Electric vehicles - the way to go?
Investigating the advantages and disadvantage of EVs

In recent years, air pollution, particularly in cities, has become a major problem. For the first time, a coroner ruled that air pollution was the cause of the death in 2013 of a nine-year old child who lived near the very busy South Circular Road, Lewisham, London in the UK. The inquest found that air pollution 'made a material contribution' to her death. Air pollution means substances in the atmosphere that are harmful to the health of people and other living things, or they cause damage to the climate or to materials. There are different types of air pollutants, such as gases, particulates, and biological molecules. Air pollution may cause diseases, allergies and even death; it may also cause harm to animals and food crops, and may damage the natural environment or built environment.

Smog and soot are the most prevalent types of air pollution. Smog (thick, polluted fog) occurs when emissions from the combustion of fossil fuels react with sunlight. Soot, or 'particulate matter,' is made up of tiny particles of chemicals, soil, smoke, dust, or allergens, in the form of gas or solids, that are carried in the air and which we can all breathe in.

It is now agreed by most people that the less petrol (gasoline) and diesel that is used, the greater will be the reduction of air pollution and of the harmful effects of climate change. Electric vehicles offer one solution to the problem.

Road sign in the London Borough of Ealing

Electric vehicles (EVs) are categorised according to their power source:
(1) battery electric vehicles (BEV) are powered by high-capacity lithium-ion batteries, recharged from public or home-charging points. BEVs are made in many forms but limited by the weight and cost of the large battery. Their range is limited at the moment by scarcity of charging points and the time taken to recharge. Most BEVs use permanent magnet motors, a type of electric motor that uses permanent magnets in addition to the usual electro-magnets to increase the magnetic field strength, while minimising battery energy consumption.

(2) hybrid electric vehicles (HEV) have a small-to-medium petrol engine, an electric motor and a smaller battery than BEVs. The vehicle may be powered by either the petrol engine or the electric motor, or both together, or the petrol engine can be used to charge the battery. HEVs are expensive because of the two motors and their complexity. Their range can be extended with the petrol engine but performance is poor with either engine alone. By using the petrol engine to charge the battery, more fuel is used than if the vehicle just used a petrol engine. However, the great advantage of HEVs is that the electric engine can be used in urban areas.

(3) fuel cell electric vehicles (FCEV) carry a tank of liquefied (-253°C) or highly compressed (300 bar) hydrogen. Hydrogen requires much energy either to liquefy or to highly compress into the large, heavy and potentially dangerous tank. In the fuel cells, hydrogen gas is catalytically combined with atmospheric oxygen to produce water vapour and electricity. The process is only 30% efficient overall compared with 60% for BEVs, owing to the inefficiency of making the green hydrogen used (see: the Earthlearningidea, 'Green hydrogen - the fuel of the future?'). The energy cost per vehicle-mile is several times that of other EVs. Although some large goods vehicles have been produced using the FCEV principle, numbers currently remain very small.

Motors for EVs
There are three main types:
(1) permanent magnet motors are efficient and perform well. The permanent magnets use rare-earth elements such as samarium. Without samarium the magnets would be much larger and heavier. These motors have brushes, usually made of carbon which rub on a divided copper ring called a commutator to vary the direction of the current as the motor rotates. This arrangement may be a weak point;
(2) induction motors do not have brushes and run for long periods without maintenance, but are not efficient at low loading and prefer to run at constant speed;
(3) switched reluctance motors are an attempt to overcome the problems of other types but are too noisy at the moment.

Charging EVs
Plug-in charging is slow, typically overnight. Fast charging normally requires removal of the battery owing to high voltage and current and may still take an hour. The answer to this may be a 'swap out-swap in' exchange system, but this implies doubling the number of batteries in circulation.
It is suggested that there is a need for one charging point for every eight EVs. Currently the UK national electricity grid is incapable of supplying power on this scale; there is insufficient generating capacity and in many places the distribution connections are also inadequate. Owners of home plug-in chargers usually require an upgrade to their domestic supply cables to avoid tripping out the whole property. Currently, on motorways in many countries, fast charging points are sometimes out of use and some early installations have been declared dangerous. There are still many challenges to charging EVs.

Some statistics (Dec 2019)
EVs form 1% of the global vehicle stock of which 47% are in China.
Global sales of EVs comprise 2.6% of new cars sold, though their proportion is higher in Europe than elsewhere due to purchase subsidies and political pressure.
New sales are mostly permanent-magnet BEVs while the proportion of HEVs is falling relatively.

Advantages and disadvantages of EVs
- reduction of pollution in towns and cities, but unless the electricity used in charging is generated cleanly or mitigated such as by carbon-capture, output of CO_2 and particulates are just transferred to the generating location;
- in the UK, there is low taxation on EVs, though at a national level the lost revenue will have to be replaced in a form other than fuel tax on petrol and diesel;
- low noise level in most cases;
- BEVs have good acceleration from standing;
- extended service intervals in most cases;
- permanent magnet motors require substantial amounts of rare-earth elements such as samarium for the magnets. Other rare elements are used for the electronic EV motor controller;
- they are generally heavier than their petrol equivalents;
- lithium batteries tend to overheat when worked hard for long periods and there have been many cases of the battery catching fire. In April 2021 80,000 faulty batteries were awaiting replacement;
- there are concerns about disposal of old lithium batteries releasing caustic lithium and plastic nanoparticles;
- lithium-ion batteries are a major cost, about £120 per kWh, so a new battery will cost several thousand pounds;
- new battery types such as lithium iron phosphate may reduce these problems. Sodium nickel chloride batteries may further minimise current problems but may introduce a new one, in that the battery has to be maintained at 300°C;
- the infrastructure of charging points needs major improvement; but construction work will release large quantities of carbon dioxide;
- even with purchase incentives (such as the current £2500 in the UK) EVs remain much more expensive than petrol or diesel equivalents, substantially because of the cost of the battery;
- in the absence of a fundamentally new technology for storing electricity, which is urgently needed, and of which there seems to be no sign, the key barrier to EVs is battery improvement. Overall, the whole system efficiency is too low.
- as demand for EVs increases and the technology improves, it may be necessary to discover new sources of materials including lithium, copper and samarium.

Electrically-driven sprayer under development
© Patrick Dixon

The electric-driven sprayer has been ordered by a football club in London to help care for its turf. It is being developed and produced by a small company in the Scottish Borders and is a very good example of a big business cooperating with a small business by sharing the expensive development costs.
Video in 'Useful links' below

Ask the pupils to work in groups and, based on the information provided, and on some of their own research, to list the advantages and disadvantages of electric vehicles, (EVs) for use in both urban and rural environments. Information could be obtained about Tesla, (Tesla Inc. is an American electric vehicle and clean energy company based in California).

Back up
Title: Electric vehicles - the way to go?

Subtitle: Investigating the advantages and disadvantage of EVs

Topic: An investigation into electric vehicles

Age range of pupils: 14 years upwards

Time needed to complete activity: 30 - 60 minutes depending on the amount of extra research

Pupil learning outcomes: Pupils can:
- describe the three types of EVs;
- describe the three types of motors for EVs;
- consider the problems of charging EVs;
- list some advantages and disadvantages of EVs.

Context: The air in many towns and cities is polluted, mostly by the emissions from vehicles using petrol or diesel as fuel. Electric vehicles offer a solution but there are still many technological problems to overcome.

Following up the activity:
Research likely future shortages of some of the materials needed to make EVs:
Lithium is needed for most EVs. Is there enough of the raw material to satisfy demand in the future?
https://www.greentechmedia.com/articles/read/is-there-enough-lithium-to-maintain-the-growth-of-the-lithium-ion-battery-m
copper:
https://www.copper.org/publications/pub_list/pdf/A6191-ElectricVehicles-Factsheet.pdf and
https://copperalliance.org/wp-content/uploads/2017/06/2017.06-E-Mobility-Factsheet-1.pdf
Most *samarium* is extracted in China by electrolysis of molten complex minerals. Although classed as a rare earth element, deposits are actually quite widespread. Samarium-cobalt magnets have strong magnetic fields (greater than iron) and strongly retain magnetism. They do not corrode and are heat-resistant but are brittle and easily cracked.
Search 'net-zero' on the Earthlearningidea website to find other Earthlearningideas relating to climate change mitigation or adaptation.

Underlying principles:
- Air pollution is a problem is many of our big towns and cities.
- Vehicles using petrol and diesel fuels are the main cause of this air pollution.
- Electric vehicles do not emit any harmful gases.
- There are three main types of EVs based on their power source.
- There are three main types of motors for EVs.
- The network of facilities for charging EVs needs major improvement.
- EV manufacture will require dramatic increases in the supply of certain raw materials.
- There are many advantages and disadvantages of EVs.

Thinking skill development:
Discussion of the topic involves metacognition and cognitive conflict will arise when it is realised that our technology and infrastructure have not yet caught up with demand for EVs.

Resource list:
- internet and reference books

Useful links:
https://www.earthlearningidea.com/Video/Electric_sprayer.html
Technology Development of Electric Vehicles: A Review (Dec 2019):-
School of Automobile and Transportation, Shenzhen Polytechnic, Shenzhen 518055, China
School of Engineering, College of Science and Engineering, University of Tasmania, Hobart TAS 7005, Australia
https://www.mdpi.com/1996-1073/13/1/90

Use a search engine like Google to explore the internet for information about likely global impacts of 'net-zero'. You can access a tool to help visualise how climate change might affect your local area at:
https://www.bbc.co.uk/news/resources/idt-d6338d9f-8789-4bc2-b6d7-3691c0e7d138

Source: Martin and Elizabeth Devon of the Earthlearningidea Team.
This information was as accurate as possible in Spring 2021

The ‘How will the ‘net-zero’ target affect your local area?’ series of Earthlearningideas

Topic			Earthlearningidea title
Introduction			How will the ‘net-zero’ target affect your local area?
Possible mitigation measures	Use alternative energy sources	Solar	Harnessing the power of the Sun
		Wave	Harnessing the power of waves
		Wind	Farming the wind: through onshore and offshore windfarms
		Tidal	Tidal energy
		Nuclear	Nuclear power - harnessing the energy of the atom
		Nuclear waste	Nuclear waste disposal
		Biofuel	Liquid biofuels: keeping our wheels turning into the future
		‘Blue’ hydrogen	Blue hydrogen: the fuel of the future? *Also:* Hydrogen of many colours
		Geothermal – hot rocks	Deep geothermal power from ‘hot dry rocks’: an option in your area?
		Geothermal – flooded mines	A new use for old coal mines
		Hydro – small scale	Small-scale hydroelectric power schemes
		Heat pumps	Heat from the Earth
		Waste – incineration	Energy from burning waste
		Waste – methane	Energy from buried waste
	Stop fuels releasing greenhouse gases	Carbon capture	Capturing carbon?
	Store energy from sources that give irregular energy supplies	Batteries	Nuclear batteries: the future?
		‘Green’ hydrogen	Green hydrogen used to even out renewable energy supplies? *Also* Hydrogen of many colours
		Hydro – storage	Matching supply and demand using stored water
		Compressed gas	Storing gas underground: What can we store? How can we do it? How will it help?
	Provide raw materials for new technologies	Electric vehicles	Electric vehicles: the way to go?
		Insulation	How do I choose the best insulation?
	Remove carbon form the atmosphere	Enhanced weathering	Speeding up nature to trap carbon dioxide
		Tree planting	Let’s plant some trees
Possible adaptation measures		Coastal flooding	How will rising sea level affect our coastlines?
		Inland flooding	Inland flooding: a Sheffield case study
		Landslides	Landslide danger
		Agriculture	The future for global agriculture