premium for hydrogen into maritime, while other RFNBOs such as ammonia and methanol (which are better for shipping applications) are not incentivised to the same extent.
- Provide clarity on the trajectory for LCF in the short, medium and long term. Further certainty and increases in RTFO targets post-2032 are required.

Managing cross-sector LCF demand

- The demand, or potential demand, for certain fuel types needs to be well modelled across industry.
- Changes to heating regulations to enable rDME and bioLPG to be used in hard to electrify homes and as a diesel replacement.
- Consider efficiency when trying to ensure the right fuel is used in the best application.

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Q3a: Ensuring availability of feedstocks and LCF

Participants proposed the following to make sure that LCF and feedstocks are available where needed:

Support infrastructure where there is a local supply

- Create local supply chain groups to maximise feedstock uses.
- Adopt similar models to the Teesside hydrogen hub. Locate production centres close to feedstock sources and terminals/export facilities. Co-locate refuelling points with production facilities.
- Promote small farm capture of fugitive methane.

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Q3b: Ensuring availability of distribution infrastructure

Participants proposed the following to make sure that the right distribution infrastructure is set in place:

Supportive policy

- Clear, consistent, long-term Government policy is needed to help support investment e.g. road pricing, fuel duties, RTFO. The UK infrastructure strategy needs more detail (the HM Treasury 2020 document was light in this area).

Future distribution

- Long-distance haulage is often between distribution centres: should warehouses move to where fuels are, or vice versa?
- Refuelling solutions need to be built for zero tailpipe emission vehicles in the future, and biomethane vehicles in the near-term.
- Access to land and driver welfare should be considered. Strategic mapping and planning are required.
- Infrastructure for road freight will be needed in huge volumes.

Maximising existing infrastructure

- The UK already has a good system of infrastructure for liquid fuel distribution. This should be retained and supported as part of the transition. rDME and BioLPG use existing LPG infrastructure, so do not require new investment.
- Biomethane feed into the gas grid needs facilitating. Current connection costs are too high and lock out small suppliers.
- During the transition, extra fuel tanks are needed. Supply chain issues and high steel prices make these difficult to obtain.

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Q3b: Ensuring availability of distribution infrastructure

Participants proposed the following to make sure that the right distribution infrastructure is set in place:

Hydrogen

- Development fuel status for hydrogen enables more than just SMR (Steam Methane Reforming): it also enables the market and distribution development that will be needed, by the time CCS infrastructure is available.
- The Netherlands are repurposing redundant gas pipelines to transport hydrogen to the Rhine. The UK has some spare capacity that could be repurposed, but this approach requires caution. Pipework and flanges are prone to fugitive emissions, which are likely to increase if converting to hydrogen. Hydrogen from the grid is lower purity and less relevant for transport.

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Q4a: Role of international cooperation

Participants suggested that international cooperation has a role to play in the following points:

Proof of sustainability

- The EU is creating a large database to trace sustainability of LCF. The UK must be linked into this.
- ISCC (International Sustainability & Carbon Certification) needs to be utilised internationally, recognised by regional mandates and supported by verification/audit compliance.

Vehicle manufacture

- Vehicles are made for multiple markets and common powertrain technologies allow fuel supply and support across different regions.

Policy frameworks in the international context

- All policies need to align. There is a need to understand how RED III is going to be replicated in UK policy.
- Fuel duty should be scaled according to carbon footprint. More applications should be included in the permitted uses (e.g. HVO is not financially viable for heating because the RTFCs have already been double ticketed).

Maritime and aviation

- The UK cannot manage maritime and aviation unilaterally, it needs to be done on a wider basis e.g. UN / EU / IMO / ICAO (International Civil Aviation Organization) / CORSIA (Carbon Offsetting & Reduction Scheme for International Aviation).
- The IMO has nothing to do with fuels production mandates and incentives.
- SAF mandates: if fuel is cheaper in other countries, airlines will practice tankering to avoid fuel refilling costs in more expensive countries. Feedstock volumes will not change but will be pulled in many directions and the total volume of feedstock coming to the UK might decrease.

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Q4b: Decisions made at regional or local level

Participants suggested several decisions that are best made at regional level, and others best made at local level. It was noted that devolved nations should also be considered as responsibilities differ for Scotland, Wales and Northern Ireland.

Decisions best taken at regional level

- Uplift of finished grade from terminals and shared tanks (e.g. consignment stock).
- Local incentivisation of feedstock usage.
- Use of existing fuel supply infrastructure.
- Hydrogen infrastructure planning and strategy.

Decisions best taken at local level

- Establishing local land use priorities (e.g. farming and forestry versus housing, urban needs, waste collection).
- Fast track planning procedures for new transportation infrastructure.
- Support for local schemes i.e. large opportunity in small modular systems that are fed by local feedstocks. Development of this supply chain would be better supported at a local level.

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LCF Strategy Workshops

Appendix

Organisations who attended the workshops

- AB Sugar
- ADS group
- Advanced Biofuel Solutions Ltd
- AECOM
- Aerial Energy Ltd
- Air Liquide Advanced Business & Technologies
- Airbus Group
- Alfanar
- Argent Energy
- Arup
- Beacon Rail
- Bennamann Ltd
- BOC Gases
- BP
- British Sugar
- Broadmanor Consulting Ltd
- Calor Gas Ltd
- Carbon Engineering
- Caterpillar
- CBI (Confederation of British Industry)
- Cerulogy
- CNG Fuels Ltd
- Construction Equipment Association
- Construction Plant-hire Association
- Coryton Advanced Fuels
- Coventry City Council
- CP Catapult
- CPT UK (Confederation of Passenger Transport)
- Cummins Inc
- DAF Trucks Ltd
- DB Cargo UK
- DFA (Downstream Fuel Association)
- DHL
- Dimeta B.V.
- Drax
- E4tech
- Eddie Stobart Ltd
- Element 2
- Energy UK
- Enerkem Inc
- Enertecgreen Ltd
- Ensus
- Equinor
- EST (Energy Saving Trust)
- European Tire Recycling
- ExxonMobil
- FABRA UK (Foodchain & Biomass Renewables Association)
- Fichtner Consulting
- Fulcrum BioEnergy
- Gasrec Ltd
- GHD
- Green Biofuels Ltd
- Green Fuels LTD
- Green Lizard Technologies Ltd
- Greenergy Fuels Ltd
- Heathrow Airport
- Highnam Assist
- HS2
- Hydrogen UK
- HydroGenus Ltd
- ICL (Imperial College London)
- Iogen
- ITM Motive

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Organisations who attended the workshops

- Jaguar Land Rover
- JCB
- John Lewis Partnership
- Knight Frank
- LanzaTech UK
- Leicestershire County Council
- Liquid Gas UK
- Logistics UK
- Lubrizol Ltd
- MCIA (Motor Cycle Industry Association)
- Mercedes-Benz Trucks UK Ltd
- Miralis Data Ltd
- Mitsui & Co Europe Plc
- National Express
- National Farmers Union
- NGET (National Grid Electricity Transmission)
- NNFCC
- Northern Trains
- Nottingham University
- Olleco
- OMNI Conversion Technologies
- Orsted
- Pavilion Energy
- Pennine Energy Group Ltd
- Petrol Retailers Association
- Phillips 66 Ltd
- Port of London Authority
- Pure Energy Professionals Ltd
- REA (Association for Renewable Energy & Clean Technology)
- Reaction Engines Ltd
- Reynolds
- RFG (Rail Freight Group)
- RHA (Road Haulage Association)
- RSSB (Rail Safety Standards and Board)
- RTFA (Renewable Transport Fuel Association)
- Sainsbury's
- SCE
- Scottish Government
- Shell
- SMMT (Society of Motor Manufacturers and Traders)
- Transport & Environment
- Travis Perkins PLC
- UK Chamber of Shipping
- UK Material Handling Association
- UK Warehousing Association
- UKIFDA (UK and Ireland Fuel Distributors Association)
- UKPIA (UK Petroleum Industry Association)
- Unica
- Uniper Technologies Ltd
- Valero Energy Ltd
- Velocys Plc
- Vitol
- WFL UK Ltd
- Williams Advanced Engineering
- Wincanton
- ZeroAvia

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