UKPIA

UKPIA Input into the Transport Decarbonisation Plan

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1. Transport: Energy Provision, Storage, and Conversion

1.1. The Greenhouse Gas Emission Reduction Challenge

As highlighted in the Department for Transport's (DfT) 'Decarbonising Transport: Setting the Challenge' document[1], transport is now the highest in-use emissions producing sector in the UK. Whilst efficiency improvements in internal combustion engine (ICE) technologies have improved average per-vehicle emissions, overall miles travelled have increased. Evidently, transport has proven a stubborn sector to decarbonise in the UK.

Additionally, given the resource demands of transport products, transport also has significant cradle-to-gate greenhouse gas (GHG) emissions[2] that must be accounted for. Currently, all motored transport modes have a lifecycle GHG emissions impact – even if their tailpipe GHG emissions may be zero. This is an important principle to recognise in the development of any transport decarbonisation strategy – the UK's transport GHG emissions footprint extends far beyond what is emitted from a vehicle's tailpipe.

The scale of this challenge therefore necessitates the need for a holistic, systems approach to energy uses and vectors. The DfT's Science Advisory Council (SAC) highlight in their position regarding transport research and innovation requirements to support the decarbonisation of transport that the challenge must be viewed through the lens of energy vectors and the net GHG emissions impact of these energy vectors. [3] This principle is also highlighted by the Energy Systems Catapult (ESC) in their 'Innovating to Net Zero' report[4] - a whole systems approach to energy uses and vectors must be adopted to understand and address the challenge.

Whilst such an approach may not perfectly align with existing transport regulatory frameworks – these are generally focussed only on in-use *or* well-to-tank (WTT) emissions – this is a technically robust approach that focuses on the shared objective of net GHG emissions reductions across the whole economy. In an environment of many powertrain technologies - each presenting advantages and disadvantages - a high-level assessment via energy vectors should provide greater clarity on technology fitness for purpose. This can then be combined with transport lifecycle GHG emissions-based policy to enable the lowest net GHG emission energy vectors to be deployed in the most cost-effective manner.

Climate scientists are clear that GHG reduction opportunities missed in the short-term will be more difficult and costly to abate in the long-term. In this document, which sits along our previous letter and workshop input to inform the TDP, the suitability of different energy vectors will be explored according to duty cycle and range demand and then linked to transport mode as set out in the 'Setting the Challenge' document.[1] We hope this helps the DfT to swiftly develop technology neutral, practical policy proposals and a coordinated plan for decarbonising transport.

1.2. Transport Energy Vector Provision in the UK

All motored transport is dependent on both energy transfer and the conversion of energy into work. Unless the energy transfer can be conducted during operation – such as via overhead catenary systems (OCS) for electrified rail – on-board energy storage is also a critical dependency for transport. This combination results in even greater complexity than the significant infrastructure challenge of supplying electricity from point to point.

[1] Decarbonising Transport: Setting the Challenge, DfT, March 2020
[2] Understanding the life cycle GHG emissions for different vehicle types and powertrain technologies, LowCVP, August 2018
[3] Position on transport research and innovation requirements to support the decarbonisation of transport, DfT, June 2020.
[4] Innovating to Net Zero, Energy Systems Catapult, March 2020

In 2018, the UK's transport sector consumed 663 TWh of energy, of which more than 99% was provided by petroleum and bioenergy products, with the remainder electricity.[5] To date, prioritisation of movement at the lowest cost has led to the proliferation of transport powered by chemical energy from fossil-derived fuels in most sectors – economic growth itself can be a technology neutral policy. The additional and urgent priority to reduce net GHG emissions of transport highlights the need to reduce the use of fossil-derived fuels and embrace the range of technologies available to meet the scale of demand currently supplied by crude oil derived energy.

Therefore, there needs to be focus on *fit-for-purpose* energy transfer, storage, and conversion – decarbonising transport pragmatically and at the lowest cost per tonne of CO_2 abated to maximise emission reductions and consumer adoption. The primary energy vectors available for transport include:

- Liquid fuels
- Carbon-based gaseous fuels
- Hydrogen
- Electricity

UKPIA's members have experience with all of these energy vectors, with many already offering provision of non-liquid fuel energy vectors to consumers. Our sector also has demonstrable expertise in understanding the net well-to-tank (WTT) emissions of energy vectors through its increasing deployment of renewable fuels – an area where we already enjoy close partnership with government.

Furthermore, our sector plays a crucial role in enabling the storage of electricity, with the UK being one of few major producers of high-grade graphite coke for anodes in lithium ion batteries. Currently, this material is exported in large quantities to China for battery manufacture, however, with the right policies, there could be opportunity to support and integrate into a domestic energy storage manufacture industry.[6] This is one example of the importance of a systems based approach to decarbonisation where such interdependencies can be understood.

The International Energy Agency (IEA) are clear that "a broad range of different technologies working across all sectors of the economy" will be required – including a combination of the aforementioned energy vectors – to have a chance of achieving net zero GHG emissions.[7] As one of the only sectors with experience across the breadth of energy vectors, the downstream sector stands ready to support decarbonised energy vector provision in the UK.

In addition, whilst we diversify the types of energy storage and conversion, we must also ensure we minimise the energy demand for transport. Minimising transport requirements (such as reduced commuting), integrating transport systems (such as multi-modal routing), and aggregating journeys (such as by pooling and consolidation centres) will all play their part in ensuring UK transport is decarbonised as rapidly as possible whilst maintaining options for the consumer and economic growth.

1.3. Other Environmental and Socioeconomic Impacts

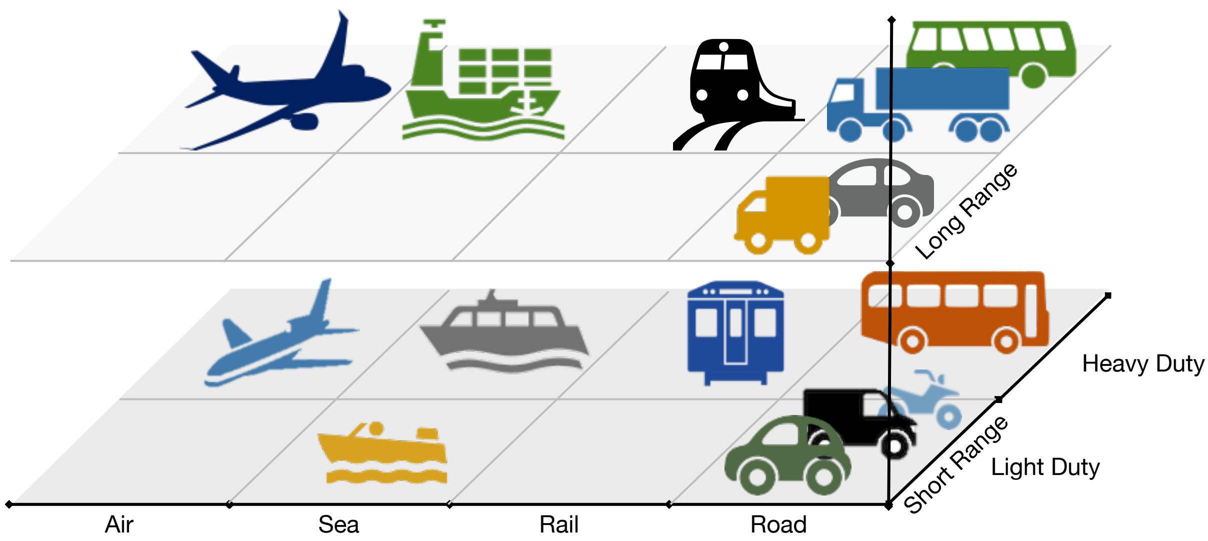
Whilst the focus of the TDP is appropriately on the decarbonisation of transport, other potential impacts of policies seeking to accelerate energy vector transitions should also be considered, in particular, the environmental impacts and sustainability of new technologies at scale. Here for example, the increased manufacture of battery electric vehicles (BEVs) has implications for the availability of rare earth metals[8] and graphite and their recovery and recycling from end-of-life batteries – with the possibility of inadvertent impacts on other

[5] Digest of UK Energy Statistics, BEIS, 2019
[6] The Economic Contribution of the UK Downstream Oil Sector, UKPIA, 2019
[7] Energy Technology Perspectives 2020, IEA, July 2020
[8] https://www.nhm.ac.uk/press-office/press-releases/leading-scientists-set-out-resource-challenge-of-meeting-net-zer.html

environmental and sustainability factors if not regulated appropriately.[9] Additionally, one must remain wary of shifting the risk of energy dependency – a well understood variable – to the risk of supply chain dependency by inadvertently favouring a single technology type.

2. Summary of Transport Modes and their Energy Demands

The chart below summarises transport modes according to relative duty cycle and operational range and seeks to highlight, at a high level, key input data when assessing the suitability of energy vectors moving forward.[10] This concept aims to support the pathways suggested in the following sections to aid the DfT in identifying the key considerations for the TDP. Please note that range and duty cycle comparisons are relative within the transport medium (e.g. short range for aircraft is different to short range for road vehicles).



Identification of the transport modes and their supporting rationale are stated in the table below:

Road	**Passenger Car**	The primary consumer transport mode accounting for 77% of the distance covered by consumers in 2019.[11] The majority of journeys are <10 miles with vehicles featuring lower utilisation and mass movement demands.
	Urban and Sub-Urban Van	One of two key transport modes for movement of goods and services equipment in cities and towns. Energy demands are similar to that of passenger cars other than potentially greater levels of utilisation.
	Powered Light Vehicle (PLV)	The other key transport mode for the movement of goods in cities and towns. Also used for personal transport. PLVs represent <0.5% of UK transport GHG emissions[12] and therefore are not discussed in detail in this document.
	Bus	Primary urban and sub-urban public transport mode with some longer-range rural routes also deployed. Duty

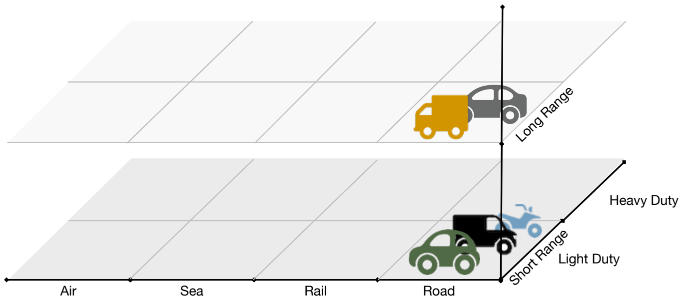
[9] Life Cycle CO_2e Emissions from Electric Vehicle Production and Wider Sustainability Impacts, Ricardo, July 2020
[10] UKPIA analysis based on typical vehicle energy demand
[11] National Travel Survey: England 2019, DfT, August 2020
[12] 2018 UK Greenhouse Gas Emissions National Statistics, BEIS, 2020

		cycle is more energy demanding than aforementioned vehicles owing to greater vehicle mass and highly transient speed demands.
	Large Van and Rigid Axle Lorry	Vans and small lorries supporting higher payload and distance requirements. Energy demands greater than that of smaller vans and passenger cars with longer periods of utilisation.
	High Mileage Car	Small proportion of passenger car segment – primarily utilised for commercial purposes. Greater average distances incorporating more highway use.
	Coach	Long-distance bus mode with reduced transient speed demands but greater range demands.
	Heavy Goods Vehicle	Primary road freight mode with significant energy demands owing to payload and distance requirements.
Rail	**Commuter Rail**	Fixed route transport for urban and suburban passenger transport. Efficiency gains compared to road transport due to removed tyre deformation resistance. High energy demands due to vehicle mass requirements.
	Intercity and Freight Rail	Longer-range fixed route transport for intercity travel. High energy demands due to vehicle mass and distance requirements.
Sea	**Light and Leisure Boat**	Small boats with low energy and range demands. Light and leisure boats represent <0.5% of UK transport GHG emissions[12] and therefore are not discussed in detail in this document.
	Inland Waterway or Port Ship	Larger ships used for inland transport (such as river passenger ferries) or port activities (such as tug boats). Greater energy demand owing to vessel mass generally required over short distances.
	International Shipping	Freight ships with high energy demand to meet significant mass movement requirements over long distances.
Air	**Domestic Aviation**	Aircraft meeting domestic/local aviation demand. Aircraft mass is lower (reduced passenger occupancy) and journeys are typically 350-500 miles.[11] Greater energy demand per unit mass moved compared to surface transport modes.
	International Aviation	Aircraft meeting international aviation demand. Aircraft are larger and heavier with greater passenger occupancy requiring significant energy demand for the smallest mass and volume possible.

The following sections will seek to highlight illustrative decarbonisation pathways for the different modes based on their energy vector demands.

3. Road

3.1. Light Duty



As the most prevalent vehicle type in the UK, and most significant source of road energy vector demand, a range of technologies will be needed to meet the scale of demand and variations in range demand.

The first phase of any decarbonisation pathway should curtail the unnecessary proliferation of oversized vehicles, which have resulted in an increase in GHG emissions in recent years[13], a trend that can be reversed. This can be achieved by scaling vehicle taxation and licensing costs based on efficiency variables such as weight, drag coefficient, and tailpipe emissions. HMT's renewed interest in the area of vehicle taxation, such as the recent VED call for evidence, provides an excellent opportunity for such reforms. The WTT GHG emissions of road transport can also be readily reduced by increasing the low carbon fuel content of the UK's fungible fuel mix – through fuels such as bio-oxygenates and hydrogenated vegetable oil (HVO) which already form part of the UK fuel mix via policies such as the Renewable Transport Fuel Obligation (RTFO).

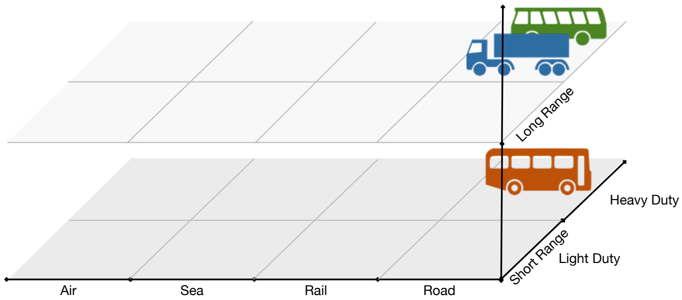
In parallel, further low carbon liquid fuel development and EV and hydrogen infrastructure improvements can take place, ensuring energy vectors are brought closer to net zero and consumer concerns regarding charging can be alleviated. OEMs and government can provide clear assurances that used battery life need not be a concern to increase the momentum of a used EV market and encouragement of fleet renewal will ensure the oldest, least efficient vehicles are replaced with suitable modern vehicles.

Lifecycle CO_2-focused vehicle policy is then implemented, most likely achieved by incorporating well-practised cradle-to-gate, well-to-tank, tailpipe, and end-of-life emissions models. This, combined with increased use of mobility as a service, results in new light duty vehicles that are likely in the majority to be electrified with ICE vehicles operating on very low carbon or climate neutral fuels for longer range applications. Electric vehicles powered by a mix of battery and hydrogen fuel cell systems, lead to the co-existence of multiple powertrain technologies.

Further information on a suitable pathway to decarbonising light duty road transport, and the opportunities and barriers to applicable energy vectors, may be found in UKPIA's response to OLEV's consultation on ending the sale of new vehicles utilising ICEs.

[13] https://www.iea.org/commentaries/growing-preference-for-suvs-challenges-emissions-reductions-in-passenger-car-market

3.2. Heavy Duty



Heavy duty vehicles in the UK are consistently reliant on volumetrically energy dense fuels such as diesel due to their payload and mass requirements. However, passenger transport heavy duty vehicles generally operate different operational ranges and levels of transience within their duty cycles providing greater suitability for other energy vectors.

Urban and sub-urban bus routes are likely to be well-placed to transition to an alternative energy vector - contingent on suitable infrastructure being implemented – owing to their shorter range requirements and return to dedicated depots. Both electric and hydrogen fuel cell buses may be suitable with both technologies already implemented and growing in the UK bus parc.[14,15] Longer routes are likely to be best served by low carbon liquid fuels owing to increased energy density requirements, but may eventually be served by hydrogen should sufficient low carbon supply become available.

Coaches also require larger operational ranges and feature a further barrier to energy vector transition - they are generally refuelled on the publicly available re-energising network. Therefore, the most readily available decarbonised energy vector for this transport mode is low carbon fuels whilst a suitable hydrogen refuelling infrastructure is implemented that could then enable hydrogen as an energy vector. These powertrains are subsequently likely to coexist. Policies to encourage coach operator fleet renewal should support replacement of the oldest powertrain technologies with modern, efficient coaches.

Heavy goods vehicles (HGVs) are the most energy density demanding sector of road transport with particular sensitivity to energy vector storage and conversion volume (due to payload requirements) and suitable re-energising coverage across the major road network. HGV ICEs are typically the most efficient available in road vehicles (up to 47% thermal efficiency) with efficiencies expected to continue to improve through the 2020s and 2030s.[16] The volumetric efficiency of high energy density liquid fuels and their conversion into work results in few readily available energy vector transitions available.

Even optimistic energy density predictions for batteries indicate future specific energies an order of magnitude below liquid fuels – including accounting for ICE's conversion efficiency.[17] Therefore, electricity is only likely to become a suitable energy vector for HGVs if in-journey charging, such as via OCS, is possible. Such an approach would be a significant infrastructure undertaking – costing at least £20 billion[18] to implement not accounting for the additional costs of disruption during construction.

Hydrogen offers a more technically viable route for an energy vector transition for HGVs, but faces significant infrastructure and supply barriers.[18] There are currently a great number of unknowns associated with hydrogen supply to vehicles at scale – including whether said hydrogen can be consistently produced with WTT GHG emissions significantly lower than

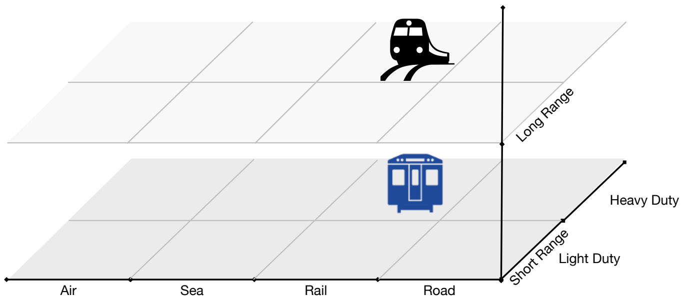
[14] https://www.london.gov.uk/press-releases/mayoral/london-has-europes-largest-electric-bus-fleet
[15] https://fuelcellbuses.eu/public-transport-hydrogen/uk-become-pioneer-development-hydrogen-fuel-cell-buses
[16] Thermal Propulsion Systems Roadmap, Automotive Council UK & APC UK, February 2018
[17] High-energy Battery Technologies, The Faraday Institution, January 2020
[18] Zero Emission HGV Infrastructure Requirements, Committee on Climate Change, May 2019

renewable fuels, although electrolysis using 100% renewable electricity could clearly offer zero WTT and tailpipe GHG emissions for this sector.

Supporting the provision of low carbon liquid fuels for HGVs may prove a highly cost-effective means of decarbonising HGVs, including the existing vehicle fleet. There are proven renewable fuels such as fatty acid methyl ester (FAME) and HVO that can be increasingly utilised. In addition, ownership and regulatory models of HGV fleets present opportunities to introduce policies that stimulate low carbon fuels development. For example, requiring HGV manufacturers to comply with a fuel decarbonisation credit target – a target independent of obligations under the ETS - could stimulate otherwise economically unviable energy vector decarbonisation projects.[19]

Furthermore, connected vehicle developments such as platooning can offer further energy efficiency benefits – reducing overall energy vector demand. The European Commission Horizon 2020 'ENSEMBLE' project aims to demonstrate a functioning platooning programme in the early 2020s.[20]

4. Rail



4.1. Short Range

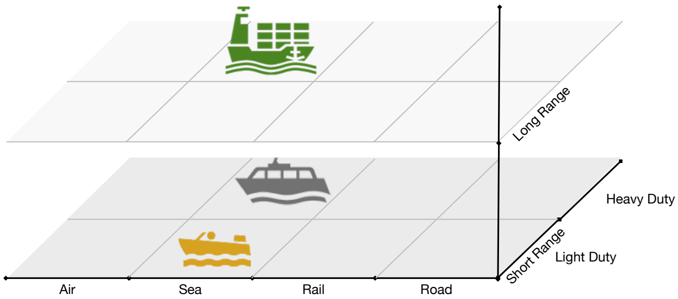
The combination of fixed, shorter routes in developed areas means short range rail such as trams, subway/metros, and commuter rail are well-placed to be electrified via OCS. Negating on-board energy storage requirements as far as practicable and decarbonising the provided electricity offers an efficient route to the decarbonisation of short-range rail.

4.2. Long Range

Intercity and freight trains are also well-placed to be electrified via OCS due to their fixed routes and the energy efficiency benefits of such a system better realised in such heavy duty applications. However, approximately 28% of UK rail routes remain diesel operated[21], with infrastructure challenges presented in electrifying these routes (predominantly due to their rural locations). Increasing the low carbon fuel content of this 1.7 billion litre per year rail energy vector[6] used to power these routes presents a readily implementable, short-term solution to decarbonising non-electrified rail. Such an approach could prove to be transitional until suitable OCS infrastructure is in place, or long-term for difficult/cost ineffective routes. 100% renewable electricity derived hydrogen (also known as green hydrogen) may present a lower GHG emission alternative to low carbon fuels if the technology can be packaged effectively with suitable supply infrastructure available.

[19] Truckin' On, Cerulogy, March 2019
[20] ENSEMBLE Regulatory Framework – State of the Art, EC Horizon 2020, February 2019
[21] Why does the government keep halting rail electrification schemes?, IMechE, May 2019

5. Sea and Inland Waterway



5.1. Short Range

Short range vessels are typically used for domestic activity in inland waterways and port operations. Batteries are already used on many short range vessels to power ancillary equipment, with an increasingly 'hybridised' approach likely to be adopted by intermediate size vessels. There is also increased focus on the use of sails to reduce energy vector demand for short range ships.[22]

Sea and inland waterway vessels are readily classified by their ranges, with bunkering intervals considered a key consideration for vessels and their utilised energy vectors. Inland waterway and port vessels are typically bunkered within a day, which means such vessels could feasibly be transitioned to hydrogen as an energy vector – perhaps batteries if operational intervals are shorter.[23] Longer range and/or heavier vessels may still continue to require the use of liquid fuels – these should be low carbon across their lifecycle.

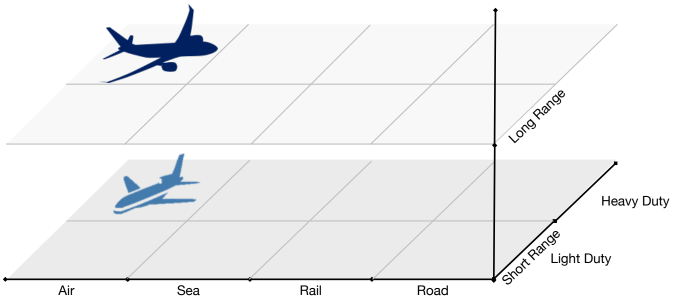
5.2. Long Range

International shipping carries approximately 90% of world trade by volume and has integrated itself as an essential route for trade[24]. The International Maritime Organisation (IMO) have set GHG emissions targets for international shipping by 2030 (40% reduction in carbon intensity) and 2050 (70% reduction in carbon intensity and 50% absolute reduction).[25] The combination of energy demand, energy storage, and payload demands of international shipping present significant challenges to transitioning energy vector in the maritime sector.

Increasingly operators are opting for liquified natural gas (LNG) as a low carbon intensity energy vector.[23] However, LNG is still a fossil-derived energy vector, therefore will need to be transitioned to a low carbon alternative. Two-stroke shipping engines are well placed to utilise low carbon liquid fuels as they move to decarbonise, with the only technically viable low carbon energy vector alternative likely to be hydrogen utilising ammonia as a carrier.[26]

[22] Reducing The Maritime Sector's Contribution To Climate Change And Air Pollution, DfT, July 2019
[23] Maritime Forecast to 2050, DNV GL, 2019
[24] Raising Ambition to Reduce International Aviation and Maritime Emissions, The New Climate Economy, April 2016
[25] Action To Reduce Greenhouse Gas Emissions From International Shipping, IMO, April 2018
[26] Ammonia: Zero-Carbon Fertiliser, Fuel And Energy Store, The Royal Society, February 2020

6. Air



6.1. Short Range

In brief, aviation presents the most significant energy demand per kg travelled. With no viable alternative to jet engines identified[27], and strict energy vector quality control measures[28], aviation is the most challenging mode to decarbonise with few alternatives to kerosene-type fuel as an energy carrier.

Fortunately, such fuels can be made with low WTT GHG emissions – sustainable aviation fuels (SAFs) are already utilised in some markets[29] with its use expected to rapidly grow as the aviation sector seeks to further decarbonise.[30] It may be possible that the shorter range and in-air utilisation of domestic aviation aircraft technically permits the use of batteries or hydrogen as energy storage for electrified aircraft.

6.2. Long Range

However, such an approach is likely to be impossible for international aviation. With no alternatives to liquid fuels, the government must focus on supporting domestic SAF production. This will include support for fuel components that may be utilised in other transport modes (e.g. diesel or distillate-type blending components), as SAF production processes will produce blending components requiring alternative use. In addition, support for approval of new SAFs will be needed – this includes the establishment of a UK 'Clearing House', and support from the Ministry of Defence in permitting the use of proven, well understood SAFs in UK infrastructure and inclusion in the appropriate fuel standards (e.g. DEFSTAN 91-091).

SAFs present a key opportunity to maintain the UK as a key global hub for aviation in the 21st century, with precedent on suitable efforts set by the United States. For example, the US government has provided support to US SAF production by supporting establishment of a Clearing House and testing novel SAFs in military hardware. The UK's fuel manufacturing, import, and distribution base is well-placed to increase SAF deployment subject to suitable policy support from the government.

In addition to aviation energy vector decarbonisation, all efforts possible to minimise the energy vector demand of UK aviation should be pursued. This includes efforts to improve the efficiency of ground activities[31], improved airspace use[32], and increasing the achievement of continuous descent operations (CDO)[33]. Furthermore, the net GHG emissions impact of aviation can be reduced via ongoing support for the International Civil Aviation Authority's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) programme.[34]

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27 Transport Chapter, IPCC WG3, February 2018
28 EI/JIG Standard 1530, Energy Institute, May 2019
29 https://Skynrg.Com/Sustainable-Aviation-Fuel/Saf/
30 Sustainable Aviation Fuels Road-Map, Sustainable Aviation, February 2020
31 Aircraft on the Ground CO_2 Reduction Programme, Sustainable Aviation, 2010
32 Airspace Modernisation Strategy, Civil Aviation Authority, July 2020
33 A Guide To Continuous Descent Operations, Sustainable Aviation, June 2018
34 What is CORSIA and how does it work?, ICAO, 2020

7. Cross Modal Decarbonisation Policies

7.1. A Systems Approach to Decarbonisation

The key to cost-effective and swift decarbonisation of UK transport is to adopt a systems approach to all energy vectors and uses. Any policy focused on a single technology – rather than net GHG emissions reduction of energy vectors – risks increased costs and challenges in meeting demand. The UK's resilience to such concerns is arguably at its lowest due to the severe impacts of COVID-19.

UK government ministers recently participated in the IEA Clean Energy Transitions Summit[35] where ministers discussed sustainable and resilient recovery from the COVID-19 crisis and how to achieve a definitive peak in global carbon emissions. As aforementioned, a key principle shared by the IEA is that reducing global GHG emissions "will require a broad range of different technologies working across all sectors of the economy in various combinations and applications" and that net zero emissions will not be achieved by focusing on a single technology.

Reduced transport demand as a result of COVID-19 crisis also presents opportunity to adopting an effective systems approach that ensures focus is made on high impact (greatest GHG emissions reduction) areas. Such an approach will encourage the required transport integration and modal shifts, lowering overall transport energy, and will subsequently accelerate the introduction of energy vectors and technologies better suited to a vehicle's required duty cycle and range.

7.2. Product Lifecycle GHG Emissions Policy

The 'Setting the Challenge' document identifies the in-use GHG emissions of transport modes and imminent need for reductions. Crucially, in-use emissions are only part of the GHG emissions footprint of transport – to truly account for the net GHG emissions impact of transport (and indeed any product), one must consider the GHG emissions impact over the full lifecycle. In summary, such a lifecycle's GHG emissions is comprised of:

- Cradle-to-gate (manufacturing including raw material extraction) emissions
- In-use (tailpipe and maintenance) emissions
- Energy vector well-to-tank emissions
- End of life (re-purposing or disposal) emissions

Understanding full product lifecycle GHG emissions for a given transport application enables consideration of where the most significant and cost effective GHG emissions reductions can be realised – prioritising the decarbonising of upfront manufacture, energy vector provision, or end of life emissions as needed.

Extensive studies have been conducted on the lifecycle GHG emissions of road transport[9,36,37,38], with studies also conducted on bunker fuel WTW GHG emissions[39], highlighting that this is an area of increasing focus for transport policymakers. Given the importance of such an approach in meeting the target of net zero GHG emissions by 2050, and complexity in combining partial lifecycle analyses, UKPIA encourages government to undertake transport lifecycle GHG emissions policy development as soon as possible. UKPIA strongly believes this holistic policy measure is essential for the cost-effective, technology neutral decarbonisation of UK transport.

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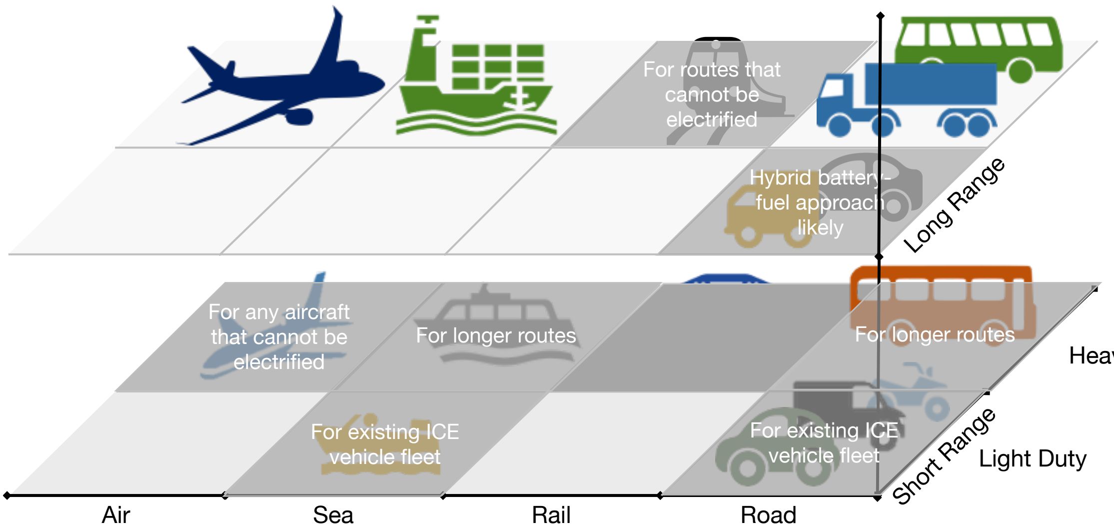
[35] https://www.iea.org/news/40-ministers-from-around-the-world-gather-to-address-the-world-s-energy-and-climate-challenges
[36] Embedding LCA into automotive manufacturing & future vehicle policy, LowCVP and APC, November 2019
[37] Impact Analysis of Mass EV Adoption and Low Carbon Intensity Fuels Scenarios –Summary Report, Ricardo, August 2018
[38] Vehicle lifecycle CO_2e emissions – integration into vehicle policy and automotive design, LowCVP, September 2019
[39] Draft Life Cycle GHG And Carbon Intensity Guidelines for Maritime Fuels, IMO, February 2020

7.3. The Role of Low Carbon Fuels

The consistent theme that emerges when assessing the transport modes and appropriate decarbonised energy vectors is that low carbon fuels offer the most readily available displacement of the currently predominant, fossil-derived, carbon-based fuels/chemical energy vector. However, like all non-fossil derived energy vectors, rapid scale-up is required to meet the enormous energy demands of UK transport.

For transport modes not immediately 'electrifiable', low carbon fuels offer the only means of decarbonising the current prevalent transport energy vector. For transport modes with particular energy density demanding operation, low carbon fuels offer a technically suitable decarbonised energy vector for the long-term. Importantly, low carbon fuels are readily deployable utilising the UK's existing infrastructure and expertise. The figure below summarises low carbon fuel deployment options in the coming decades.



What can be introduced in its place is a wide range of compelling, climate neutral fuels (and fuelling models) to power UK transport with net zero emissions. These fuels will be readily deployable in existing infrastructure and proven on road transport in the shorter term. Their deployment can continue as needed depending on climate neutrality and supply – for example in the case of limited feedstocks they can be diverted to aviation and marine as light duty vehicles are electrified.

FuelsEurope have identified a realistic pathway for the deployment of low carbon fuels up to 2050, with a clear increasing role for the use of HVO and lignocellulosic residue fuels.[40] These fuels offer a cost-effective and pragmatic route to GHG emissions reduction and complement the simultaneous deployment of other decarbonisation technologies.

Increasing utilisation of low carbon fuels is an approach also endorsed by the engineering community – one of the recommendations by the IMechE in its 'Accelerating Road Transport Decarbonisation' report was for "substantial investment (similar to that provided for battery electric vehicles and charging infrastructure) in sustainable and low-carbon fuel development and associated internal combustion engine technology."[41]

UKPIA has recently demonstrated its support for increased deployment of low carbon fuels in the UK by responding to the DfT's consultation on the introduction of E10 with full support for its mandated introduction. UKPIA also responded to the DfT's recent consultation on

[40] Clean Fuels for All - A Potential Pathway to Climate Neutrality by 2050, FuelsEurope, June 2020
[41] Accelerating Road Transport Decarbonisation, IMechE, January 2020

increasing the buy-out price of the RTFO – fully supporting an increase to support renewable fuel blending in the UK into the 2020s.

The government is correct in identifying the essential role low carbon fuels have to play in decarbonising UK transport. The TDP is the strategic level document for government to cement its commitment to the UK as a global hub of low carbon fuel development and deployment. UKPIA looks forward to continuing working with government on renewable fuels policy such as the upcoming consultation on the RTFO.

7.4. Mobility Paradigm Shift

The ESC Innovating to Net Zero report is clear: to achieve net zero emissions by 2050, a mobility paradigm shift is required. Consumers must approach – and be offered – transport differently, to ensure transport modes use is optimised, inefficient ownership models reduced, and all low carbon technology options utilised to ensure the most fit-for-purpose energy transfer, storage, and conversion for a given application.

By definition, such a fundamental rethink of how transport is used is cross-modal. The TDP should support efforts to disrupt traditional ownership and use models – creating space for innovation – to increase transport efficiency and thereby reduce energy vector demand. Integrating transport systems and increasing vehicle utilisation must be considered an essential component in decarbonising UK transport.

Such shifts in approach are not limited to passenger transport. There must be significant changes in how freight and goods are transported to reduce energy vector demand for freight activity. For example, government should encourage the increased use of consolidation centres for delivery into urban areas[42] and continue to support the increased utilisation of rail for land freight[43].

7.5. Connected and Autonomous Vehicle Technologies

Connected and autonomous vehicle (CAV) technology has the potential to play a key role in the decarbonisation of transport by reducing overall transport energy vector demand. This may be achieved via the execution of more efficient driving patterns (such as the aforementioned use of platooning for HGVs) and also optimise vehicle engine operation by reducing transience and further enabling vehicle right-sizing.

Connected technologies offer further benefits by improving fleet operational efficiency. For example, improving airspace and port operations offers opportunities to further reduce energy vector demand.[32,44] Therefore, CAV technologies is a truly cross-modal enabler to UK transport decarbonisation.

However, there is still a high degree of uncertainty regarding when significant CAV technology deployment may feasibly occur.[45] Government should consider potential vehicle efficiency gains through connected vehicle initiatives as important 'low hanging fruit' for transport decarbonisation.

[42] Consolidation Centres: Why Offsite Is On Trend, Offsite Hub, June 2017
[43] Rail Freight Strategy, DfT, September 2016
[44] Technology and Innovation in UK Maritime: The case of Autonomy, DfT, January 2019
[45] Market Forecast for Connected And Autonomous Vehicles, Transport Systems Catapult, July 2017

8. Glossary

BEV	Battery Electric Vehicle
CDO	Continuous Descent Operations
FAME	Fatty Acid Methyl Ester (also known as biodiesel)
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse Gas
HGV	Heavy Goods Vehicle
ICE	Internal Combustion Engine
LNG	Liquefied Natural Gas
OCS	Overhead Catenary System
PHEV	Plug-in Hybrid Electric Vehicle
PLV	Powered Light Vehicle
SAF	Sustainable Aviation Fuel
WTT	Well-To-Tank
WTW	Well-To-Wake