**First generation biofuels**

**Getting started with the research**

**Questions to ask during your research**

* Can you identify key stakeholders? Who is affected by biofuels? Who influences what happens with biofuels?
* Who makes a profit from first generation biofuels? What is involved in creating this profit?
* Is there anything that connects different stakeholders, e.g. interests or impacts?
* Which stakeholders have the most power in these relationships?

**Background information: first generation biofuels**

First generation biofuels are made by fermenting sugars in edible carbohydrates (like sugarcane and corn) to produce ethanol. Bioethanol is the most common biofuel, particularly in the USA and Brazil, where it is used in transport. Bioethanol has recently been included in the standard UK petrol formulation.

Chemistry plays an essential role in converting biomass into fuels. During photosynthesis, the sugarcane converts carbon dioxide into sugars:

6CO2 (g) + 6H2O (l) → C6H12O6 + 6O2

When the sugarcane has been harvested, milled with water and clarified, the glucose-containing sugarcane juice is fermented with a microorganism (e.g. yeast) at 25–30°C in anaerobic conditions:

C6H12O6 (aq) → 2C2H5OH (aq) + 2CO2 (g)

The reaction is exothermic, so the temperature is controlled using refrigeration. After fermentation, the ethanol is separated from the fermented broth by fractional distillation. The bioethanol can then be used as a fuel, undergoing combustion to release energy:

C2H5OH (l) + 3O2 (g) → 2CO2 (g) + 3H2O (l)

A significant problem with first generation biofuel production is that it involves the use of land that could be used to grow food. Consequences include food scarcity and increases in food costs. It might appear that bioethanol is a carbon neutral fuel, but sugarcane is grown on land that could be a forest sequestering carbon dioxide. Furthermore, energy resources are needed for agricultural and industrial processing, and for the transportation of bioethanol to its place of use.

To create your actor network map, you will need to research further online to find out who the stakeholders are, who and why they are affected and who holds more power in relationships. Selecting one biofuel crop will allow you to focus in greater detail. The articles in further reading might help you begin your investigations. Consider a range of sources - policy documents, newspapers reporting specific cases, research articles and reports from national and international organisations.

**Further reading**

* [Environmental sustainability of biofuels: a review. Royal Society journal article](https://royalsocietypublishing.org/doi/10.1098/rspa.2020.0351)

* [Official UK government biofuel statistics](https://www.gov.uk/government/statistics/area-of-crops-grown-for-bioenergy-in-england-and-the-uk-2008-2020/section-1-biofuels)

* [New Zealand has announced a biofuel mandate to cut transport emissions, but that could be the worst option for the climate: Conversation article](https://theconversation.com/new-zealand-has-announced-a-biofuel-mandate-to-cut-transport-emissions-but-that-could-be-the-worst-option-for-the-climate-189960)

* [Six of the best biofuels New Scientist article](https://www.newscientist.com/gallery/biofuels/)
* [Wikipedia list of biofuel companies and researchers](https://en.wikipedia.org/wiki/List_of_biofuel_companies_and_researchers)

**Strategy for developing an ‘actor network map’**

* Decide on one specific case/location (e.g. second generation biofuels in Brazil). Make this your central actor.
* As you explore, list the actors (one per post-it-note, so you can move them). Remember these can be people, organisations and things.
* Group your actors according to the effect they have on biofuels, or that biofuels have on them - think about direct and indirect effects.
* Draw lines where there are connections between actors. Label the lines. You might also use arrows to identify the direction of influence.
* Provide a key.
* Prepare to present your map to others.

**Second generation biofuels**

**Getting started with the research**

***Questions to ask during your research***

* Can you identify key stakeholders? Who is affected by biofuels? Who influences what happens with biofuels?
* Who makes a profit from first generation biofuels? What is involved in creating this profit?
* Is there anything that connects different stakeholders, e.g. interests or impacts?
* Which stakeholders have the most power in these relationships?

***Background information: second generation biofuels***

Most biodiesel and bioethanol currently in use comes from the first generation biofuel industry.

A potential response to the ‘food versus fuel’ problem of first-generation biofuels is to use food waste rather than the food crop itself to produce biofuels. However, this is technologically challenging because the sugars are locked up in cellulose fibres in cell walls. The sugars must be released before ethanol can be produced.

Second-generation biofuels can be produced by using enzymes to act on the cell walls of non-edible biomass. The enzymatic action can degrade the lignin and cellulose in the plant cells into usable sugars. Once released, the sugars can be fermented to produce bioethanol. This means that potentially any biomass source can be used to make biofuels, including leaves and waste from sugarcane.

In the natural world, brown rot fungus decomposes wood. Two chemists at the University of York, Professors Paul Walton and Gideon Davies, along with colleagues, discovered the active site of a new enzyme (biological catalyst) that helps to break down cellulose. They found that a class of enzyme - lytic polysaccharide monooxygenases or LPMOs - can break down complex carbohydrates (xylans) in wood into simpler carbohydrates (sugars). Enzymes increase reaction rates of specific reactions by providing alternative pathways, which lower the activation energy for the reaction. LPMOs, acting with other enzymes, convert cellulose (a large, insoluble carbohydrate polymer) into glucose, which can be fermented to produce bioethanol. The substrates (in this case, a polysaccharide and oxygen) bind to the active site of the LPMO enzyme, and when the products (here, fermentable sugars) are made, they leave the active site, and the reaction is repeated at the same active site. This means that waste sugarcane material, rather than the sugarcane itself, can be converted into ethanol. In some sites where second generation biofuels are being produced, they are located near to first generation biorefineries, with the potential to intensify existing agricultural models associated with biofuel production.

To create your actor network map, you will need to research further online to find out who the stakeholders are, who and why they are affected and who holds more power in relationships. Selecting one biofuel crop will allow you to focus in greater detail. The articles in further reading might help you begin your investigations.

**Further reading**

* [Explainer: what are biofuels? Conversation article.](https://theconversation.com/explainer-what-are-biofuels-12907)
* [Raízen plant spotlight: Low-carbon opportunities in second-generation biofuels. Fossil fuel industry website.](https://www.shell.com/business-customers/catalysts-technologies/resources-library/raizen-second-generation-biofuels.html)
* [Second generation biofuel markets. Report from UN Conference on Trade and Development.](https://unctad.org/system/files/official-document/ditcted2015d8_en.pdf)
* [Sustainable production of second-generation biofuels OECD report.](https://www.oecd-ilibrary.org/docserver/5kmh3njpt6r0-en.pdf?expires=1675502691&id=id&accname=guest&checksum=45946685765CC6CA2582123AF145E28D)
* [Wikipedia list of biofuel companies and researchers](https://en.wikipedia.org/wiki/List_of_biofuel_companies_and_researchers)

**Strategy for developing an ‘actor network map’**

* Decide on one specific case/location (e.g. second generation biofuels in Brazil). Make this your central actor.
* As you explore, list the actors (one per post-it-note, so you can move them). Remember these can be people, organisations and things.
* Group your actors according to the effect they have on biofuels, or that biofuels have on them - think about direct and indirect effects.
* Draw lines where there are connections between actors. Label the lines. You might also use arrows to identify the direction of influence.
* Provide a key.
* Prepare to present your map to others.

**Third generation biofuels**

**Getting started with the research**

**Questions to ask during your research**

* Can you identify key stakeholders? Who is affected by biofuels? Who influences what happens with biofuels?
* Who makes a profit from first generation biofuels? What is involved in creating this profit?
* Is there anything that connects different stakeholders, e.g. interests or impacts?
* Which stakeholders have the most power in these relationships?

**Background information: third generation biofuels**

Third generation biofuels are fuels produced from algae. The idea is to mimic and accelerate the natural processes that have produced fossil fuels over geological timescales. Algae grow faster than crops, can convert over half their biomass to oils due to high lipid content, and they do not have to be grown on land. High reproduction rates mean that more viable strains can be selectively bred. However, large volumes of water and nutrients are needed, as well as access to light and carbon dioxide.

A number of industrial processes are involved in extracting oils from algae, including pressing and extraction with a solvent. An alternative method uses carbon dioxide as a supercritical fluid to extract the oil from the algae. The extracted oils are then converted into biodiesel by transesterification - a reaction of fatty acids with alcohol, using a catalyst such as sodium hydroxide. This produces biodiesel as well as glycerol and other products which must be removed before the fuel can be used.

It can be challenging to calculate and compare the carbon footprint of different generations of biofuels because a range of approaches are used in producing the fuel, there are different process designs, system boundaries, and assumptions about the feedstocks and nutrients needed. The Royal Academy of Engineering has concluded that biofuels from microalgae are not a feasible alternative at present because their greenhouse gas emissions are higher than those from fossil fuels.

To create your actor network map, you will need to research further online to find out who the stakeholders are, who and why they are affected and who holds more power in relationships. Selecting one biofuel crop will allow you to focus in greater detail. The articles in further reading might help you begin your investigations.

**Further reading**

* [Algal biofuel production is neither environmentally nor commercially sustainable: article from the Conversation](https://theconversation.com/algal-biofuel-production-is-neither-environmentally-nor-commercially-sustainable-82095)
* [Algal biofuels: article from The Biologist](https://thebiologist.rsb.org.uk/biologist-features/algal-biofuel-in-bloom-or-dead-in-the-water)
* [Biofuel breakthroughs bring ‘negative emissions’ a step closer: Conversation article](https://theconversation.com/biofuel-breakthroughs-bring-negative-emissions-a-step-closer-82513)
* [Biofuel: how new microalgae technologies can hasten the end of our reliance on oil: Conversation article](https://theconversation.com/biofuel-how-new-microalgae-technologies-can-hasten-the-end-of-our-reliance-on-oil-176723)
* [Energy from floating algae pods: Ted Talk](https://www.ted.com/talks/jonathan_trent_energy_from_floating_algae_pods/transcript)
* [Fuel from plants Biological Review article](https://www.hoddereducation.co.uk/media/Documents/magazine-extras/Biological%20Sciences%20Review/BSR%20Vol%2030%20No%204/BiologicalReview30_4_FuelFromPlants_Poster.pdf?ext=.pdf)
* [Sustainability of liquid biofuels. Report from the Royal Academy of Engineering.](https://raeng.org.uk/media/pk1k5mie/raeng-biofuels-report-1-1.pdf)
* [Sustainable oil from algae: the technology is ready, but what about the politics? Conversation article](https://theconversation.com/sustainable-oil-from-algae-the-technology-is-ready-but-what-about-the-politics-44969)
* [Wikipedia list of biofuel companies and researchers](https://en.wikipedia.org/wiki/List_of_biofuel_companies_and_researchers)

**Strategy for developing an ‘actor network map’**

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* Prepare to present your map to others.