Intended Use of Resources

This project has been designed so that teachers from different STEM areas can pick and choose sections relevant to their subject area to work on. All activities in this package do not need to be completed to get value from the package – each activity can be completed as a stand-alone or can be approached, as a team, as a larger project. The package has potential to be extended into a much longer project to include curriculum points from different STEM subjects.

There are three **student workbooks - Open, Guided and Scaffolded,** that go alongside this resource; all have the same suggestions for activities; however, they have been written and edited to provide differentiated learning options to support good teaching practice**.** Teachers may pick and choose which versions they give which students and may wish to edit them further to address their learning needs. Due to the differentiation of the workbooks, the **Open** activities will enable more syllabus links to be addressed, which is why each activity has its own syllabus links key. However, if you wish to give a truly open-ended investigation then you could just give the students the challenge and background information section of the Student Booklet.

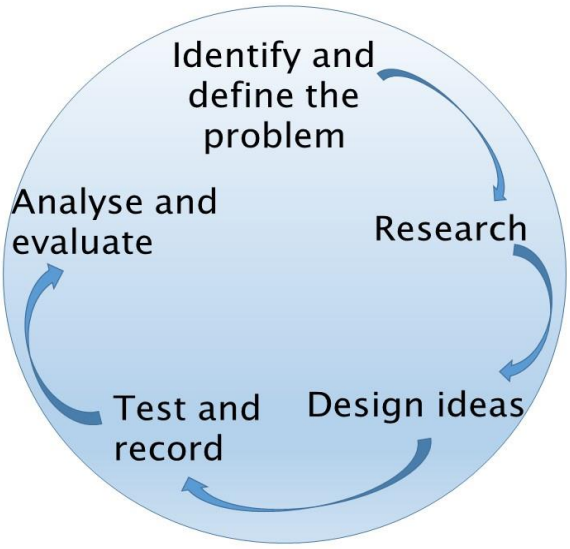
The Woodside Australian Science Project (WASP) STEM resources aim to be accessible and supportive for teachers and students, please contact us if you have questions, feedback, require assistance or would like to arrange an incursion or a professional development workshop - www.wasp.edu.au.

Moving Forward – Teacher Resource

The Student Challenge

The global demand for transportation is constantly increasing. This includes aviation, trains and vehicles used for commercial, industrial, and logistical purposes, not to mention personal vehicles. In 2018, nearly a quarter of global CO_2 emissions were from transportation (Our World in Data, 2020). This means that new technologies need to be developed and employed to meet transport demand, while minimising CO_2 emissions. Due in part to this increase in demand, many governments around the world have agreed to work towards reducing their carbon emissions, some agreeing to net zero emissions by 2050.

Your challenge will be to investigate different technologies and to assess and compare their feasibility.



Background Information

In 2015, the United Nations General Assembly set up the Sustainable Development Goals, also known as the "Global Goals". These are a collection of 17 interlinked global goals designed to be a "blueprint to achieve a better and more sustainable future for all." The future of fuel for transport relates to many of these sustainability goals, and governments must consider these when introducing new legislation and approving new projects for companies developing these fuels and technologies.

Figure 1. The UN 17 Sustainable development goals. (un.org, 2015)

One of the major hurdles in meeting the sustainability goals is that the global population is expected to increase, reaching nearly 11 billion by 2100. This will, no doubt, increase the demand for vehicles, both personal and commercial.

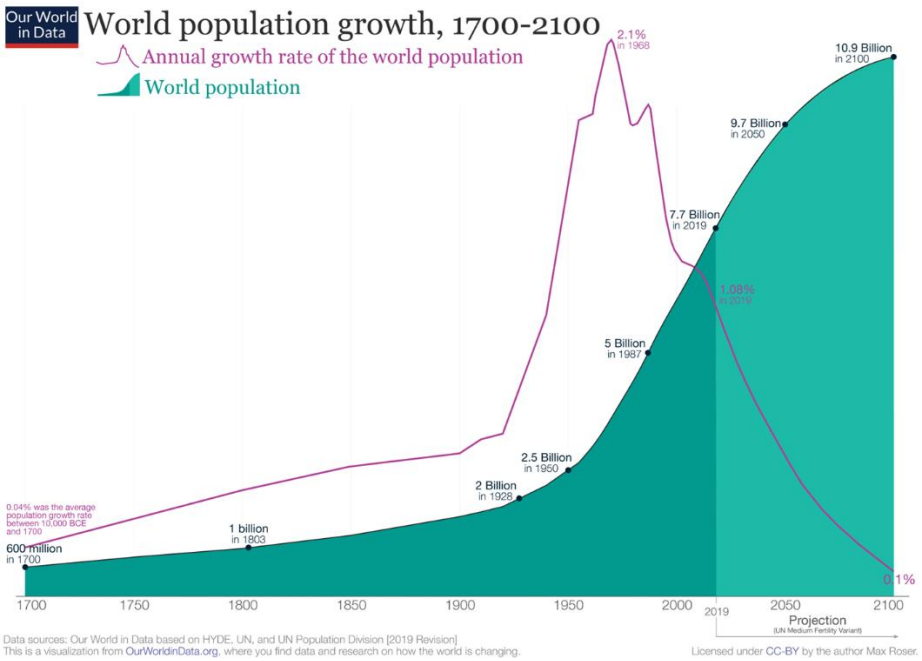


Figure 2. Past and predicted population growth of the world. (OurWorldData.org, 2022)

Moving Forward – Teacher Resource

The race is now on between countries and companies to develop more efficient transport, which will lead to lower greenhouse gas emissions. There are already many alternatives to standard petrol and diesel vehicles on the road.
The first mass-produced hybrid vehicle was the Toyota Prius, which was launched in Japan in 1997. Hybrid vehicles use a technology which generates energy that is stored in a battery whenever the brakes are applied. However, hybrid vehicles still release CO_2.
All electric vehicles (EVs), now have much greater range than when first put on the market and this is constantly being improved upon. Their price has also dropped dramatically and will likely continue to do so as technologies advance. They are much cheaper to run than regular fuel cars. However, although the vehicles themselves do not emit CO_2, their carbon footprint will depend upon how the electricity they use is generated.
In America and other countries, biogas and hydrogen fuelled vehicles are also becoming more common. These, again, have a very varied carbon footprint depending on how the fuel is produced.

When considering how sustainable a fuel or energy type is, it is important not only to think about the emissions, but the full 'cradle to grave' life cycle. This considers factors such as production of the fuel, transportation of the fuel and efficiency. This means that some fuel or energy types may be more suited to different countries and transport uses, and that there may not be a one size fits all approach.

Activities

This booklet contains extra information on each activity, including syllabus links the overall activity objective, suggestions for recommended equipment or alternative ways to run investigations as well as useful resources and website links. Please note that any reference websites provided in the entirety of our resource documents were current at the time of publication. Please advise if links are no longer accessible.

The syllabus links have been colour-coded. Please see the colour key below:

Covered in Scaffolded, Guided and Open student workbook
Covered in Guided and Open Student workbook
Covered in Open student workbook

Moving Forward – Teacher Resource

List of activities

Background Research

Objective

Students will gain a general understanding of some of the less conventional options available for fuelling cars and consider their carbon intensity. They will research Australia's current energy mix and consider how this impacts the sustainability of electric cars at present.

Students will dive deeper into the UN Global Goals and consider how different fuel types can affect reaching these goals. This will enable them to consider much more than only the carbon intensities of different fuel types, but also the impacts of production of different fuel types on society, business, and the economy.

	Australian Syllabus Links
Science	ACSSU189 Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere. ACSHE230 Values and the needs of contemporary society can influence the focus of scientific research.
Design and Technology	ACTDEK040 Critically analyse factors, including social, ethical and sustainability considerations, that impact on designed solutions for global preferred futures and the complex design and production processes involved ACTDEK041 Explain how products, services and environments evolve with consideration of preferred futures and the impact of emerging technologies on design decisions

Useful resources and websites:

- The National Grid (UK and US) Website has some good resources regarding different energy types and how electricity is generated for the grid: https://www.nationalgrid.com/
- The Australian Government: Department of Climate Change, Energy, the Environment and Water has relevant information about energy use in Australia as well as information about government priorities, which may aid students considering energy for the future: https://www.energy.gov.au/

Hydrogen Fuel

Objective

Students will investigate the relationship between electrolyte concentration and hydrogen production during hydrolysis (electrolysis of water) and consider how this could affect production yield.

We suggest using bicarbonate of soda as the electrolyte as this is safe and inexpensive. We do not recommend using seawater as this can produce chlorine gas. The container they use must be able to be easily pierced by a drawing pin. You may want to watch the demonstration video on the AusEarthEd YouTube channel before running the investigation.

For more able students you may ask them to do some calculations to calculate the percentage concentration and the ppm of the electrolyte. This may produce more scientific graphs and enable more detailed analysis and discussion.

Students will discover that although the use of electrolytes can increase the yield of hydrogen, it can also lead to much faster corrosion of the anode and cathode. Presently pure water is used by most companies undertaking hydrogen production. This can be costly and also can cause conflict within communities in some regions where fresh water is scarce. Recent research has developed safe, economical and efficient means of using seawater for hydrolysis, although it is yet to be upscaled and trialled on an industrial scale.

At present very few car companies are researching hydrogen, preferring instead to develop electrical vehicles. However, hydrogen fuel will become important where electricity is not as viable – for example shipping, industry and possibly aviation as well.

	Australian Syllabus Links
Science	ACSSU187 Different types of chemical reactions are used to produce a range of products and can occur at different rates. ACSSU189 Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere. ACSHE192 Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries ACSHE230 Values and the needs of contemporary society can influence the focus of scientific research. ACSIS198 Formulate questions or hypotheses that can be investigated scientifically

	ACSIS199 Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; asses risk and address ethical issues associated with these methods. ACSIS200 Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately ACSIS203 Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies ACSIS204 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence ACSIS205 Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of data. ACSIS208 Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations
Technologies	ACTDEP049 Develop, modify and communicate design ideas by applying design thinking, creativity, innovation and enterprise skills of increasing sophistication ACTDEP050 Work flexibly to effectively and safely test, select, justify and use appropriate technologies and processes to make designed solutions ACTDEP051 Evaluate design ideas, processes and solutions against comprehensive criteria for success recognising the need for sustainability ACTDEP052 Develop project plans using digital technologies to plan and manage projects individually and collaboratively taking into consideration time, cost, risk and production processes ACTDEP040 Critically analyse factors, including social, ethical and sustainability considerations, that impact on designed solutions for global preferred futures and the complex design and production processes involved ACTDEP041 Explain how products, services and environments evolve with consideration of preferred futures and the impact of emerging technologies on design decisions
Mathematics	ACMSP251 Use scatter plots to investigate and comment on relationships between two numerical variables

Useful resources and websites:

- Media release from National Science Foundation discussing new research which may enable the use of seawater for hydrolysis: https://beta.nsf.gov/news/generating-renewable-hydrogen-fuel-sea
- How to calculate concentration of a solution (as a percentage and also parts per million): https://www.wikihow.com/Calculate-the-Concentration-of-a-Solution
- Shell give a clear and easily digestible explanation of the different methods of hydrogen production and possible uses: https://www.shell.com/energy-and-innovation/new-energies/hydrogen.html
- You can download factsheets about hydrogen and Woodside's hydrogen projects here: https://www.woodside.com/what-we-do/new-energy/hydrogen

Biogas production

Objective

Students will investigate which organic matter creates the most biogas and consider the viability of using biogas to fuel vehicles.

Due to the equipment required for this investigation we recommend that it is conducted as a class investigation. It will also take a few days/ weeks to get results depending on the temperature of the room, so make sure you have space somewhere to put the experiments so that they will not be tampered with and preferably so they can get warmth and light as this will speed up the reaction. This experiment can also be conducted more simply by just placing a balloon over the top of a bottle/ flask – however, often the balloons can be quite permeable, and the gas production is slower than rate of loss. This method can make determining the volume collected more challenging and creative (we suggest submersing in Eureka cans). You may wish to try different methods for students to compare and evaluate.

Be very careful when disposing of the contents as they will contain rotten material and can be very smelly. Glassware will need to be very well cleaned and disinfected.

Although biogas can be easily produced at home, to be used as a fuel it needs to be pressurised and often liquified. In America, biofuel is increasingly used for vehicles – although more commonly biodiesel (liquified biogas mixed with diesel).

The sustainability of biofuels is heavily debated, as in many places the crops are grown just to be used to produce fuel (rather than using waste as feedstock). In many cases this means deforestation or replacement of natural and native plants which has other environmental implications.

	Australian Syllabus Links
Science	ACSSU187 Different types of chemical reactions are used to produce a range of products and can occur at different rates. ACSSU189 Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere. ACSHE192 Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries ACSHE230 Values and needs of contemporary society can influence the focus of scientific research ACSIS198 Formulate questions or hypotheses that can be investigated scientifically

	ACSIS199 Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; asses risk and address ethical issues associated with these methods. ACSIS200 Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately ACSIS203 Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies ACSIS204 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence ACSIS205 Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of data. ACSIS208 Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations
Technologies	ACTDEP040 Critically analyse factors, including social, ethical and sustainability considerations, that impact on designed solutions for global preferred futures and the complex design and production processes involved ACTDEP041 Explain how products, services and environments evolve with consideration of preferred futures and the impact of emerging technologies on design decisions ACTDEP049 Develop, modify and communicate design ideas by applying design thinking, creativity, innovation and enterprise skills of increasing sophistication ACTDEP050 Work flexibly to effectively and safely test, select, justify and use appropriate technologies and processes to make designed solutions ACTDEP051 Evaluate design ideas, processes and solutions against comprehensive criteria for success recognising the need for sustainability ACTDEP052 Develop project plans using digital technologies to plan and manage projects individually and collaboratively taking into consideration time, cost, risk and production processes

Mathematics	ACMSP251 Use scatter plots to investigate and comment on relationships between two numerical variables

Useful resources and websites:

- An explanation of biofuels from the U.S Energy Information Administration, and also an overview of how they are created and used can be found here: https://www.eia.gov/energyexplained/biofuels/
- Details about biofuel use in Australia can be found here, this also has a link to a full list of vehicle models which can use biofuel: https://www.accc.gov.au/consumers/petrol-diesel-lpg/biofuels
- This research paper in Bayero Journal of Pure and Applied Sciences, discusses in-depth studies of using fruit and vegetable waste to generate biogas: https://www.ajol.info/index.php/bajopas/article/view/58513

Resistance in the Grid

Objective

Students will investigate the relationship between the length of a wire and its resistance and relate this to energy loss in the grid.

This is a very simple experiment which is excellent for discussing the flow of electrons through a wire in terms of collisions. Students will very quickly establish that the longer the wire is the more resistance there is (due to more collisions). They may also note the heating effect – be aware of this as thin wires can heat up quickly and become dangerous. You may want to add a resistor to minimise heating or use a switch so that students only turn on the circuit for as long as it takes to get a reading. Encourage students to have roles (one to measure the current and another to record the voltage) to speed up the process. Also allow time for the wire to cool between readings (they can start plotting results on a graph), as the hotter the wire is the higher the resistance will be.

Students may want to do further research into the efficiency of the national grid, and possibly do some calculations into the energy loss in transmission lines. They can compare this to efficiency of solar panels or domestic wind turbines. They may also research different materials and their resistivity, also their price and availability.

According to "Our World in Data" 940 million (**13%** of the world) do not have access to electricity. Students may want to reflect on life without electricity.

	Australian Syllabus Links
Science	ACSSU190 Energy conservation in a system can be explained by describing energy transfers and transformations ACSHE230 Values and needs of contemporary society can influence the focus of scientific research ACSIS198 Formulate questions or hypotheses that can be investigated scientifically ACSIS199 Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; asses risk and address ethical issues associated with these methods. ACSIS200 Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately ACSIS203 Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies

	ACSIS204 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence ACSIS205 Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of data. ACSIS208 Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations
Technologies	ACTDEP040 Critically analyse factors, including social, ethical and sustainability considerations, that impact on designed solutions for global preferred futures and the complex design and production processes involved ACTDEP041 Explain how products, services and environments evolve with consideration of preferred futures and the impact of emerging technologies on design decisions ACTDEK046 Investigate and make judgements on how the characteristics and properties of materials, systems, components, tools and equipment can be combined to create designed solutions ACTDEP049 Develop, modify and communicate design ideas by applying design thinking, creativity, innovation and enterprise skills of increasing sophistication ACTDEP050 Work flexibly to effectively and safely test, select, justify and use appropriate technologies and processes to make designed solutions ACTDEP051 Evaluate design ideas, processes and solutions against comprehensive criteria for success recognising the need for sustainability ACTDEP052 Develop project plans using digital technologies to plan and manage projects individually and collaboratively taking into consideration time, cost, risk and production processes
Mathematics	ACMSP251 Use scatter plots to investigate and comment on relationships between two numerical variables ACMSP253 Evaluate statistical reports in the media and other places by linking claims to displays, statistics and representative data

Moving Forward – Teacher Resource

Useful resources and websites:

- Information on energy availability globally. Hannah Ritchie, Max Roser and Pablo Rosado (2020) - "Energy". Published online at OurWorldInData.org. Retrieved from: https://ourworldindata.org/energy
- Good explanation of the role of an Electrical Engineer can be found here along with other career guides: https://jobs.newscientist.com/en-au/article/what-does-an-electrical-engineer-do-/
- The Australian Energy Market Commission released a report outlining factors leading to transmission loss and what is being done to overcome it: https://www.aemc.gov.au/energy-system/electricity/electricity-system/transmission-loss-factors
- Excellent simulation from PhET Colorado demonstrating resistance in a wire: https://phet.colorado.edu/en/simulations/resistance-in-a-wire

Regenerating Energy

Objective

Students will will learn about regenerative breaking in hybrid cars and create a simple generator, investigating factors which will affect the induced current.

This activity is really useful to give students an idea regarding how electricity is generated – not only in terms of hybrid cars. You may wish to adapt this activity to look at electricity generation in power plants, with wind turbines and tidal energy.

Creating simple generators also enables students to consider how much energy needs to be put into the system to generate electricity (their hands will quickly become tired spinning the shaft on their generator). They should find that as the magnetic field strength (number of magnets) increases so does the induced current. However, it is very difficult for them to maintain a steady speed which they can discuss as a source of error in their evaluation.

There are many areas on a car where a generator could be added – for example over the suspension. This works similarly to wave power generation as the car bounces up and down the magnets move within a coil of wire and generate electricity. Car manufacturers have to consider the weight to power output and determine if adding the extra weight is worth it in terms of energy production.

Students will research hybrid cars in comparison to their non-hybrid equivalent and determine if a hybrid car would work out financially better in the long run due to the amount of fuel they could save. This will depend on many factors, including how much they use the car, if they drive in metro areas or mainly on freeways. Some students may look at the cost of repairing and insuring a hybrid car compared to its equivalent.

	Australian Syllabus Links
Science	ACSSU190 Energy conservation in a system can be explained by describing energy transfers and transformations ACSHE230 Values and needs of contemporary society can influence the focus of scientific research ACSIS198 Formulate questions or hypotheses that can be investigated scientifically ACSIS199 Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; asses risk and address ethical issues associated with these methods. ACSIS200 Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately

	ACSIS203 Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies ACSIS204 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence ACSIS205 Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of data. ACSIS208 Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations
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Mathematics	ACMSP251 Use scatter plots to investigate and comment on relationships between two numerical variables ACMSP253 Evaluate statistical reports in the media and other places by linking claims to displays, statistics and representative data

Useful resources and websites:

- Excellent simulation from PHET Colorado showing how a basic generator works: https://phet.colorado.edu/en/simulations/faradays-law

Cars of the World

Objective

Students will conduct research which will enable them to discuss the pros and cons of different vehicle fuel types for cars.

Scaffolded students will compare the different fuel type options considering their availability and viability where they live and in another location in the world (suggestion is London due to high EV infrastructure availability, however China, India and America also have very varied fuel types available and are leading the way in many areas).

Guided students are asked to consider which car they would choose for themselves now and in 30 years' time, using research to explain their answer and why their choice may change as technologies advance and new laws are passed.

Open students will discuss the pros and cons of different vehicle fuel types for cars and explain why some fuel types are favourable for different locations around the world and consider how this may change in the future.

Students are asked to present this activity as an essay, table, video, slideshow or through some other means as directed by your teacher.

This activity enables students to consider what the future of fuels may look like and also consider how political and social climate can affect technological progress. They may want to reflect on the global goals again at this stage.

	Australian Syllabus Links
Science	ACSSU189 Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere. ACSHE230 Values and needs of contemporary society can influence the focus of scientific research ACSIS204 Use knowledge of scientific concepts to draw conclusions that are consistent with evidence ACSIS208 Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations
Technologies	ACTDEP040 Critically analyse factors, including social, ethical and sustainability considerations, that impact on designed solutions for global preferred futures and the complex design and production processes involved

	ACTDEP041 Explain how products, services and environments evolve with consideration of preferred futures and the impact of emerging technologies on design decisions

Useful resources and websites:

- Excellent simulation from PHET Colorado showing how a basic generator works: https://phet.colorado.edu/en/simulations/faradays-law

Bibliography

Figure 1: 17 Global Goals, https://www.globalgoals.org/, accessed on 12/08/22

Figure 2: Two Centuries of rapid global population growth will come to an end, accessed at https://ourworldindata.org/world-population-growth-past-future on 1/08/22

Figure 3: BMW Hydrogen 7 CleanEnergy car, accessed at https://commons.wikimedia.org/wiki/File:BMW_Hydrogen_7_CleanEnergy_car_seen_from_above_-_Verkehrszentrum.JPG on 12/08/22