Hydrogen revolution activity sheet

39 Ways to Save the Planet

Royal Geographical Society with IBG

Advancing geography and geographical learning

Hydrogen

This resource has been created from the BBC Radio 4 series 39 Ways to Save the Planet. Listen to the episode Hydrogen Revolution to complete the activity.

75% of the universe's mass is hydrogen, and it is the lightest and most abundant element. As hydrogen is ultimately powered from the sun, it can be extracted from many different sources such as solar and wind, natural gas, nuclear power, and biomass. Because Hydrogen has no flumes, no emissions, and (many people say) best of all — is a silent fuel, it is increasingly being considered as an alternative to electric batteries in cars.

There are many different types of hydrogen (see Further reading). The key types are brown, green, blue, grey, and gold, which are outlined below. The colours correspond to the GHG emission profile of the energy source and how it was extracted.

- Brown hydrogen is produced from coal, through a process called 'gasification'
- Green hydrogen is extracted using a method that does not produce GHG emissions
- Blue hydrogen is made by converting natural gas and capturing the CO_2
- Grey hydrogen is the same as blue except the GHGs are released into the atmosphere
- Gold hydrogen is naturally occurring, for example in the northern Spanish province of Aragon

The source of hydrogen is important. For example, if blue hydrogen is adopted there is widespread concern that it may create an extended economic 'lock-in effect' with fossil fuels as it emits more than green hydrogen. The UK climate change committee have endorsed the use of blue hydrogen in the short-term, whilst renewable energy is scaled up.

1. How are grey, blue, and green hydrogen are made? Read this Guardian article and write an explanation.

2. State why green hydrogen is the best source of gas.

Once the hydrogen is pumped into a vehicle, a chemical reaction is created using oxygen in the air and is pumped into the fuel cell. Inside the fuel cell electrons are extracted from the hydrogen to charge a small battery and produce electricity. The only exhaust products are water vapour and warm air.

The Toyota Mirai in Figure 1 for example only requires 5 kg of hydrogen required for a 300-mile journey the vehicle only needs about 50 litres of water. The end waste product is just 50 litres of water vapour.

There is much excitement about hydrogen technology with 2,000 fuel cell cars on the road throughout Europe.

However, hydrogen infrastructure remains a problem as fuelling stations remain sparse. The fuel cell technology is also expensive, as are the vehicles themselves. The Toyota Mirai RRP is £65,219.

Another concern has been the danger of leakage. As a volatile gas if hydrogen leaks it is flammable and potentially explosive.

3. Go to UKh2mobility and open the interactive map of hydrogen stations. Describe the hydrogen infrastructure in the UK today.

Figure 1 the Toyota Mirai. The yellow tanks are for storing hydrogen. The fuel cells are located in the engine bay © Toyota 2021

JCB hydrogen in the UK

> Our sort of machinery will need to be powered by something other than fossil fuels. We make machines which are powered by diesel, so we have to find a solution and we are doing something about it now.
>
> JCB Chairman Lord Bamford News Release 18 October 2021

In 1945 JCB began life as a small equipment manufacturing company, making agricultural tipping trailers. Since 2004 it has been manufacturing engines at plants in Derbyshire and in Delhi, India. Today the company has 22 plants across 4 continents and is intent on manufacturing super-efficient hydrogen engines.

The 1-tonne electric mini excavator is a successful example of a green machine from JCB, but it is battery technology which is hard to scale up to larger machinery (such as a 20-tonne digger). Larger machinery would require an external battery, at huge cost. It would also take a long time to recharge, whereas hydrogen can also be brought to a site in a can or in tanker easily. A team of 100 engineers is working on the development of hydrogen-powered backhoe loaders (Figure 2) and telescopic handlers at JCB, which are on show at COP26 in Glasgow.

Prime Minister Boris Johnson said of the technology:

> It was fantastic to see JCB's super-efficient hydrogen engines, which could overhaul UK manufacturing, help us to rapidly reach our climate targets and ramp up the UK's hydrogen economy – an exciting area that will be essential to tackling climate change, creating new jobs, and attracting investment.
>
> Prime Minister Johnson 18 October 2021

Figure 2 a JCB hydrogen-powered backhoe loader © JCB

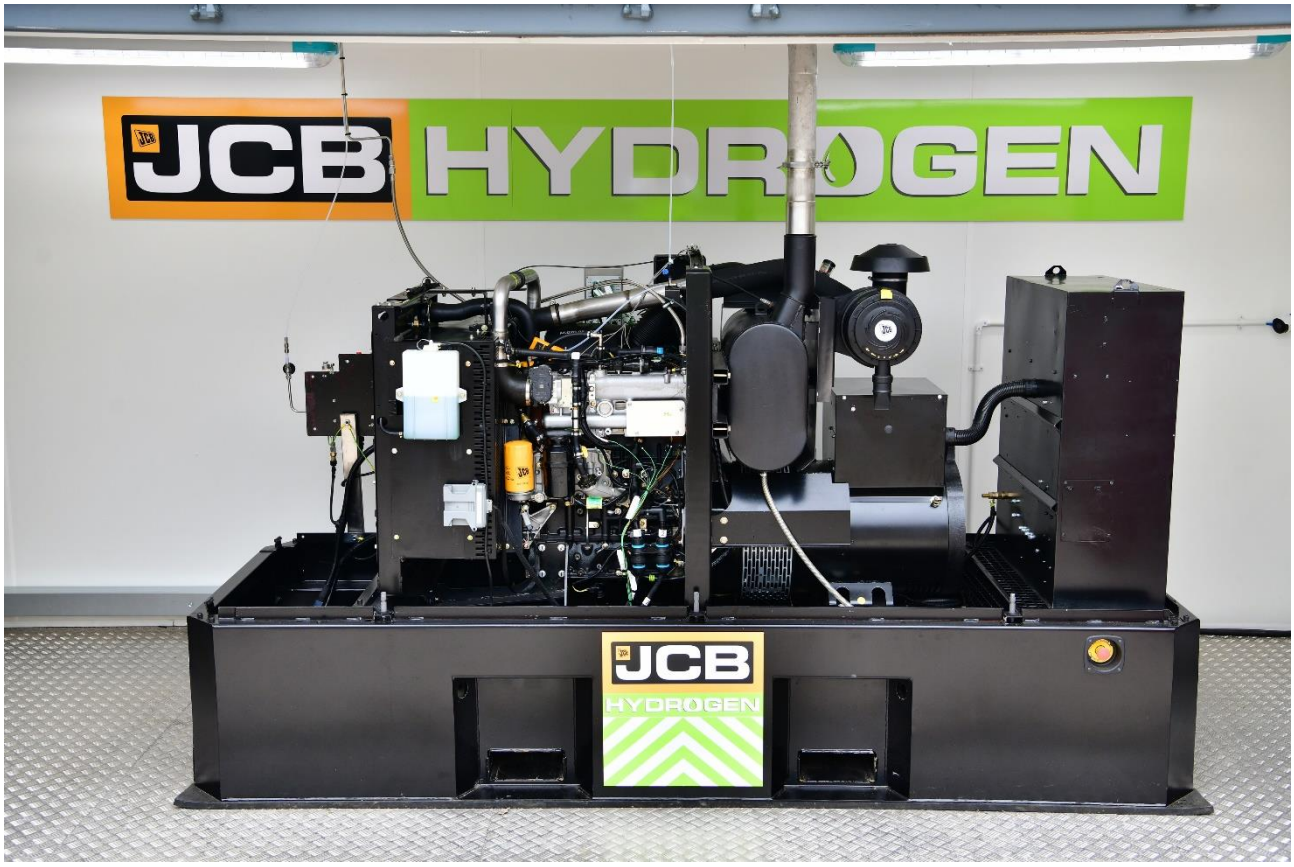

Figure 3 the JCB hydrogen engine © JCB

Research and development of hydrogen engines by JCB continues with a £100 million investment in the project having been announced in October. JCB won the Dewar Trophy for their 'pioneering step towards a zero-carbon future' in November 2021.

The hydrogen economy in California

Whilst hydrogen cars remain a rarity on UK roads in California there are already 9,000 private vehicles on the road and 20,000 forklifts operated indoors using hydrogen. With $20 million annual funding from the California Energy Commission through vehicle license fees and a target of 50,000 hydrogen cars on California highways by 2025, it is the leading US state for hydrogen technology.

Whilst there is an initial success in public uptake of hydrogen cars, there is currently a debate on whether a more realistic short-term achievement would be the conversion of trucks, buses, and airplanes to hydrogen. This is because more fuel can be pumped into smaller and lighter fuel cell tanks, leaving more room for cargo and passengers. Demonstration hydrogen trucks are used at the Port of Los Angeles, and 48 hydrogen buses are being used by local transportation agencies in the city.

The key problem in California is heat. When temperatures exceed a threshold fuelling stations simply have to close in the Golden State. This is because the ignition temperature for hydrogen in air is very low at around 500°C which is problematic when cars overheat in hot climates. Advocates of hydrogen argue that fuel cells have been designed to high standards and are made from highly durable carbon fibre, which are assessed in extreme crash tests. In the Mirai there are additional failsafe measures; an electronic system shutdown procedure (if a leak is detected) and enhanced structural integrity around the tank.

The technology remains popular in California, and it remains one of the few places around the world with hydrogen distribution infrastructure.

4. Read about hydrogen investment in California in 2021. What plans have been announced signalling ongoing support for hydrogen?

Further reading

- Durham University. What is gold hydrogen?
- Shell launches its first hydrogen refuelling station in the UK
- New York Times California Is Trying to Jump-Start the Hydrogen Economy
- Los Angeles Times Is California's 'Hydrogen Highway' a road to nowhere?
- Shell photographic services
- BBC News Hebridean Hydrogen
- CSIRO the colours of hydrogen explained

Answers

1. Grey hydrogen is Hydrogen is extracted from fossil gas releasing CO2 emissions into the air. Blue hydrogen is extracted from fossil gas before CO2 emissions are trapped and stored permanently underground. Green hydrogen is 100% renewable and is extracted from water using renewable electricity and releasing oxygen into the air. Whilst gold hydrogen is naturally occurring.

2. Blue hydrogen is pointless as it is made from natural gas, even though it is a waste product of the industrial process it still produces emissions. Green hydrogen must be the main choice as it manufactured with renewable energy and is CO_2-free. It is produced when water is split with renewable electricity. There are also reserves of subterranean hydrogen called gold hydrogen which would be equally environmentally friendly although extraction would be required.

3. Hydrogen clusters have been carefully invested in. Almost the entirety of hydrogen infrastructure has been developed in the south, around London and Swindon. These areas have received priority development to match the demand in hydrogen vehicles.

4. California plans to open the first hydrogen-powered rail line in San Bernardino by 2024 and has invested in another 134 refuelling stations from an injection of $115 million in funding from the California Energy Commission.

Suggested questions for Hydrogen Revolution

a. If buses, steel, chemical production, and shipping are all decarbonise with hydrogen cells, what would the drop be in global greenhouse gas emissions?

b. The IEA roadmap for net zero by 2050 assumes what percentage split between blue and green hydrogen?

c. When was the clean green hydrogen-engine JCB prototype ready?

d. At the innovation centre, what 3 machines are mentioned?

An RGS-IBG expert

Go to What our experts say to hear further analysis from Society Fellows Dr Katriona Edlmann, Dr Romain Viguier and Dr Ali Hassanpouryouzband from the University of Edinburgh and Mickella Dawkins from Loughborough University.