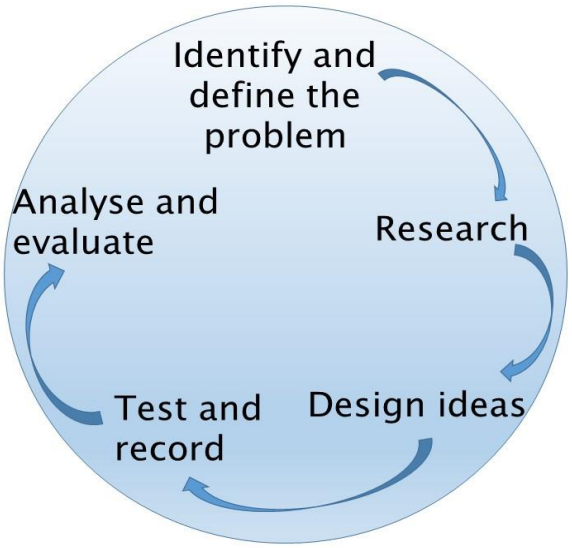
Moving Forward – Student Booklet

The 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.

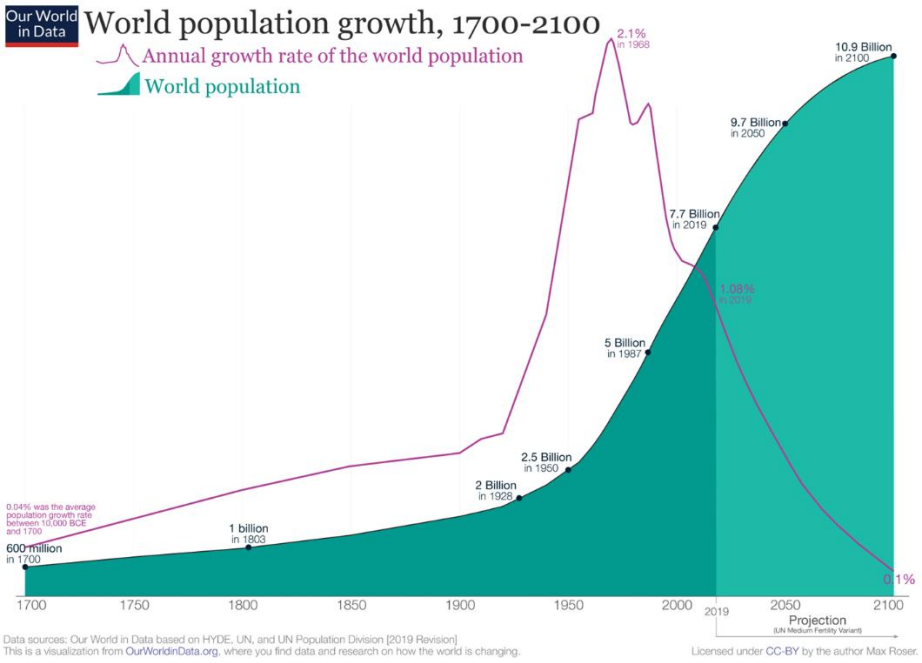


Figure 2. Past and predicted population growth of the world. (OurWorldData.org, 2022)

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.

Background Research

1. Which state or territory in Australia has the highest recorded number of EV car sales per 10,000 vehicles? Suggest why this may be the case.

2. Compare this to the number of EV cars sold in other countries (e.g., China, Germany, and America).

3. Hydrogen is generally described in terms of colours, this relates to how it is produced. Create a table to explain how each of the types of hydrogen are produced.

4. Why is it important to consider the colour coding of hydrogen when determining how sustainable a fuel type is?

5. Rank the colours of hydrogen from highest to lowest carbon intensity.

6. Create a table or pie graph to show the energy mix in Australia in 2021 as percentage?

7. Why is this energy mix relevant to considering the use of electric cars?

8. Consider the UN sustainability goals. Rate them from 1 – 17 in terms of how much the future of fuels used for transport relates to them and explain your answer.

Hydrogen fuel

Background information

Hydrogen is being trialled as a fuel of the future, and infrastructure is being built and developed with this goal in mind. Hydrogen can be created through splitting water into its two components, hydrogen and oxygen, through a process called hydrolysis. Many hydrogen production facilities, such as Woodside Energy's H2TAS, will be designed to create green hydrogen and ammonia.

Figure 3. BMW 7 series prototype, powered by hydrogen. (Creative commons).

Job Alert

Chemists and chemical engineers play a vital role in the resources industry. Part of their role can involve investigating the efficiency of reactions and how to generate the highest yield of the desired product.

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Objective

To design and conduct an investigation to determine the relationship between electrolyte concentration and hydrogen production during hydrolysis (electrolysis of water) and consider how this could affect production yield.

Background research

1. What are the main factors which can increase the rate of a chemical reaction?
2. What does the term cation mean?
3. What is a cathode?
4. What does the term anion mean?
5. What is an anode?
6. What is the purpose of the battery/applied voltage during electrolysis?
7. What is an electrolyte and what is its purpose in terms of electrolysis?
8. What is the chemical formula of water?
9. What is the ratio of oxygen atoms to hydrogen atoms in water?
10. Considering your answers to Q8 and 9, would you expect more oxygen or hydrogen to be produced during hydrolysis? Explain your answer.
11. Research some techniques for simple hydrolysis/ electrolysis of water to assist you in planning your investigation and ensure you reference them

Hypothesis

What do you hypothesise the relationship between the concentration of the electrolyte and the amount of hydrogen will be. Explain your answer using references to support your hypothesis.

Equipment

What equipment will you need for your investigation?

Method

Write a method for the investigation, ensuring you have made it clear how it will be conducted safely, what will be the independent and dependent variables and how will you measure these? How will you ensure it is a fair test?
Include a diagram to show how you will set up the investigation.
Show all of this to your teacher, for approval, before you conduct the investigation.

Results and Analysis

How can you present the results so that it is easy to make comparisons between other groups?
Remember if you are doing this as a class investigation it is important that the whole class measures and records their results the same way so that results can be fairly compared.

Describe the relationship between the concentration of the electrolyte and the volume of hydrogen gas produced.

Evaluation

1. How did your results compare to your hypothesis?

2. Were there any potential sources of error in your investigation? (Hint: consider what other variables may increase the rate of reaction in this experiment)

3. How could you improve this investigation?

4. Salt is also an electrolyte. Research and discuss the pros and cons of using seawater to create hydrogen through hydrolysis. Ensure you reference any sources you use.

5. Planned Hydrogen plants in Australia will be using fresh, processed, water (e.g., from a desalination plant). What environmental implications might this have and does this affect the carbon intensity of hydrogen?

6. Considering the main factors which can increase the rates of reaction, outline any ideas you have to research the rate of hydrogen production, through hydrolysis, further.

Biogas Production

Background information

Biogas is produced by the breakdown of organic matter. Biogas can be generated on a small or large scale. Some households and farms have their own digesters to create biogas, which is used for heating. Across Australia more local councils are starting to collect food waste to generate electricity (City of Cockburn, 2022). Biogas can also be used as a fuel for transport.

Job Alert

The role of a **chemist** can include investigating yield production. In the case of biogas, this would involve trialling different organic materials to determine which ones create the most biogas. **Environmental engineers** and **scientists** may then consider the impacts of biogas on the local environment where it is produced, monitoring potential hazards from freshwater contamination. An **environmental advisor** can use the research to help in creating policy and provide feedback to local councils and parliament, enabling them to make safe decisions regarding biogas production plants.

Objective

To design and conduct an investigation to determine which type of organic matter creates the most biogas.

Background research

1. What does the term anerobic digestion mean?

2. Give some examples of the sort of waste products that can be used to produce biogas.

3. Research some simple biogas production experiments/ science fair projects to assist you planning this investigation.

Hypothesis

Use scientific research to support a hypothesis about which organic matter will create the most biogas, explaining your answer.

Equipment

What equipment will you need for your investigation?

Method

Write a method for the investigation, ensuring you have made it clear how it will be conducted safely, what changes you would expect to observe and how you will measure these changes.
Will you be able to get any quantitative data and carry out statistical analysis?
How will you set up a control?
Include a diagram to show how you will set up the investigation.
Show all of this to your teacher, for approval, before you conduct the investigation.

Results and Analysis

How can you present the results so that it is easy to make comparisons between other groups?
Remember if you are doing this as a class investigation it is important that the whole class measures and records their results the same way so that results can be fairly compared.
If possible present your results in a table and graph.

1. Which waste material produced the most biogas over the whole experimental period?
2. Which waste material produced the least biogas over the whole experimental period?
3. Were there any trends in the data, for example, the rate of gas production was linear/ exponential/ inverse exponential? Why could this information be important considering biogas production as a business?

Evaluation

1. How did your results compare to your hypothesis?
2. Were there any potential sources of error in your investigation? (Hint: consider what other variables may increase the rate of reaction in this experiment)
3. How could you improve this investigation?
4. What does this investigation show you about the production of biogas?
5. Outline any more ideas you have to take this research further. Consider factors which could increase the rate of reaction.

Extension

Biogas needs to be compressed to be used as a fuel. Research the viability of home production of biogas to be used in a private vehicle and compare this to the viability of the use of biogas in fleet vehicles (such as a Transperth buses).

Resistance in the Grid

Background information

With many countries, such as the UK, announcing that they will ban the sale of new cars powered wholly by petrol and diesel (BBC, 2020) in the not-so-distant future, many people are beginning to purchase electric cars instead. This in turn may lead to people considering how they get their electricity.

Most households have their energy supplied by the national grid. This is a network of cables which distribute electricity around the country from a variety of sources such as coal-and-gas fired power plants, solar arrays and wind farms. You can also feed any excess electricity your household generates (from solar panels etc.) back into the grid.

People can also live "off grid" which means that they produce all their own electricity. This may be via solar panels which would also require battery storage and/ or a back-up generator.

Job Alert

The role of an **electrical engineer** often involves working with large scale systems, such as designing an efficient national grid. An electrical engineers' responsibilities can include undertaking research, creating test procedures, and writing reports. Electrical engineers need to have a good understanding of physics and material science, particularly conductivity and resistivity of materials. They also need to be competent mathematicians, to enable them to present and interpret data.

Objective

To design and conduct an investigation to determine the relationship between the length of a wire and resistance. Then relate this to energy loss in the grid and what this means for electric vehicle recharging.

Hypothesis

Use scientific research to support a hypothesis stating the relationship between the length of a wire and resistance, explaining your answer.

Equipment

What equipment will you need for your investigation?

Method

Write a method for the investigation, ensuring you have made it clear how it will be conducted safely, what will be the independent and dependent variables and how will you measure these? How will you ensure it is a fair test?
Include a diagram to show how you will set up the investigation.
Show all of this to your teacher, for approval, before you conduct the investigation.

Results and Analysis

How can you present the results so that it is easy to make comparisons between other groups?
Remember if you are doing this as a class investigation it is important that the whole class measures and records their results the same way so that results can be fairly compared.
If possible present your results in a table and graph.

1. Describe the relationship between the length of wire and the resistance.

2. Using any prior understanding of how current flows, explain your results. You may wish to draw a diagram to aid your explanation.

3. Use your results from this experiment to explain what happens the further an energy source is away from a customer.

4. Would it be more **efficient** to charge an electric car using the energy produced at your house, e.g., rooftop solar, or to use energy distributed from the national grid? Explain your answer referring to your experimental results. You may also want to consider the efficiency of rooftop solar panels compared to the efficiency of a powerplant.

Evaluation

1. How did your results compare to your hypothesis?

2. Were there any potential sources of error in your investigation? (Hint: consider what other variables may increase the resistance of a wire in this experiment)

3. How could you improve this investigation?

4. What does this investigation show you about the efficiency of electricity transmission?

5. Outline any ideas you have to take this research further.

Extension

1. Which other careers might involve researching electrical energy transmission and efficiency?
2. One of the main problems with using household solar to charge an EV is that the car is usually in use during the day when the solar panels are generating electricity. Research battery swapping stations and discuss the pros and cons of these.

Regenerating Energy

Background information

Automotive **designers** and **engineers** will consider factors to increase a vehicle's efficiency and assist with car design. Many hybrid and electric vehicles make use of regenerative braking systems. When a driver removes their foot from the accelerator, or applies pressure to the brake, the motor spins in the opposite direction and thus acts as a generator, which creates electricity to help recharge a battery. The energy is also used to assist the braking system, to help slow the car down.

A generator generates electricity and can be a relatively simple device. There are three main components required for a generator: a magnet, a coil of conductive metal wire and a force. When the force is applied to the magnet, to make it move in and out of the coil of wire (or the coil moves over the magnet), then a current is generated.

Objective

To design and create a simple generator and investigate the variables which affect the current induced.

Hypothesis

Using scientific research, make predictions about how changing different variables will affect the amount of induced current and explain your answers.

Equipment

Research basic generators to help you create a design. What equipment will you need for your investigation?

Method

Write a method for the investigation, ensuring you have made it clear how it will be conducted safely, what will be the independent and dependent variables for different trials and how will you measure these? How will you ensure it is a fair test?
Include diagrams to show how you will set up the investigation and create the generator.
Show all of this to your teacher, for approval, before you conduct the investigation.

Results and Analysis

How can you present the results so that it is easy to make comparisons between other groups?
Remember if you are doing this as a class investigation it is important that the whole class measures and records their results the same way so that results can be fairly compared.
If possible present your results using tables and graphs.

1. Describe any relationships you found during your investigations.
2. Hybrid cars are recommended for city driving, but less so for freeway travel. Explain why this is the case considering the purpose of regenerative braking and changes in velocity during city travel versus freeway travel.
3. Explain why brake pads on a hybrid car will last longer than brake pads on a regular car.

Evaluation

1. How did your results compare to your hypothesis?
2. Were there any potential sources of error in your investigation
3. How could you improve this investigation?
4. Outline any more ideas you have to take this research further.

Extension

1. What is meant by pay- back time in terms of a hybrid vehicle?
2. Compare the specifications of some hybrid and equivalent non-hybrid models to determine how many kilometres you would have to travel before the hybrid car stated to save you money.
3. Consider your family's car usage and determine what the payback time for different hybrid cars would be.
4. What other factors may you want to research before deciding if a hybrid would work out to be more economical for you/your family?
5. Using your research, discuss if a hybrid vehicle would be a good choice for your next family car.
6. Research electromagnetic suspension systems and how they work.

Cars of the World

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.

Objective

To discuss the pros and cons of different fuel types for cars and explain why fuel types are favourable for some locations around the world, and not others, and to consider how this may change in the future.

Suggested areas of research

What different fuel options are available in your area now and are there any projects which may make other options available in the future. How does this compare to other countries?

Compare the specs and payback time of equivalent cars with different fuel types. Look at historical prices and note the rate of change in pricing, considering how this may track with improvements in technology.

Research laws being passed in Australia, and other countries, which may affect the types of vehicles available for purchase (possible bans on diesel and petrol only cars).

Consider the sustainability of different fuel/energy types and carbon intensity of these. How might this vary in different countries (e.g think about using solar to create electricity in the UK versus Australia).

Results

You may wish to present all or some of your findings as an essay, table, video, slideshow or through some other means, as directed by your teacher.