Science Beyond the Boundaries

**Biofuels**

**Teacher notes**

**Intended learning outcome**

Students will appreciate that research on biofuels takes place in a social, political and cultural context and that the interactions of biofuel science with society creates new questions that need to be answered by science and other disciplines. In particular, students will learn about how energy systems interact with food systems, and about power relations between these systems and society.

***Commentary:***

‘Permacrisis’ was the Collins Dictionary word of the year for 2022, meaning ‘an extended period of instability and insecurity’ and used to describe the ongoing crises relating to climate change, energy and cost-of-living (amongst others). These can all be understood and seen to interact in the context of biofuels.

Global demand for energy and concerns about the climate emergency require a move away from fossil fuels towards more sustainable energy solutions. Biofuels are often hailed as an alternative to fossil fuels which enable energy to be generated more sustainably. A biofuel is a fuel made from biomass, i.e. plant or other organic matter. The fuel can take the form of biogas, or a liquid such as biodiesel or bioethanol. Biofuels are considered renewable resources, because plants remove carbon dioxide (CO2) from the atmosphere as they grow, offsetting CO2 released during combustion of the fuel. In the UK, E10, containing 10% bioethanol has recently been introduced as the standard fuel for petrol driven cars. However, biofuels have come under scrutiny for their potential effects on land dedicated to food production, and consequently on food supplies, prices, and scarcity (Kirshner et al., 2022).

First-generation biofuels are made by fermentation of sugars in edible carbohydrates such as sugarcane and corn. Bioethanol is the most produced and used biofuel, particularly in the USA and Brazil, where it is used as a transport fuel. A potential solution to the ‘food vs fuel’ problem associated with first-generation biofuels is to use food waste rather than the food itself. However, this is technologically challenging because the sugars (needed for conversion into ethanol) are locked up in cellulose fibres in cell walls. Before ethanol can be produced, the sugars need to be released. This is achieved using specific enzymes to degrade the lignin and cellulose in plant cells into usable sugars for fermentation. Second generation biofuels typically use more intensive agricultural models (such as intensive monoculture) than first generation biofuels. A third generation of biofuels involve the use of algae, which can produce biomass faster on smaller land surfaces.

This unit prompts students to consider the relationships between food and fuels, and how these relate to the climate crisis and the fossil fuel and food industry. Students will conduct independent research with an eye on power relations, and synthesise their findings to create a policy brief on biofuel research and development. Students will navigate the environmental, social, economic and political complexities to examine whether biofuels represent the future of fuel, and gain skills in writing for policy purposes.

**Outline of teaching unit**

In this unit, students work together with the end goal of producing policy briefs which present a series of recommendations for policy makers based on an analysis of first, second and third generation biofuels.

To inform their policy briefs, students work together to create *actor network maps* which they present to each other, to support the process of analysing the strengths, weaknesses, opportunities and threats of each different generations of biofuel.

At the end of the unit, students will evaluate the briefs they have created.

**Bold sections are classroom-based activities,** those not in bold can be completed either in or out of the classroom.

**Phase 1.**

**Engage students with an introduction to biofuels and some of the controversies surrounding their development and use**

**Introduce tasks for phase 2**

Phase 2.

Students explore the biofuel industry and identify some strengths, weaknesses, opportunities and challenges of a biofuel future.

First, students learn about actor network mapping. They look at some existing examples to identify strengths and weaknesses.

The class is divided into three groups, with one group researching first generation biofuels, one group researching second generation biofuels and one group researching third generation biofuels. Each group is provided with a ‘getting started’ set of resources to help them learn about biofuels, they each decide on one specific case or location for which they prepare an actor network map. The map can be created with paper and post it notes (if in the classroom) or using an online tool such as Mural, Miro or Lucidchart (or other mapping or graphical organising tool available in the school or college).

**Phase 3.**

**Students share and explain their actor network maps build up an understanding of biofuel research, who is affected, and who has power to make decisions about biofuel research, development and use.**

**Each student completes a SWOT analysis of biofuel production to help discuss what they think the key policy recommendations are based on current research.**

**Introduce tasks for phase 4**

Phase 4.

Students synthesise what they have learnt through the presentation of the actor network maps and SWOT analysis to produce a policy brief for a government funder. Students can work together in class or using a collaborative platform such as Google docs of Canva for asynchronous drafting of their policy brief.

**Phase 5.**

**Students peer-assess their policy briefs, evaluate their learning and consider whether they currently think that biofuels are the future fuels.**

***Activities for each of the five phases of learning***

Phases 1, 3 and 5 are classroom based; and phases 2 and 4 can be completed either in the classroom or independently out of the classroom.

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| **Phase** | **Activity** | **Reason for it** | **Activity summary** | **Estimated time** |
| **Phase 1 – Engage**  **An introduction to three generations of biofuels, and a brief consideration of the advantages and disadvantages of each generation of biofuel.**  **Factors are introduced that students may not immediately think about, such as emissions from extraction and transportation, or the effect on alternative uses for land.**  **The task for phase 2 (Explore) is introduced.** | **1 Introduction to biofuels** | **To understand the use of biofuels in everyday road transport, to determined what students know about where fuels come from, what emissions are associated with different fuels and why biofuels might cause controversy.**  **To give a brief overview of biofuels and associated controversies.**  **To develop media literacy (questioning sources and identifying messages)**  **To develop an overview of the different generations of biofuels** | **Teacher shares slides and questions.**  **Each question is a think-pair-share activity.**  **Teacher prompts students to think about emissions from extraction and transportation of fossil fuels, and those associated with nutrients and transport of biofuels, as well as from combustion. They might also identify issues with land use, using food as fuel, amongst other issues.**  **Teacher explains that bioethanol used in E10 in the UK is produced from wheat and sugar beet. These are first generation biofuels because they are made from edible food crops. Other sources of bioethanol include corn and oilseed rape.**  **The video explains some of the problems with first generation biofuels.**  **Students discuss the questions, and record their responses to the last question to return to in the next phase.**  **Teacher explains that second generation biofuels use non-edible arts of the plant, and third generation biofuels use algae.** | **10 minutes**  **5 minutes**  **15 minutes**  **5 minutes** |
| **2: Actor network mapping** | **To introduce students to what an actor network map is, what a good actor network map looks like, and what it should show.** | **Teacher records strengths and weaknesses identified by students.**  **For detailed guidance on good and bad environmental actor network maps:** [**examples of actor network maps**](https://jimproctor.us/envs/mapping-actors-processes/)**.** | **20 minutes** |
| *Phase 2 – Explore*  *Students each carry out further research focusing on one type of biofuel, and identify and map connections between different interest groups.* | *3: Group task* | *To explore research findings through an analysis of power relations.* | *Students carry out research in one of three groups, with each group developing an actor network map for one specific case or location of one generation of biofuel.*  *Useful information about getting started with research and strategy for developing a map is included, separately for each generation of biofuel, on the resource sheets for this activity.*  *Time will need to be allocated for students in each group to share their research in order to develop one map, or else maps are developed individually and the next task adapted so that students share their actor network maps within groups of three or six students (so that all three generations of biofuel are represented in each).* | *1 or more hours* |
| **Phase 3 – Explain**  **Students share the information they have researched about each generation of biofuel and analyse the information, identifying key types of useful information for decision making.** | **4. Review of actor network maps** | **To share knowledge about different generations of biofuels, and to carry out a SWAT analysis on each generation of biofuel.** | **Teacher reminds students about the qualities they identified in activity 2 that describe a good actor network map and provides opportunity for each group to edit their map.**  **Each group presents their actor network map to the rest of the group. Where possible, display the maps for reference in the next phase.**  **A SWOT analysis is carried out by each student to identify strengths, weaknesses, opportunities and threats of biofuel production based on the presentations.** | **30 minutes**  **10 minutes** |
| **Phase 4 – Elaborate** | **5: Introducing a policy brief** | **For students to understand the purpose and structure of a policy brief.**  **To introduce students to the policy brief task** | **Share the three examples of policy briefs provided in the resources. Give students 5 minutes to skim and identify similarities and differences. Ask students what they think a policy brief is, and what it is for, having seen some examples.**  **What did they have in common?**  **What were better and worse examples and why?**  **Teacher presents slide showing guide on writing a policy brief and working groups organised.** | **10 minutes**  **5 minutes** |
| *Phase 4 – Elaborate (student task)*  *Students use the information they analysed during the explain phase in order to write policy briefs, which sum up the key findings and justify points of action.* | *6. Writing a policy brief* | *To synthesise research into recommendations, and learn how these might be communicated to a policy audience.* | *In groups, students each take a section of the policy brief to write. See slide notes for in-class instructions.*  *In groups of 3, one student takes the context, one takes the evidence and one takes the recommendations. Set a deadline for this.*  *On the deadline, contact students and ask them to look at the section(s) they did not write and make edits in ‘suggesting’ (Google) or ‘track changes’ (Microsoft), and add comments and questions. Set a deadline for this.*  *On the deadline, ask students to look at the edited version, and edit their own section in light of this.*  *In the next classroom session, allow time for final review and edits.* | *1 or more hours* |

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| **Phase 5 – Evaluate**  **Students reflect both on the quality of their research, analysis and summarising skills; and on the benefits or otherwise of biofuels.** | **7: Self and peer evaluation.** | **To assess learning of biofuels and writing for a policy audience.** | **Teacher reminds students of the qualities of good policy briefs identified in Phase 4 Activity 1.**  **Students self- and peer-review their learning on the unit. Students read each briefing and identify**   * **knowledge and skills gains** * **points for improvement** * **what further research is needed** | **40 minutes** |
| **8: Last words** | **To assess the pros and cons of biofuels.** | **Class organised in circle.**  **Teacher asks ‘are biofuels the future of fuels?’ and each student gives their response.** | **10 minutes** |

**Guidance notes: pedagogical approaches**

In this unit, students investigate how science, industry, policy and society interact in food and fuel systems. As they do this, the students work in interdisciplinary teams to research biofuels and produce shared policy recommendations. The intention is to provide students with opportunities to agree and disagree with each other, find shared ground that is actionable in policy, and present this professionally.

**AS/A level specification links**

The biofuels unit could be used to add context to the following areas of examination specifications:

**AQA A-Level Chemistry**

**Organic chemistry**

* Alcohols have many scientific, medicinal and industrial uses. Ethanol is one such alcohol and it is produced using different methods, which are considered in this section. Ethanol can be used as a biofuel. Ethanol is produced industrially by fermentation of glucose. The conditions for this process. Ethanol produced industrially by fermentation is separated by fractional distillation and can then be used as a biofuel.
* Students should be able to explain the meaning of the term biofuel, justify the conditions used in the production of ethanol by fermentation of glucose, and discuss the environmental (including ethical) issues linked to decision making about biofuel use.

**AQA A-Level Biology content:**

**Energy and ecosystems**

* Most of the sugars synthesised by plants are used by the plant as respiratory substrates. The rest are used to make other groups of biological molecules. These biological molecules form the biomass of the plants. Biomass can be measured in terms of mass of carbon or dry mass of tissue per given area.

**Biological molecules (in discussing how second generation biofuels are produced)**

* Each enzyme lowers the activation energy of the reaction it catalyses. The induced-fit model of enzyme action. The properties of an enzyme relate to the tertiary structure of its active site and its ability to combine with complementary substrate(s) to form an enzyme-substrate complex. The specificity of enzymes.

**AQA A-Level Environmental Science**

**Energy resources**

Strategies to secure future energy supplies. Students should understand how specific technologies increase the usability of each energy resource. Biofuels: biofuel crops; hydrogen from algae

**AQA A-Level Politics**

Students should analyse and evaluate how policy is made.