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Low Carbon Transport
Research Briefing

May 2019

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Low Carbon Transport
Research Briefing

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Paper Overview:
This Research Briefing is part of a series of briefings on low carbon energy in Wales. This paper focuses on the role of low carbon energy in transport, and provides an overview of low carbon fuel and transport technologies.

Senedd Research acknowledges the parliamentary fellowships provided to Robert Abernethy and Jeni Spragg by the Engineering and Physical Sciences Research

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Introduction

This Research Briefing is part of a series on low carbon energy in Wales, focusing on the role of low carbon fuels and technologies in the transport sector. Further information on different elements of low carbon energy can be found in other parts of the series:

- **Low Carbon Energy in Wales** discusses the national and global context for low carbon energy in relation to the energy trilemma, and outlines the policy landscape in Europe, the UK and Wales;
- **Low Carbon Electricity** describes the main low carbon electricity sources; and
- **Low Carbon Heat** describes the main low carbon heat sources.

The need for low carbon transport

Welsh emissions targets

The ***Environment (Wales) Act 2016*** commits Wales to reducing carbon emissions by at least 80% by 2050 (compared to 1990 levels). The trajectory towards the target will be set through a series of **carbon budgets**, each covering a five year period. The Welsh Government asked the **UK Committee on Climate Change** (UK CCC) for **advice on setting the carbon budgets** and the design of carbon targets. The UK CCC published this advice in two stages. The first, **Advice on the design of Welsh carbon targets**, was published in April 2017. The second, **Building a low-carbon economy in Wales**, was published in December 2017, and provides advice on how carbon budgets should be set, as well as how the targets may be achieved. The first two carbon budgets were **set in Regulations** by the Welsh Government at the end of 2018:

- First carbon budget (2016-2020): an average of 23% below 1990 emissions; and
- Second carbon budget (2021-2025): an average of 33% below 1990 emissions.

The Regulations also contained interim emissions targets for the decades to 2050:

- A 2020 target for an emissions reduction of 27% on 1990 levels;
- A 2030 target for an emissions reduction of 45% on 1990 levels; and
- A 2040 target for an emissions reduction of 67% on 1990 levels.

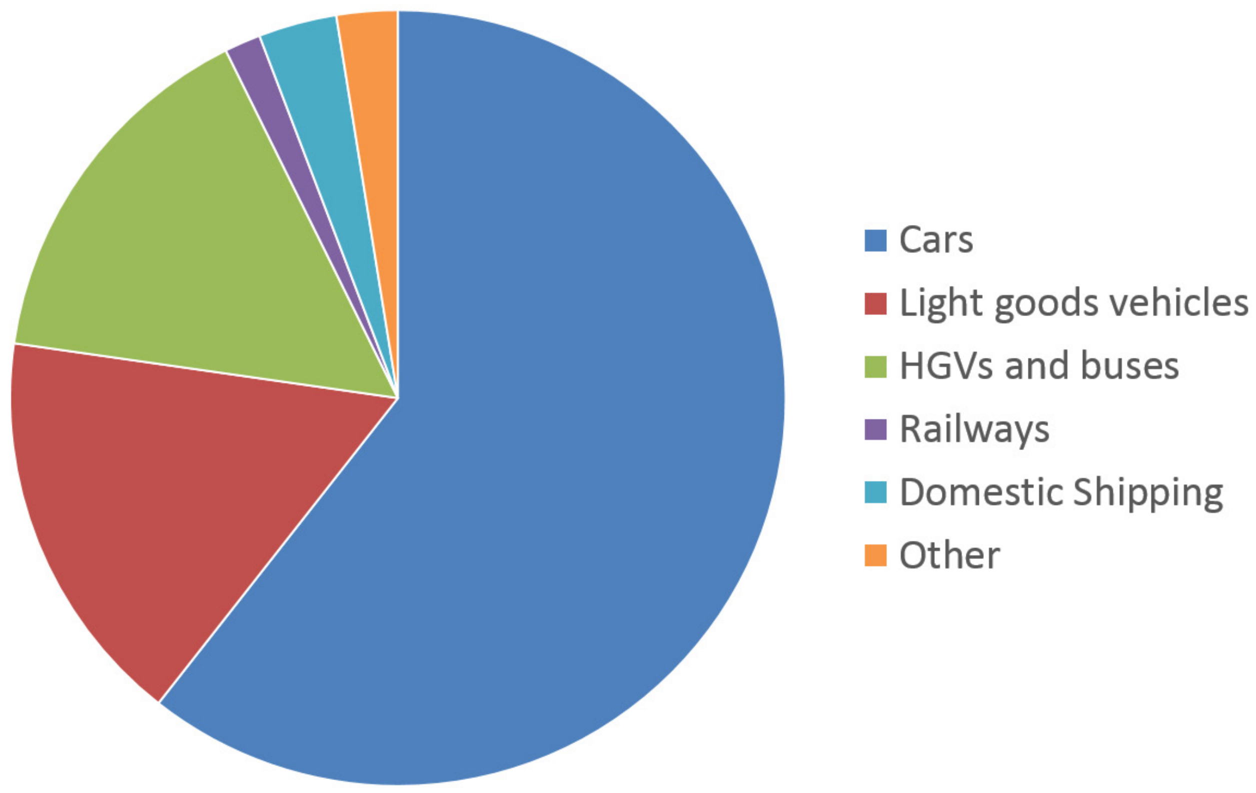
Following the UK CCC advice, the Welsh Government decided to **include international shipping and aviation** in the Welsh carbon budgets. These areas **are not included** in UK carbon budgets. This increases the emissions from transport covered by the carbon budgets. In March 2019, the Welsh Government published its plan for how the first carbon budget would be met. **Prosperity for All: A Low Carbon Wales** sets out 76 existing policies and 24 new proposals that aim to help Wales meet its emissions reduction target for the first carbon budget period. The cross-Government plan contains a number of transport related policies and proposals, including infrastructure for electric vehicles, the promotion of active travel and the decarbonisation of public transport.

Carbon emissions from transport

According to the **latest figures from the UK CCC**, transport contributes 13% of total Welsh carbon emissions, compared to 28% across the UK. Emissions from transport in Wales increased in 2016 by 2.0%, the third consecutive annual increase, with Welsh transport emissions 1.2% lower than in 1990. The lower proportion of total emissions from transport in Wales is due to greater emissions per capita from other sources in Wales, particularly Aberthaw B coal power station (which alone accounts for **14% of CO2e emissions in Wales**) and large-scale industry. **Per capita CO2e emissions in Wales** (1.9t per person per year) are slightly higher than those across the UK (1.8t per person per year). Additionally, the high proportion of Welsh emissions from hard to decarbonise sources, such as industry, means that to achieve the 80% target, greater cuts will be needed in other sectors.

The makeup of **CO2e (carbon dioxide equivalent)** emissions from transport in Wales is shown in Figure 2. This shows that the vast majority of emissions are from road transport, primarily cars. This data excludes international aviation and shipping, which make up around 7% of CO_2e emissions in the UK (Wales only data for international aviation and shipping is not currently available).

Figure 2 Breakdown of CO2e emissions from transport in Wales (data excludes international aviation and shipping) (Source: NAEI)



Air quality in Wales

Although a UK wide issue, Wales has some of the worst air quality nationally. Cardiff and Port Talbot both have **higher particulate matter levels** than Birmingham or Manchester, and a **road in Caerphilly** is the most polluted outside of London. Public Health Wales (PHW) figures show that air pollution contributes to **around 2,000 deaths per year in Wales**.

Section 83 of the *Environment Act 1995* requires Local Authorities to designate an air quality management area (AQMA) when a national air quality objective is not being achieved, or is not likely to be achieved. **All current AQMAs** in Wales, except Neath Port Talbot, have been declared for exceeding nitrogen dioxide (NO_2) limits. **Road transport is specified as the main source of NO2 (PDF 5.16MB)** in 96% of UK AQMAs declared for exceeding NO_2 limits. The **PHW website** also says "most local air pollution problems are caused by emissions from road vehicles". While the Welsh Government is not responsible for vehicle emissions standards, it is responsible for Welsh trunk road/motorway highway schemes and developing public transport/integrated transport policy. In November 2018, the Welsh Government published its **supplemental plan for Tackling roadside nitrogen dioxide concentrations in Wales.**

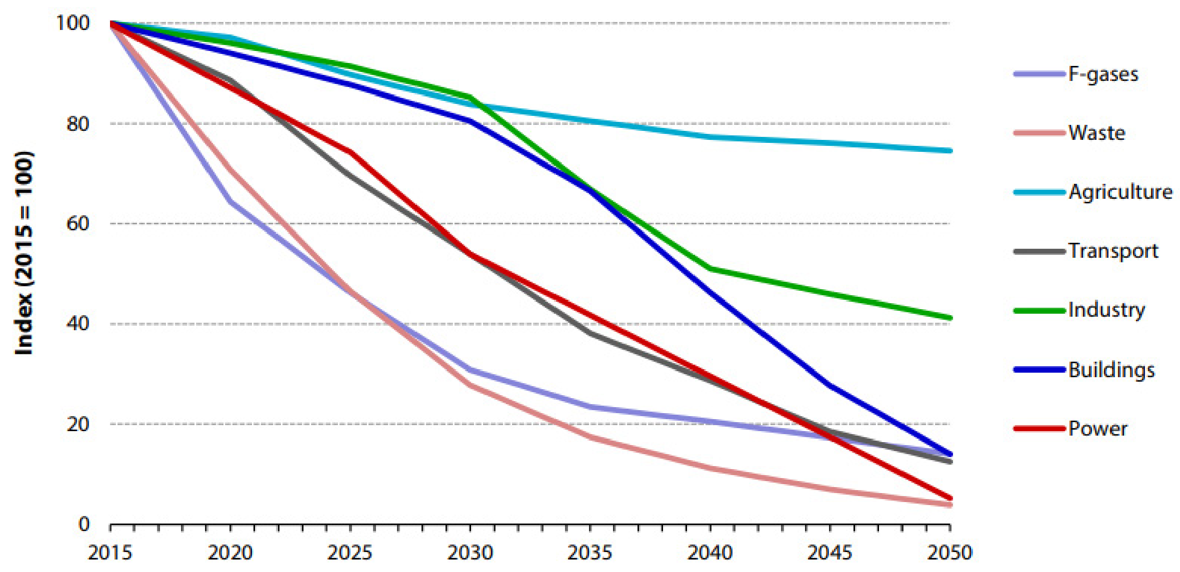
Action required

The UK CCC, when advising on Welsh carbon budgets, **set out a scenario** for achieving the 2050 target (Figure 3). This scenario included a steep reduction in carbon emissions from transport to around 85% of 2015 levels by 2050. It suggested this needs to be achieved mostly through efficiency improvements and significant uptake of ultra-low emission vehicles (ULEVs), such as electric cars, with 60% of new vehicle sales in 2030 being ULEVs.

Welsh Government powers in these areas are somewhat limited since many relevant aspects of road transport – particularly the construction, equipment and regulation of motor vehicles and trailers - are reserved powers under the ***Wales Act 2017***. As a result, the UK CCC recommendations are that action by the Welsh Government should focus on reducing the number of car journeys through increased use of public transport and the promotion of active travel.

The UK CCC mapped the sectoral emissions reductions needed in order for Wales to achieve its 80% target by 2050. This is shown in Figure 3 below.

Figure 3 Sectoral emissions reductions for reaching the Welsh 2050 target (UK CCC Analysis)



Reducing car use

One key area for cutting emissions from transport is reducing car usage. Promoting active travel, which has zero emissions at the point of use, can help to achieve this, alongside a greater use of public transport, since bus and rail transport have far lower emissions per passenger-mile than cars (see Table 1 below). The **UK CCC scenario** projects that 6% of car journeys in Wales in 2030 will be avoided by increased use of public transport and active travel.

Table 1 CO2e emissions from different transport forms within the UK (Source: BEIS)

	CO_2e emissions per passenger - km / kg
Average car	0.18
Local bus	0.10
National Rail	0.05
Domestic flight	0.27

Active travel

The ***Active Travel (Wales) Act 2013*** aims to increase in walking and cycling for travel, which would reduce the use of transport that emits carbon dioxide. The Act places a responsibility on Welsh local authorities to map current and future active travel routes, and to continuously improve infrastructure through the improvement of existing routes and facilities, and the construction of new infrastructure. The Welsh Ministers and local authorities must take reasonable steps to enhance provision for active travel when creating and maintaining highways, and must also promote active travel journeys. There has a limited in participation in active travel since the Act was passed (see Table 2).

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Table 2 Participation in active travel between 2013 and 2018 (Source: National Survey for Wales)

Proportion of / %	2013-14	2014-15	2015-16	2017-18
Adults that frequently walk for active travel	46	43	47	58
Adults that frequently cycle for active travel	6	6	5	6
Primary school children who typically walk to school	49	49	42	-
Secondary school children who typically walk to school	32	35	34	-
Primary school children who typically cycle to school	3	2	1	-

The Welsh Government introduced an **active travel plan for Wales** in 2016 to support the Act. The plan aims to increase the proportion of adults that cycle at least once a week from 6% in 2014 to 10 % in 2026, and the proportion that walk at least once a week from 64% in 2014 to 80% in 2026. The plan includes a broad range of actions under the headings: leadership; legislation, standards and tools; infrastructure; promotion and behaviour change; skills and training; and monitoring and evaluations.

While active travel can reduce carbon emissions, it is generally only suitable to replace short car journeys. While this might suggest the impact on total carbon emissions may be limited, **data for England in 2014** showed that 56% of all car journeys were under 5 miles. Wider benefits arise through **health improvements** from exercise and improvements in air quality (as a result of reduced vehicle emissions) in urban environments.

Public transport

Replacing long car journeys with coach or train travel can reduce carbon emissions by **80% on average**. Recent Welsh Government policy has focused on the proposed metro systems for **North East** and **South Wales**, with proposals also being developed **for the Great Western and north Wales mainlines**. The Welsh Government has also **published a case for investment in Welsh rail infrastructure**. It **is currently consulting** on proposals to improve local bus services in Wales and on changes to taxi and private hire vehicle licensing arrangements. The Welsh Government has also **awarded the contract** to operate rail services in Wales and to develop and operate the South Wales Metro to KeolisAmey.

While **total rail passenger journeys in Wales** have increased from about 20 million in 2005-06 to just over 30 million in 2016-17, **bus passenger journeys in Wales (Excel 20 KB)** have decreased from about 123 million in 2004-05 to about 100 million in 2016-17.

The Welsh Government does not have any published targets for increased use of public transport.

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Cars

Cars contribute over half the carbon emissions from transport in Wales (Figure 2). Beyond reducing their use through increased active travel and use of public transport, there are several possibilities for de-carbonisation. These primarily involve moving away from conventional petrol and diesel cars to ULEVs, with the UK CCC predicting that **60% of car sales in 2030** will need to be ULEV to meet carbon targets in Wales.

The fuel efficiency of cars has increased significantly in recent years, but this has been counteracted by an increase in vehicle miles driven. **Total distance driven** in Wales increased by around 17% between 2000 and 2017 off setting a 40% improvement in the **efficiency of new cars**. Previous improvements in fuel efficiency have been encouraged through **EU standards**. After the UK leaves the EU, it will be the responsibility of the UK Government to establish new standards.

Battery powered vehicles

Battery powered vehicles (also referred to as electric vehicles) are the most common type of ULEV. They include **a range of vehicles**, from hybrids that cannot be charged from the grid to vehicles that exclusively use battery power (Figure 4).

Figure 4 Nissan Leaf, the bestselling electric vehicle in the UK in 2017 (Taken by Richard Kelly, licensed under Creative Commons)

Hybrid electric vehicles (HEV) run primarily on a petrol or diesel powered internal combustion engine (ICE). They also have a battery and electric motor as part of an electric drivetrain. The battery charges from braking or the ICE under certain conditions. The electric drive train is then used to power the vehicle at low speed or to provide a boost when needed, e.g. driving uphill. These vehicles provide a small reduction in carbon emissions but are not considered ultra-low emission vehicles.

Plug-in hybrid electric vehicles (PHEV) have a battery capacity that typically provides a range of 15-30 miles. After this an ICE takes over. When used for only short distances (up to around 20 miles) between charges, they can produce zero carbon emissions at the point of use ("tailpipe" emissions). Beyond this range they produce similar emissions to HEVs.

Battery-only electric vehicles (BEV) do not have an ICE. Instead they have larger batteries that provide a significantly increased range. They produce zero tailpipe emissions and their overall carbon emissions are dependent on the method of grid electricity production.

Some BEVs have range extenders (BEVx). These are ICEs that are used to recharge the batteries on long journeys. This makes the vehicle similar to a PHEV but with a greater emphasis placed on the electric propulsion (larger batteries and smaller ICE). As a result, they typically produce lower tailpipe emissions.

Plug-in vehicles is an umbrella term for PHEV, BEV and BEVx. It excludes HEV.

Battery development

The key driver for electric vehicles in recent years has been the dramatic improvement in storage capacity alongside decreasing costs. **Prices of lithium-ion (Li-ion) automotive batteries have fallen** from $1000 per kWh in 2010 to $273 per kWh, and are predicted to drop below $100 per kWh by 2025. Given that automotive battery packs cost **between £5,000 and £25,000** for full-EVs, a continuing decrease in costs is important for electric vehicles to become cost-competitive without a subsidy.

At the same time the energy density (kWh/kg) of automotive batteries has increased as new technologies have become viable as automotive batteries (Table 3). For example, the decrease in cost of Li-ion batteries that has allowed these to be used **in place of older technologies** that had lower energy density. Higher energy density batteries allow electric cars to be designed with greater range without being over encumbered by heavy batteries.

Table 3 Improvement in energy density of automotive batteries over time (sources embedded in table)

Technology	Energy density (kWh/kg)	Example car/year
NiMH	0.05-0.07	Toyota Prius (2001-2015)
Li-ion	0.1-0.3	Nissan Leaf (2010-)
Solid state Li-ion / Li-S	0.3-0.4	Dyson electric car (2020 onwards)
Lithium-air	1.0-1.4	2026 onwards

The next generation of battery technology is likely to be solid state Li-ion batteries or lithium sulphur batteries (Li-S). In addition to higher energy densities these technologies offer improved safety (an issue that has **hindered Li-ion batteries**). Lithium-air batteries, which could increase energy density by up to 10 times compared to Li-ion, have drawn the **attention of major car manufacturers** and offer a potential range of 500 miles for battery powered cars.

The potential benefits of future battery technology show that electric cars have not yet reached their maximum potential. Future models are expected to have **increased range at lower cost**.

Carbon emissions from electric vehicles

Concerns have been expressed over the carbon emissions from electric vehicles when complete life cycle analysis is carried out. Greater carbon emissions are produced during manufacturing of electric vehicles than conventional vehicles and if the electricity used to charge the car is generated from fossil fuels then it will contribute additional emissions during use (although still less than a conventional vehicle).

However, a **study carried out for the UK CCC** found that the emissions from both production and use of electric vehicles are lower than conventional vehicles and rapidly declining, due to decarbonisation of electricity generation. Switching from a conventional to an electric vehicle is expected to reduce whole life carbon emissions by 70% in 2020.

Charging electric vehicles

One key challenge for electric vehicles is charging capacity. This is a challenge for the electricity supply grid and an obstacle to potential drivers.

The National Grid's **future energy scenarios** report predicts that electric vehicles could contribute to an increase in peak electricity demand by up to 30% by 2050. However, there is also the possibility of electric vehicles being used for storage through **vehicle-to-grid charging**, enabling better use of renewable energy. The ***Automated and Electric Vehicles Act 2018*** includes a requirement that all electric vehicle charging points must be "smart". Smart charging points will enable external controllers, such as the national grid, **to reduce peak demand**.

The availability of chargers is very important for potential electric vehicle owners. Electric vehicle owners need to be able to charge at home, work or other public places. In these locations, a slow charger (3kW) that takes several hours to completely charge a vehicle may be sufficient. However, to reduce concerns over the short range of electric vehicles, a **network of rapid chargers** (22kW or greater) that can charge a vehicle to 80% in 30 minutes is needed along the trunk road network.

Figure 5: EV charging point at Cardiff West services. (Taken by Jeff Gogarty, licensed under Creative Commons).

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Wireless charging has been identified as a technology that could help overcome the range limitations of electric vehicles. A system of cables can be installed under major roads and can provide power to electric vehicles as they are driving along at a rate of 20kW. This would avoid the need for "top-up" stops at service stations on long trips. However, it would require extensive infrastructure investment to install the cables under a significant proportion of the motorway network.

Electric vehicles in Wales

In 2017, **760 new plug-in vehicles** (PHEVs and BEVs) were registered in Wales (just 1.6% of the total across the UK). This represents 0.8% of new cars registered in Wales. Two factors holding back electric vehicles in Wales are the high upfront cost (although the lower running costs can offset this in the long term) and the lack of available **public charging points**. According to the electric charging point map **Zap Map**, Wales currently has 617 charging points, 3.32% of the UK's total. Wales has around 30 rapid chargers, compared to around **3,000 across the British Isles**.

The UK Government currently runs a **Plug-in Car grant scheme** to help people across the UK with the cost of buying an electric vehicle. The grant applies to a government approved list of vehicles – and is administered directly through dealerships and manufacturers. There have been changes to the scheme over the past year - grants for new plug-in hybrids were scrapped, while discounts on all-electric cars were cut from £4,500 to £3,500. The **Department for Transport (DfT) say** that the grant was introduced seven years ago to help the market become established and that the focus was changing to support zero-emission models such as pure electric and hydrogen fuel cell cars.

There are also grants for the installation of electric vehicle charging points at **home, workplaces and on-street.**

The Welsh Government is planning to install electric vehicle charging points to encourage the uptake of electric vehicles, with £2 million of funding over two years announced in the **2018-19 Welsh Government budget.** It has said that the funds will be invested in developing a network of rapid EV charging points – ensuring that the deployment of public funds takes into account private sector activity.

Hydrogen vehicles

Hydrogen vehicles use a fuel cell to convert hydrogen gas to water while producing electricity, which is used to power a drivetrain similar to those in battery powered vehicles. Since water is the only by-product of this process, there are zero tailpipe emissions. Hydrogen vehicles have been considered as a **potential replacement for petrol cars** for some time since they have similar ranges and refill times as conventional cars. However, the technology and market is expected to arrive **several years after** battery-powered vehicles.

Currently, hydrogen vehicles are **only available on a lease** in the UK (representing a very early market stage) and there are just **12 hydrogen refuelling stations available**, two of which are in Wales. Despite this, the **UKH2Mobility** project, of which the Welsh Government is a member, predicts that hydrogen vehicle sales could reach 300,000 in the UK by 2030.

Toyota **sold 2,700 hydrogen cars globally in 2017**. From this, it is clear that the technological challenges associated with storing hydrogen and fuels cells have been mostly overcome. The commercially available hydrogen vehicles also **have very high safety** standards in an attempt to combat consumer concerns over the dangers of hydrogen fuel.

The main challenges now are cost, hydrogen production and infrastructure.

Currently hydrogen vehicles cost **more to purchase and more to run** than either conventional or electric vehicles. The growing size of the market will result in reduced cost through economies of scale. **UKH2Mobility predict** that the cost of hydrogen vehicles will still be more than conventional vehicles by 2030 (although hydrogen cars will have lower running costs) but **Toyota claim**s that it will be cost competitive with hybrid vehicles by 2025.

The **H21 Leeds City Gate project** found that producing hydrogen through electrolysis of water (the reverse process to the fuel cell that powers hydrogen cars) was not likely to be feasible on a large scale for the foreseeable future. The main alternative production route is steam-methane reforming of natural gas. This involves high temperatures and produces CO_2. As a result carbon capture and storage (CCS) is needed to make this route carbon neutral. The additional Senedd Research briefings in this series on **low carbon electricity** and **low carbon heat** provide more information on CCS and hydrogen production.

The lack of available refuelling stations acts as a deterrent for potential hydrogen vehicle owners. Japan has around 100 hydrogen refuelling stations, compared to 12 in the UK, and **over 2,000 hydrogen cars** have been sold in the country. The UK government has launched a **£23 million fund,** to support hydrogen for vehicles until 2020. This will provide match funding for 17 more refuelling stations.

The Welsh car firm **Riversimple Movement** has created a hydrogen car called the Rasa (Figure 6). The car's development benefitted from **£2m of support from the Welsh Government** and a €2m grant from the EU. Riversimple is aiming to bring the first car to the market in late 2018.

Figure 6 Riverside Rasa (taken by Matthew Lamb, licensed under Creative Commons)

Biofuels

Crops can be converted to **bioethanol (from sugar cane or corn) or biodiesel (from oil seed rape and vegetable oils)**. These fuels can supplement conventional fuel in ICEs up to **5% without modifying the engine** (and modern cars can generally take higher proportions).

Biofuels are generally viewed as being low carbon. Emissions produced by burning the fuel have recently been captured during growth of the fuel source. However, the carbon emissions from biofuels depend on the source and the production methods needed to convert them into fuels.

Use of biofuels in the UK peaked in **2015 at 3% of all fuels**, and has declined slightly since then. The UK CCC **predicts limited use of biofuels** for surface transport in the future due to limited supply and readily available low carbon alternatives such as battery and hydrogen power.

The greatest limitation for biofuels is the competition for land to produce food crops. Biofuel production was **associated with the food price increases of 2008,** Additionally, there are a number of other uses of biofuels that may need to take precedence over surface transport. For example **the UK CCC highlights that** difficult to decarbonise sectors, such as industry and aviation, may need the majority of the limited supply of biofuels.

The UK CCC estimates that around **10% of our primary energy could come from biofuels in 2050**. This is similar to the **UK Government figure of 12%.** To achieve emissions reductions it is essential that biofuels are sustainably sourced and their production is low carbon. Future technologies, such as biofuels from algae, may allow some expansion of their role but surface transport is likely to remain a low priority area since aviation, shipping and industry will be competing for supplies.

Commercial vehicles

Light goods vehicles

Battery powered LGVs

Light goods vehicles (LGVs) are the second largest contributor to emissions from transport, after cars, and the number on the **road is growing rapidly**. The battery powered LGV market is growing and several major manufacturers now have **battery-only models**. There are **5,200 battery-only LGVs in the UK**, which is 0.1% of all LGVs in the UK. The technology for battery powered LGVs is very similar to that of electric cars.

Typical ranges vary between 100-200 miles, so battery powered vans are only **suitable for certain users**. However, LGVs are typically driven further than cars (vans make up 10% of vehicles on UK roads but **17% of distance travelled**) and are less fuel efficient so van owners will typically benefit more from the **low running costs** of electric vehicles.

One concern for large electric vans is the additional weight of the batteries. Drivers without a HGV licence cannot drive vehicles weighing over 3.5 tonnes. This led to a **UK government consultation** on raising the weight limit for ultra-low emission LGVs.

Hydrogen LGVs

Hydrogen vans are becoming **available** in the UK. Sheffield City Council has five **hydrogen-battery hybrid vans** that it claims are cheaper than diesel vans once running costs are included. The hydrogen capability doubles the range of the van, relative to battery only vehicles.

Currently most hydrogen vans are produced by **third party** modification of electric vehicles. No major vehicle manufacturers currently have plans for large-scale production of hydrogen vans. The small scale of hydrogen distribution in the UK means that at present hydrogen prices are **relatively high**, as a result hydrogen vans have **higher fuel costs** than diesel vans.

Electric and **hydrogen** LGVs are covered by the **plug-in grant scheme**. This will cover 20% of the cost of the vehicle up to £8,000. With ongoing **air quality concerns** in the UK, the possibility of some cities introducing **zero emission zones** has been raised. Zero emission zones would ban conventional vehicles from such areas from 2020 onwards, so electric or hydrogen vans would become necessary.

Heavy goods vehicles

There are significant ongoing developments in the ultra-low emission HGV market, particularly in the USA. Two competitors that are aiming to shape the long-haul market are the battery powered **Telsa Semi** and the **Nikola One hydrogen truck**. European and Japanese manufacturers appear to be more focussed on the short-haul and final-mile market for ultra-low emission HGVs.

Battery powered HGVs

Battery powered HGVs are best suited for short-haul and "final-mile" journeys. The range limitations of battery powered vehicles are less important in these applications. The movement towards battery powered, short-haul HGVs could be driven by air quality regulations that may see polluting HGVs **banned from some cities in the future.**

Tesla is the only company to have announced a long-haul battery powered HGV, the **Tesla Semi**. It aims for production from late 2019, with a range of over 500 miles. This combined with a charge time of 30 minutes for 80% could facilitate long-range haulage. However, at present it is unclear how Tesla will provide the battery capacity and charging facilities for these vehicles. This may rely on improvements in technology arriving in the next two years.

Estimates suggest that the Tesla charger would need to be around 1.2MW (ten times the speed of the current Tesla supercharger). This is a challenge not only for the connection to the vehicle but would also require significant generation and transmission infrastructure, as each charger would require a power supply **equivalent to thousands of homes.**

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Figure 7 The Tesla Semi, a battery-powered HGV with a range of over 500 miles (taken by Korbitr, licensed under Creative Commons)

Hydrogen HGVs

Hydrogen HGVs could have greater range and faster refuelling than battery powered HGVs. Long haul HGV drivers are likely to be willing to travel further than car drivers to reach hydrogen refuelling stations. This has prompted Nikola to announce the introduction of **hydrogen HGVs** with a 1,200 mile range for production from 2021. Toyota has also launched a **short-haul hydrogen HGV** with a range of 200 miles.

Public Transport

Public transport has lower emissions per passenger mile than private vehicles on average (see Table 1) with local bus services reducing emissions by 40% and national rail services by 70%. These savings could be increased even further by the adoption of ultra-low emission vehicles in the public transport sector.

Buses

Electric buses have been rolled out in many places across the UK. The UK Government **announced £30.4 million of funding in 2015** to increase the uptake of ultra-low emission vehicles and help improve air quality. A further £100 million **was announced in 2016** for the 2017-21 period. Denbighshire was one of the local authorities that were awarded funds, being granted **£500,000 for four electric buses**. Cardiff Bus has **recently announced** it would be deploying 36 electric buses, in a move to improve air quality in the city. Caerphilly Council has also **committed to increasing electric vehicle usage** amid plans to create an £8 million all-electric public transport network within the borough. Stagecoach has launched a bid for UK Government funding to convert buses currently servicing Caerphilly town from diesel to electric operation. The £3.45 million requested from the Department for Transport's Ultra-Low Emission Bus Scheme would pay for 21 electric buses, with charging points available for fast charge throughout the day.

The low average speed along urban bus routes, combined with the high volume of **space for batteries** in buses, has led some to predict that half the buses on the road could be **electric by 2025**. This is mainly driven by growth in China, but the **UK is leading the way in Europe**. However, the cost of electric buses is currently significantly higher than conventional, which acts as a barrier to uptake.

Aberdeen is the first city in the UK to develop a fleet of 10 hydrogen powered buses which travelled a total of 250,000 miles in their first year. There are plans to increase the number to 20 with increased funding from the Scottish Government. Hydrogen buses are more easily facilitated than other vehicles since their regular routes mean that only one refuelling station is needed.

The **Low Carbon Vehicle Partnership** has published a **Low Emission Bus Guide** aims to provide bus operators and local authorities with an overview of the benefits of a range of low emission fuels and technologies that reduce both air pollution and greenhouse gas emissions. It has also published **case studies** on the range of low emission bus technologies in use across the UK.

Trains

In 2016 rail accounted for **8% of passenger-miles** in England and less than **1% of emissions in the UK**. Carbon emissions are low per passenger-mile even for diesel trains but **electrification reduces running costs, improves local air quality and reduces CO2 emissions by 20-35%**.

Electrification plans for Wales include the **South Wales mainline** from the Severn tunnel to Cardiff and the South Wales Metro. However, plans to electrify the mainline between Cardiff and Swansea **have been dropped**.

The start-stop nature of electrification of railway lines in the UK, **largely due to increased Network Rail costs**, has led to changes in the way **rail infrastructure enhancements are planned** in England and Wales. The new approach focuses on the development a project pipeline, providing a rolling programme of enhancements.

Battery or hydrogen trains are possible replacements for diesel engines along non-electrified rail.

Battery trains have limited range and so are best deployed on short-routes, urban lines, or part-electrified rail. Alternatively **battery-diesel hybrid engines** can replace diesel trains to reduce carbon emissions and improve air quality in urban areas. Five have already been deployed in Germany.

The first hydrogen powered train was piloted **in Germany in 2017**, and may be tested on **British railways by 2020**. The high fuel efficiency of trains would make hydrogen production and refuelling infrastructure more achievable than it is for road vehicles. **A hydrogen fuel cell demonstrator train is being developed** by the University of Birmingham and rolling stock leasing company Porterbrook Ltd.

Bi-mode, tri-mode and battery trains

Bi-mode trains will be used on the Great Western Mainline as an alternative to electrification between Cardiff and Swansea. Bi-mode trains run on 25kv overhead electric power where possible but have a diesel engine for non-electrified track. These are part of UK Government ambitions to **phase out diesel-only trains** by 2040.

In future, battery powered trains could be deployed along part-electrified railways. These were **trialled in the UK in 2015**. These trains can charge their batteries along the electrified section of rail, then use the batteries as a power source along non-electrified sections.

Following the award of the new contract for the Wales and Borders Rail Franchise in June 2018 **the Welsh Government announced** plans to procure new trains. Alongside conventional diesels, these include bi-mode "Metro Vehicles" from Swiss company Stadler for use on the Metro, but also innovative "tri-mode" trains. These tri-modes, also from Stadler, combine diesel, 25KV overhead electric and battery traction for maximum flexibility.

Tri-modes and battery / diesel bi-modes will facilitate "smart electrification" – reducing cost by avoiding the need to electrify through tunnels, for example, since trains will switch to battery. They also allow battery electric journeys on non-electrified sections of the network.

However, tri-mode trains are extremely innovative, and **stakeholders have raised concerns (PDF 1MB)** about 'early adopter risk' for new technology, and highlighted the complexity of the fleet with implications for driver and maintenance training etc.

International aviation and shipping

Welsh carbon budgets **include international aviation and shipping**, unlike the UK counterparts. While these are only a small proportion of emissions from transport currently, these sectors are difficult to decarbonise. Aviation and shipping will grow significantly as a proportion of total emissions by 2050 since they are likely to remain level at best, while emissions across all sectors decrease by 80%.

Aviation

The International Civil Aviation Organisation (ICAO) has agreed a target of **offsetting any growth in emissions after 2020**. Emissions from the aviation sector should stay level after 2020.

Emissions from aviation in Wales are low. Aviation contributes **5% of CO2e emissions in the UK** but according to **December 2018 figures from the Civil Aviation Authority** (PDF 77KB) Cardiff Airport accounts for just 0.4% of passengers in the UK. However, the airport aims to **double the number of passengers by 2025** and the Welsh Government is **investing significantly** in its growth.

A lack of low emission technologies prevents short-term decarbonisation of the aviation sector. In the medium term, **improved fuel efficiency of new aircraft** and **increased use of biofuels** may be used to offset the growth in passenger numbers, in order for the ICAO target to be achieved. Battery or hydrogen powered commercial planes may begin flying shorter routes from **2027 onwards**.

Shipping

International shipping contributes 1.6% of carbon emissions in the UK. The UK CCC predicts this to decline by around a third by 2050, but includes a large possible range in **its models**. More than **10% of international shipping** in the UK is to or from Wales.

The **International Maritime Organisation** is attempting to reach an agreement on emissions from shipping, but currently it remains as the only **sector without any carbon targets**. A **Lloyd's Register report** identified advanced biofuels or hydrogen power as the most likely ultra-low emission fuels for shipping by 2050, but currently the only action being taken in the shipping industry is improved fuel efficiency for new ships.