

University of Wales Trinity Saint David

Institute of Science & Art



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

Use of Energy Carriers: Legislation & Practicality Approach
Automotive Materials & Sustainability (ACHA6012)

Elisha Atif
2003581

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1. Introduction

Although emission regulations date back to 1970, the first EU emissions standard, known as Euro 1 was not introduced until 1992 where catalytic converters became compulsory on new cars, standardising fuel injection. Since 1992 European Union regulations have been imposed on new vehicles with the aim to improve air quality meaning when a vehicle is built it must meet the euro emissions standard to be allowed on the roads of Europe. Since then, there have been many euro standards, each with more strict emission standards. The RAC states that within EU, 20% of the CO₂ emissions are produced by the transportation sector and the emission standards aim to reduce this. (Euro 1 to Euro 6 guide, 2023)

This report will analyse the operation and effectiveness of alternative fuels, electric, and hybrid propulsion and energy recovery systems to reduce the environmental impact.

2. Current & Future Legislation

Table 1 - Euro Emission Standards

Euro standard	Introduction date		Emission limits		
	New approvals	All new registrations	Petrol NOx	Diesel NOx	Diesel PM
Euro-1	1 July 1992	31 December 1992	0.97g/km*	0.97g/km*	0.14g/km
Euro-2	1 January 1996	1 January 1997	0.5g/km*	0.9g/km* (direct injection)	0.1g/km
Euro-3	1 January 2000	1 January 2001	0.15g/km	0.5g/km	0.05g/km
Euro-4	1 January 2005	1 January 2006	0.08g/km	0.25g/km	0.025g/km
Euro-5	1 September 2009	1 January 2011	0.06g/km	0.18g/km	0.005g/km
Euro-6	1 September 2014	1 September 2015	0.06g/km	0.08g/km	0.0045g/km

(Vehicle Emission Testing, n.d.)

In recent years, the UK has released many measurements and regulations that are stricter on reducing exhaust emissions, improving air quality, and providing sustainable transport which will and is having a significant impact on the UK fleet of transport. On 1st January 2020, two new regulations were set by EU for 2020-2024 and sets new targets for 2025-2030. The current regulations require the average for all new cars in the UK to be no more than 95g/km of CO₂. For light commercial vehicles, CO₂ emissions must be no more than 147g/km of CO₂. (CO₂ emissions performance standards, 2020).

While euro standards have made a good impact on the reduction of vehicle emissions, the 'dieselgate' scandal proved that there is still much work to be done if manufacturers felt the need to cheat the emission tests (Euro 1 to Euro 6 guide, 2023). By 2025, all passenger cars and light commercial vehicles must meet an average CO₂ emissions reduction of 15% in comparison to the baseline target set in 2021. For 2030 the target is a reduction of 37.5% for cars and 30% for vans (CO₂ emissions performance standards, 2020). These new regulations will be part of the new euro standards known as Euro 7. It is expected to be the final iteration of this type of legislation before Europe looks to end the manufacturing and sale of new petrol and diesel vehicles by 2030.

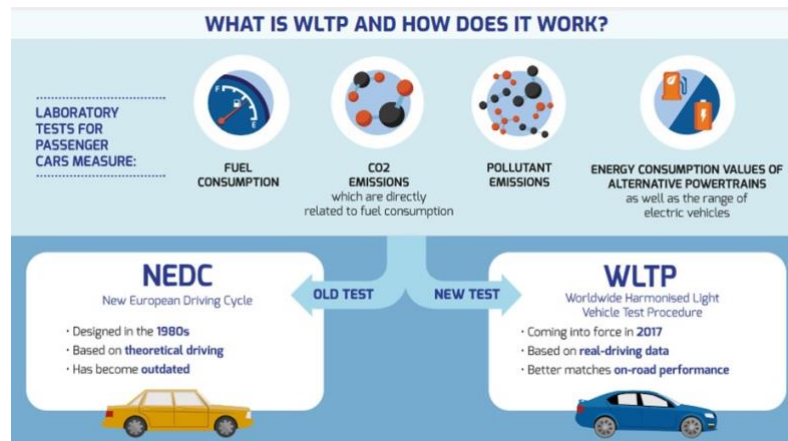


Figure 1 - New WLTP Test

(What is WLTP and how does it work?, n.d.)

A new test is expected to be introduced to check for limits of these greenhouse gases along with the introduction of 'real world emissions monitoring' to make sure the vehicles meet the necessary requirements when driving in the real world (Euro 1 to Euro 6 guide, 2023). Emission limits for tyres and brakes will also be introduced. To be more precise, tyres and brakes shed particulate matter which are very little pieces of materials as they wear over time. Euro 7 will set limits to how much brake dust and tyre particles can be produced by new vehicles. Cars must stay cleaner for longer. Euro regulations are based on testing new vehicles but also as they age and the engine becomes less efficient, resulting in a less clean burn. Euro 7 is set to double this period over which the vehicle is checked from 5 years (62k miles) to 10 years (124k miles). Euro 7 regulations will add an average of £264 to the cost of each new car (Griffiths, 2022). This could affect the UK fleet and transportation network by slowing down either the sales or the number of vehicles manufactured.

Aside from petrol and diesel vehicles, EVs and plug-in hybrids will also have the longevity of their batteries assessed under Euro 7, checking how much battery capacity they hold as time and mileage increases. This will mainly be done to improve confidence in second-hand electric vehicles. (Griffiths, 2022)

2.1. Sustainable Innovations

By 2050, the UK tends to reduce greenhouse gas emissions by 80% compared to 1990 levels. These harmful gases in the air have increased at a steady pace and their effects are more visible than ever through heatwaves, floods, droughts, and storms becoming more frequent and unpredictable (Ostler, 2022). Countries like UK are also using low emission zones to improve air quality by reducing the number of vehicles that don't meet emission standards within those zones, creating a cleaner environment. (Why we have ULEZ, n.d.)

The automotive industry is moving away from traditional materials used in a vehicle that are difficult to recycle and instead, they are moving to new, more sustainable resources. While exhaust emissions are key to lowering carbon emissions and EV vehicles is one way of doing so, the products that go into a car also matter. Consulting

firm McKinsey estimates that 60% of automotive industry emissions by 2040 will be produced by the materials used in production. (Sustainable materials are driving change in the automotive industry, 2022)

Replacing traditional leather with vegan alternatives is one of the main ways to be more sustainable for many manufacturers. The advantage of this is that vegan leather can be made from many natural resources such as mushrooms or pineapple waste. Manufacturers such as Volvo have vowed to make their EV range vegan-friendly by 2030. Other brands such as BMW are also collaborating with other companies to create cactus-based biomaterial which can be replace leather in seats and panels. (Sustainable materials are driving change in the automotive industry, 2022)

There is also plastic, a material which is well known for not being environment friendly. Through recycling, manufacturers are using discarded plastic bottles or plastic caps for their vehicle interior including dashboard, foam seats, and airbags (Sustainable materials are driving change in the automotive industry, 2022). S&P Global state these natural resources have the potential to meet car interior production feasibility by 2030 (Sustainable alternatives for in-cabin materials, 2023)

3. Petrol & Diesel Alternatives

With the current and future proposed emission standards, petrol and diesel will not be sufficient to reduce exhaust gases. Therefore, alternatives need to be invested in if the automotive industry wishes to continue as it is.

3.1. Biofuels

Biodiesel:

Biodiesel is a renewable, biodegradable fuel manufactured mainly from vegetable oil, animal fats, or recycled restaurant grease. The performance of biodiesel, especially in cold weather, depends on the blend of biodiesel, the feedstock, and its petrol-diesel features. In general, blends with smaller percentages of biodiesel perform better in cold temperatures. The biodiesel's physical characteristics can be seen in the table below. (Biodiesel Fuel Basics, n.d.)

Table 2 - Biodiesel

Biodiesel's Physical Characteristics	
Specific gravity	0.88
Kinematic viscosity at 40°C	4.0 to 6.0
Cetane number	47 to 65
Higher heating value, Btu/gal	~127,960
Lower heating value, Btu/gal	~119,550
Density, lb/gal at 15.5°C	7.3
Carbon, wt%	77
Hydrogen, wt%	12
Oxygen, by dif. wt%	11
Boiling point, °C	315-350
Flash point, °C	100-170
Sulfur, wt%	0.0 to 0.0015
Cloud point, °C	-3 to 15
Pour point, °C	-5 to 10

(Biodiesel Fuel Basics, n.d.)

Biodiesels are usually blended with petrol-diesel, typically less than 10% because most engines cannot run on pure biodiesel without modifications. 5% biodiesel, 95% petrol-diesel is labelled as B5. 7% biodiesel, 93% petrol-diesel is labelled B7. These are the most common diesel blends seen across UK fuel stations. It was found that the feedstock used to make biodiesel can considerably alter the exhaust gas and particulate matter emissions. A study performed by Chonbuk National University found that a B30 biodiesel blend reduced carbon monoxide emissions by 83% while reducing particulate matter 33%. The study also found B20 biodiesel fuel significantly reduced engine emissions (Biodiesel, n.d.). However, these blends cannot be used worldwide at the moment because engines are not built to handle fuels with such properties.

Renewable Diesel

Renewable diesel is a fuel made from fats and oils such as soybean oil or canola oil and is processed to be chemically the same as diesel. Renewable diesel is distinct to biodiesel. Renewable diesel, also known as green diesel, can be produced through many processes such as hydrotreating, biological sugar upgrading, catalytic conversion of sugars, gasification, pyrolysis, and hydrothermal processing. (Renewable Diesel, n.d.)

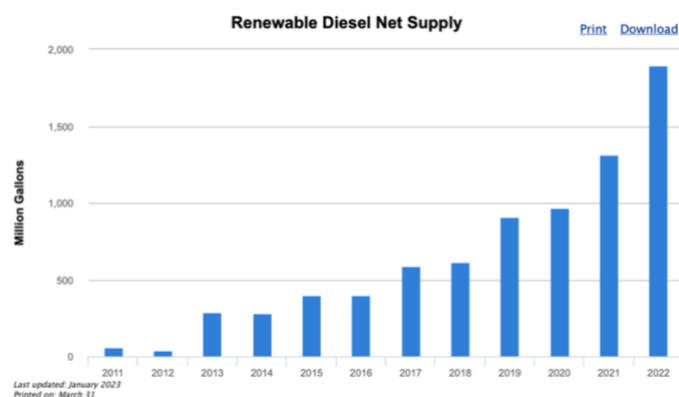


Figure 2 - Renewable Diesel Supply

(Renewable Diesel, n.d.)

The graph above shows the supply of renewable diesel in the US as tracked by Renewable Identification Numbers (RINS). The supply of this fuel has hit an all-time high in 2022 with supplying almost 2000 million gallons. Some of its advantages are that it can meet the normal diesel specifications which means this fuel can be used in current diesel engines without requiring modification. A study found renewable diesel also reduces both carbon dioxide and nitrogen oxide emissions when compared to diesel as well as reducing carbon emissions by 65% when compared to diesel. (Renewable Diesel, n.d.)

Ethanol:

Bioethanol fuel is a renewable fuel made of different plants, usually made of sugarcane and grains, along with their by-products. In the US, 98% of petrol contains an ethanol blend (Ethanol Fuel Basics, n.d.). In the UK, E5 with 5% ethanol and E10

with 10% ethanol petrol blends are commonly used. It is estimated that bioethanol can reduce CO₂ emissions by 750,000 tonnes per year which is equivalent of taking 350,000 cars off the roads. (What is E10 fuel and how will it affect you?, 2021). This is because ethanol is significantly less carbon-intensive than petrol, reducing emissions by 76% in 2021 compared to petrol. Bioethanol also advances engine performance, including boosting the octane rating when blended with petrol, allowing for more efficient engines. (Why Use E10?, n.d.)

The advantage is that current engines do not need to be modified to use E5 and E10 fuel blends. Countries such as Brazil are already using E85 fuel which is an 85% ethanol blend with petrol which produces a much cleaner fuel and reduces emissions. However, vehicles in the UK are not equipped to handle such a high blend. (How much ethanol is in gasoline, and how does it affect fuel economy?, 2022)

3.2. Propane

Propane, also known as LPG, is a clean burning alternative fuel that has been used widely for decades to power light, medium, and heavy-duty vehicles. Propane has a high-octane rating, making it an excellent choice for petrol engines. If it is spilled, it serves no harm to the soil, surface water, or ground water. Along with those advantages and it being a clean burning, low cost, and domestically available fuel, this makes it the third most common transportation fuel. However, propane's lower British thermal unit rating per gallon results in worse fuel economy almost consuming twice as much as petrol to drive the same distance. On the other hand, its lower per gallon cost can offset the lower fuel economy. (Propane, n.d.)

3.3. Electric Vehicles

In EVs, onboard batteries power one or more electric motors. These batteries are charged by using charging stations connected to the grid along with energy regained during braking through energy recovery systems (Powering Vehicles with Electricity, n.d.). The main point of interest that attracts many people towards EVs is the fact that it produces no emissions whatsoever. This means that EVs do not produce any gases associated with global warming, making them the most 'green' transportation option. A medium sized car can almost cost £100 for a full tank. In comparison, fully charging an EV at home could cost only £15.10. There are also fewer mechanical parts than a traditional engine making them low maintenance over long term. However, if an electrical part or the battery fails, it could be more expensive to replace. (Advantages of Electric Vehicles, 2022). They do not disappoint when it comes to performance either, thanks to the immense power that can be created from the batteries and instant acceleration.

Despite this, EVs are far from fully being the alternative to petrol and diesel. Making the batteries require rare materials that can be difficult to mine. The whole process of mining and manufacturing can create high amounts of greenhouse gases. The whole production process of making a petrol or diesel car can produce 7-10 tonnes of CO₂. In comparison, the whole production process of making an electric car produces 16-19 tonnes of CO₂. At this point, EVs seem to be more harmful for the environment

than a combustion engine vehicle. The production process also makes the vehicles more expensive to buy and driving range is also very limited compared to petrol or diesel cars. (Electric Cars, n.d.)

3.4. Hydrogen

The interest in hydrogen fuel comes from its ability to produce zero emissions, its potential for domestic production, and high efficiency. The US department of energy state that hydrogen cell coupled with electric motor is two or three times more efficient than an internal combustion engine. (Hydrogen Basics, n.d.)

However, despite being the most abundant element, extracting hydrogen requires a significant amount of energy. Hydrogen fuel cells need investment for them to become a viable alternative. The cost of hydrogen fuel cell is currently greater than any other energy source (What Are Pros and Cons of Hydrogen Fuel Cells, n.d.). Hydrogen's energy content by volume is low. This means that storing hydrogen is a challenge because it requires high pressures, low temperatures, or chemical processes (Hydrogen Benefits and Considerations, n.d.).

4.0. Energy Recovery Systems

There are different types of energy recovery systems that can help vehicles become more sustainable and environment friendly. Below are some examples of systems the government can encourage manufacturers to use.

4.1. Waste Heat Recovery System

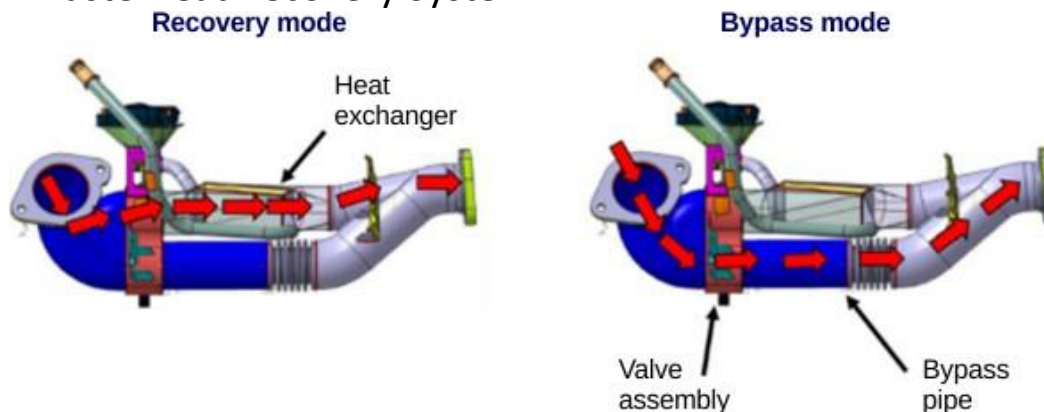


Figure 3 - Waste Heat Recovery System

(Jääskeläinen, n.d.)

Peak thermal efficiency of an internal combustion engine is around 35% which means 65% of the energy released through fuel is lost as heat. A waste heat recovery system turns waste heat energy produced through exhaust gases into electric energy for batteries in EVs or mechanical energy reintroduced to the crankshaft for combustion engines. This increases efficiency, saves fuel, and reduces emissions. (Exhaust heat recovery system, n.d.)

4.2. Start-Stop Technology

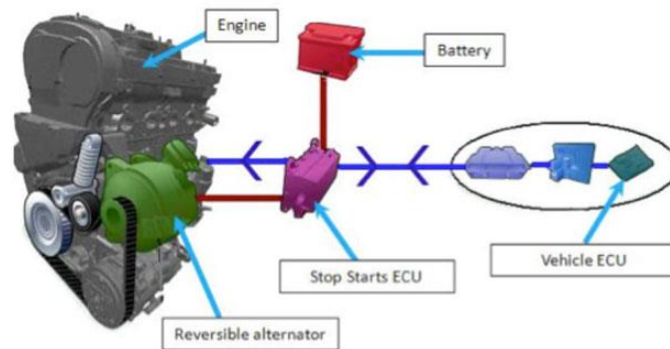


Figure 4 - Start-Stop System

(How do Stop-Start systems work?, 2014)

Start-stop technology detects when the vehicle is stationary and idling and stops the engine automatically. It restarts when the throttle or clutch is pressed. An idling vehicle still produces emissions even when stationary in traffic. If all vehicles use this technology, carbon emissions could be reduced significantly. Although it may not be a huge amount, it will also save some fuel that would be used to keep the engine idle.

4.3. Regenerative Braking System

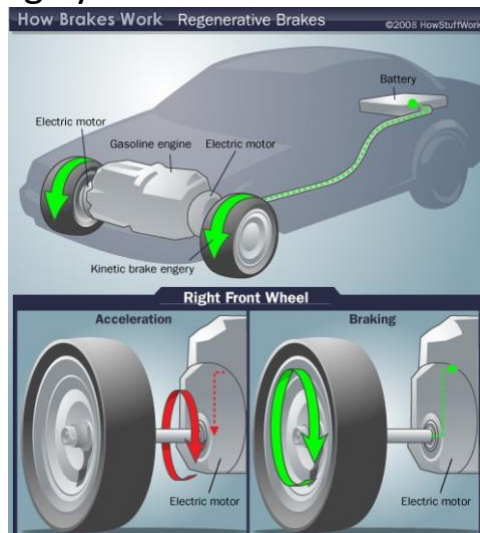


Figure 5 - Regenerative Braking System

(Regenerative Braking: How It Works in Electric and Hybrid Vehicles, 2020)

Regenerative braking system is a type of kinetic energy system that transfers the kinetic energy of the wheels into stored or potential energy to slow the vehicle down and as a result, increasing fuel efficiency (Regenerative Braking, n.d.). Since regenerative braking helps slow down the vehicle, it may help the brake pads and rotors last longer. For EVs the extra captured energy will help extend the driving range.

5.0. Motorsports Technology in Automotive Industry

Motorsports teams invest millions of pounds into their cars to give their drivers the winning edge. To get a return on their investment, the manufacturers include their innovations onto their automotive vehicles. (Lawrence, 2018) Below are some examples.

Semi-automatic gearbox:

- Developed for the Porsche 962 in 1984, this enabled easy, automatic clutch-less shifting by using flappy paddles while still having the manual control of when to shift (Lawrence, 2018)

Disc Brakes:

- Originally made for the Porsche competing in 24 hours of Le Mans, disc brakes began to be common in normal vehicles in the 1980s. Disc brakes enabled fast braking without locking the steering. (Lawrence, 2018)

Carbon Fibre Chassis:

- Very light, flexible, and ten times stronger than steel, carbon fibre is an excellent construction material for high-speed vehicles on and off the track. In addition to that, it's also popular with electric vehicles such as BMW i3. Using a light material saves weight which improves fuel efficiency (Deaton, n.d.)

Active Suspension:

- Active suspension actively raises and lowers the chassis at each wheel to give better handling, improved traction, and a smooth ride. Originally developed by F1, Toyota first introduced active suspension to their 1983 Soarer (Deaton, n.d.)

All wheel Drive:

- Originally introduced by the Audi rally team, Audi quickly introduced the technology into their Quattro road cars in 1980. All wheel drive varies the power to each wheel depending on its individual traction needs. This technology is now used by manufacturers all around the world in vehicles such as Suzuki SX4, Subaru Impreza, and Nissan Juke (Lawrence, 2018). This technology gives better traction through corners, especially in slippery conditions, increasing the overall handling safety of the vehicle (Clarke, 2019). This also improves performance as the power is going to all four wheels rather than just two.

6.0. Conclusion

Based on the supporting evidence then, it is clear that EVs do not seem to be the replacement of automotive petrol and diesel cars. They are only a small fraction of the solution. From the points made, I believe the government should be focusing and investing more in Propane fuel and Hydrogen fuel cells as an alternative fuel along with the biofuels already used in the UK. In addition to that, energy recovery systems such as waste heat recovery systems and regenerative braking systems should be installed in all new production vehicles going forward because even though they have small effects individually, if installed in every vehicle on the roads, this technology can have a tremendous effect on reducing emissions and making vehicles more efficient. With all these technologies combined on a vehicle, the impact automotive industry has on the environment can be lowered and perhaps positive.

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