

## FULL STEAM AHEAD

### **LEVEL**

Year 11

VCE: Systems Engineering

### **ACTIVITY DESCRIPTION**

An innovative approach for sustainable fuel for steam locomotives is well underway around the world. The lack of availability and increasing price of coal has led many heritage steam railways to trial ways to reduce their carbon emissions by using alternate fuel sources.

The UK heritage railway industry used 26,000 tonnes of coal per year pre-covid, accounting for just 0.02% of the UK's carbon emissions. Even with these low emissions, heritage railways need to find alternate fuel options.

As a heritage railway Puffing Billy Railway are looking at ways to be more sustainable. One of the seven key strategic aspirations at Puffing Billy Railway is to “Commit to Environmental Sustainability” which emphasises the importance of the stunning Dandenong Ranges that the rail corridor passes through. Puffing Billy Railway is committed to minimising the impact on the environment in which it operates.

Students investigate a renewable energy technology that could be trialled in the locomotives at Puffing Billy Railway. They work in groups to explore one of these options and create an A4 infographic using PowerPoint or Canva to present their findings.

### **SUBJECT AREA**

Systems Engineering Unit 3: Integrated and controlled systems

Area of Study 2- Clean energy

### **MATERIALS REQUIRED**

- “Full Steam Ahead” Task Sheet
- Devices with access to the internet to conduct research
- Devices with access to PowerPoint and/or Canva

### **INSTRUCTIONS**

1. Ask students where is Puffing Billy Railway (PBR)? Discuss the Temperate Rainforest habitat that Puffing Billy Railway passes through.
2. Ask students what is a steam engine? Is it sustainable? Discuss the progress in sustainability of the transportation industry. What types of trains do we use now?
3. Alongside the sustainability initiatives of the railway, with the closure of many coal mines and the increasing price of coal, Puffing Billy Railway is investigating alternative renewable fuel sources for their steam engines. Watch how engineering is turning agricultural waste into an affordable energy source - <https://www.abc.net.au/education/engineering-fuel-solutions/13745774>.
4. Discuss the video as a group. Make a list on the board of alternative fuel sources for heritage steam trains. Add any alternatives to the list that students have missed (use background information).

5. Have students break into pairs or groups to research one of the renewable fuel sources for steam railways. Allow students to have access to school computers and/or their own devices to research information about their energy source, using at least 2 different websites.
6. Students will be showcasing the chosen fuel source as an infographic created in PowerPoint or on Canva. Give students enough class time to accurately research their chosen fuel source and create the infographic.
7. On completion of their infographic students are to display the alternate fuel sources around the room with students to undertake a gallery walk to view others work.

## ✔ SUGGESTIONS FOR ASSESSMENT

Ability to work in a team and equally contribute to the task. Successful completion of the infographic.

## ▶ CURRICULUM LINKS

### SYSTEMS ENGINEERING

Unit 3: Integrated and controlled systems

Area of Study 2 – Clean energy technologies

Outcome 2

Discuss the advantages and disadvantages of renewable and non-renewable energy sources, and analyse and evaluate the technology used to harness, generate and store non-renewable and renewable energy.





## RENEWABLE AND NON-RENEWABLE ENERGY

There are five main renewable energy sources:

### Renewable Energy

- Solar energy from the sun
- Geothermal energy from heat inside the earth
- Wind energy
- Biomass from plants
- Hydropower from flowing water

There are five main non-renewable energy sources:

### Non Renewable Energy

- Petroleum products
- Hydrocarbon gas liquids
- Natural gas
- Coal
- Nuclear energy

Crude oil, natural gas, and coal are called fossil fuels because they were formed over millions of years by the action of heat from the earth's core and pressure from rock and soil on the remains (or fossils) of dead plants and creatures such as microscopic diatoms. Most of the petroleum products consumed are made from crude oil, but petroleum liquids can also be made from natural gas and coal. Nuclear energy is produced from uranium, a non-renewable energy source whose atoms are split (through a process called nuclear fission) to create heat and, eventually, electricity.

Puffing Billy is a Steam Engine, using steam energy to move. Steam energy is water heated into steam.

Steam is usually converted to motive power by a reciprocating engine or turbine. The pistons are driven by the steam power. The steam engine inside the locomotive relies on the burning of coal in order to work. The woodfire burns in the engine room until it turns into hot coal, which can burn for long periods of time. The coal heats up the connected boiler, which is full of water, creating steam. The steam is then squeezed into a very small space and forced into a metal rod called a piston. The steam is so powerful it moves the pistons, which are connected to the wheels of the train. The wheels start moving, and the pistons keep pumping.

## LOWER EMISSIONS

Moving freight by rail is 16 times more fuel efficient than moving freight by road. This modal shift will reduce the carbon emissions of Australia's freight industry. But how do we make the rail industry lower emissions? The University of Wollongong is doing some amazing research in this space – (<https://www.uow.edu.au/media/2023/heres-how-we-can-bring-back-rail--and-cutemissions.php>) with the UK leading the way: <https://www.birmingham.ac.uk/research/climate/climate-publications/clean-transport/decarbonisation-and-heritage-railways>

Do Heritage steam railways need to lower emissions? Hear from Talylyln Railway about the changes they, and others are making across the UK - We Need to Talk About Coal - Talylyln Railway coal: <https://www.youtube.com/watch?v=VraSUVfGyq8>



## ALTERNATIVE TYPES OF FUELS FOR HERITAGE STEAM RAILWAYS

Research into alternative fuels to coal is being undertaken, and trials have been conducted in steam locomotives. Steam locomotives use high-quality, low pollution coal that produces very little smoke. Most of what comes out of a steam locomotive chimney is steam, harmless water vapour.

Steam coal produces large amounts of energy and high temperatures that can be harnessed by a locomotive. It is very different to the house coal that most people are familiar with, which burns at lower temperatures and produces more emissions (Reference: <https://www.hra.uk.com/resources/coal>). Due to the closing of coal mines and the cost of coal mining all steam heritage railways around the world are now looking for alternatives.

### BIOENERGY

Australia's Bioenergy Road map sets out a vision for a sustainable bioenergy industry that delivers lower emissions, regional growth, energy resilience and waste management benefits for Australia. Bioenergy is a form of renewable energy generated from the conversion of biomass into heat, electricity, biogas and liquid fuels. Biomass is organic matter derived from forestry, agriculture or waste streams available on a renewable basis. It can also include combustible components of municipal solid waste. Many of the bioenergy feedstocks come from agricultural activities, such as from sugarcane waste and the livestock industries. See more here: <https://arena.gov.au/assets/2021/11/australia-bioenergy-roadmap-report.pdf>

### WILDFIRE

Burning with a natural and high-heat flame, Wildfire is an approved Ready to Burn smokeless fuel and produces up to 20% less CO<sub>2</sub> than traditional coal.

Wildfire offers a direct smokeless replacement to traditional coal while providing a low inherent ash and high heat output.

See more here: <https://willowwarm.ie/>

### TORREFIED BIOMASS/BIO-COAL



Solid fuels made from rice husk biomass (30 g), mandarin peel (30 g), cornstarch (15 g), glycerol (10 ml) and acetic acid (5 ml).

Reference: Solid fuels made from rice husk biomass (30 g), mandarin peel (30 g),... | Download Scientific Diagram ([researchgate.net](https://www.researchgate.net))

Imagine a fuel with the same energy, density and material handling properties of coal, without the associated carbon footprint, heavy metal or sulphur content. The University of Minnesota's Natural Resources Research Institute (NRRI), a leader in the efficient processing of cellulosic biomaterial into carbon neutral bio coal, has engineered such a fuel. Known as torrefied biomass (or biocoal), the fuel conversion process is a derivative of coffee roasting technology originally designed in the early 20th century in France (torrefaction = "to roast" in French)

Reference: *Torrefied Biomass — Coalition for Sustainable Rail* ([csrail.org](https://csrail.org))

<https://csrail.org/everett>

<https://csrail.org/newsroom/2022/3/23/csr-a-status-update>

On Sat 24th September 2022, Ireland saw the first passenger train to be hauled by a steam locomotive using a 100% renewable biomass-based coal substitute. This was on the Stradbally Woodland Railway, a short narrow-gauge line with steep gradients. Being in woodland, the old saying 'from small acorns do great oaks grow' could be perfectly appropriate for this significant trial.

The fuel used was a stove-ready commercial product called 'Harvest Flame' that is made via the process of Torrefaction from biomass – in this case olive stones, a residue from the food industry.

In California they are also beginning the next chapter in the history of locomotives by leading a pilot project to determine the effectiveness of utilising 100% biofuel in their locomotive fleet - [https://www.up.com/aboutup/community/inside\\_track/biofuel-locomotive-test-it-220714.htm](https://www.up.com/aboutup/community/inside_track/biofuel-locomotive-test-it-220714.htm)

In New Zealand the MOTAT tram is trialling renewable energy sources - <https://www.timberbiz.com.au/steam-tram-100-to-run-on-biofuels/>

Reference:

<https://vb.nweurope.eu/projects/project-search/three-c-creating-and-sustaining-charcoal-value-chains-to-promote-a-circular-carbon-economy-in-nwe-europe/news/first-irish-trial-of-a-new-fuel-for-heritage-railways-a-huge-success/>

<https://www.railengineer.co.uk/bio-coal-trials-show-promise/>

Puffing Billy Railway have trialled a briquette version from the Latrobe Valley and are investigating the use of waste vegetable oil in their oil burning steam engine - <https://puffingbilly.com.au/news/workshop-blog/would-you-rather/>

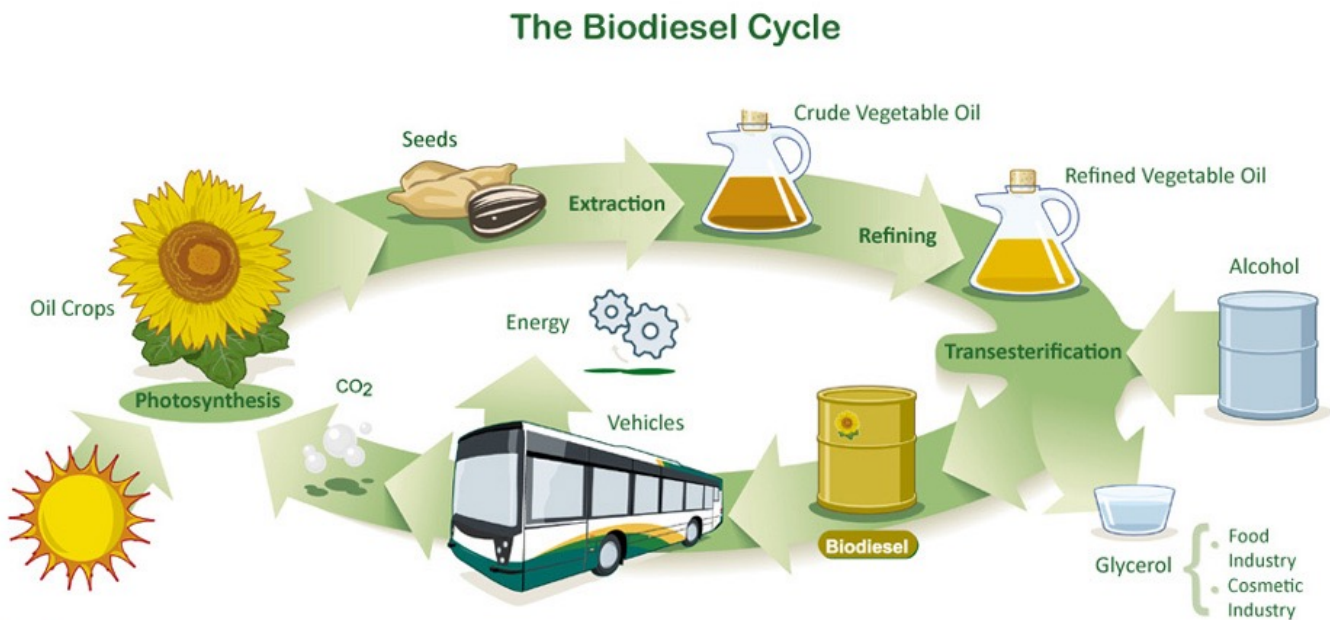
[https://rail.nridigital.com/future\\_rail\\_may22/sustainability\\_biofuels\\_wabtec](https://rail.nridigital.com/future_rail_may22/sustainability_biofuels_wabtec)

### BIODIESEL - USED COOKING OIL

Biodiesel is liquid fuel derived from various types of cooking or vegetable oils and fats. It has similar combustion properties to regular petroleum diesel fuel. Because it is produced from cooking oils and fats, biodiesel is non-toxic and biodegradable. When burned, it produces significantly fewer emissions than petroleum-based diesel fuel which makes it much more environmentally friendly.

Reference: *How to Recycle of Used Cooking Oil : From Restaurant to Biodiesel* (grandnaturalinc.com)

<https://www.mamod.co.uk/mamod-news/tips-and-guides/meet-the-eco-friendly-steam-locomotives>



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## DIESEL



By the end of the 1960's, diesel had almost completely superseded steam as the standard railroad motive power on nonelectrified lines around the world. The chance came first in North America, where, during the 25 years 1935-1960, railroads in the USA completely replaced their steam locomotives.

What caused the diesel to supersede the steam locomotive so rapidly was the pressure of competition from other modes of transport and the continuing rise in wage costs, which forced the railroads to improve their services and adopt every possible measure to increase operating efficiency. Compared with steam, the diesel traction unit had a number of major advantages.

1. It could operate for long periods with no lost time for maintenance; thus, in North America the diesel could operate through on a run of 3,200 km (2,000 miles) or more and then, after servicing, start the return trip. Steam locomotives required extensive servicing after only a few hours' operation.
2. It used less fuel energy than a steam locomotive, for its thermal efficiency was about four times as great.
3. It could accelerate a train more rapidly and operate at higher sustained speeds with less damage to the track.

In addition, the diesel was superior to the steam locomotive because of its smoother acceleration, greater cleanliness, standardized repair parts, and operating flexibility (a number of diesel units could be combined and run by one operator under multiple-unit control).

Diesel mechanical locomotives were first introduced in Australia in the 1930s and these were replaced in the 1950s by diesel electric locomotives. These were a powerful addition to the railways. Diesel fuel powers an engine which drives a generator to make electricity. The electricity powers traction motors that turn the wheels. Diesel electric locomotives were used to transport enormous quantities of materials over huge distances. They were also more efficient and smoother than steam trains and carried much heavier loads. Both steam and diesel locomotives are used at Puffing Billy Railway.

## WOOD



Puffing Billy Railway's Climax 1694 took 10 years to restore and is the only wood burning loco at Puffing Billy. It is one of only four operational Climax locomotives in the world with the other three being based in the USA

Chief Mechanical Officer Chris De Witt of Nevada State Railroad explains the science behind wood-burning locomotives - <https://www.youtube.com/watch?v=HrMjQ3WPL1c>

### References

- *Coal fired steam- can it last?*

<https://csrail.org/newsroom/2016/3/29/coal-fired-steam-can-it-last>

[https://www.railadvent.co.uk/2022/10/net-zero-steam-becomes-a-reality-at-stainmore-railway-company.html#google\\_vignette](https://www.railadvent.co.uk/2022/10/net-zero-steam-becomes-a-reality-at-stainmore-railway-company.html#google_vignette)

## FULL STEAM AHEAD TASK SHEET

An innovative approach for sustainable fuel for steam locomotives is well underway around the world. The lack of availability and increasing price of coal has led many heritage steam railways to trial ways to reduce their carbon emissions by using alternate fuel sources. Puffing Billy Railway is committed to minimising the impact on the environment in which it operates.

In pairs or groups, you are to investigate a renewable energy technology that could be trialled in the locomotives at Puffing Billy Railway. You will create an A4 infographic using PowerPoint or Canva to present your findings.

**NOTE:** You must reference 2 or more websites where you found your information.

Infographics usually use striking, engaging visuals to communicate information quickly and clearly.

Infographics can:

- Provide a quick overview of a topic
- Explain a complex process
- Display research findings or survey data
- Summarize a long blog post or report
- Compare and contrast multiple options
- Raise awareness about an issue or cause

Your Infographic should contain the following information:

- Description of the energy source, including how it is renewable?
- Where is the energy source found and how it is recovered?
- How the energy is stored and how the energy is released?
- How is the energy source used today?
- Advantages and disadvantages of the energy source?
- Future of the energy source? Other interesting facts about the energy source.
- Model, demonstration or labelled diagram of how the energy source works.
- Reference list – small at the bottom



Once complete your infographic will be displayed in the classroom, with all students undertaking a gallery walk to view others work.

Reference: <https://stock.adobe.com/images/coal-mine-the-train-with-coal-infographic-production-and-transportation-of-coal/184164551>