Investigating straw as a biofuel

Lesson overview:

The UK produced approximately 10.4 Mt (million tonnes) of natural straw from barley or wheat in 2016. Approximately 8.8 Mt was usefully used: 5.8 Mt for animal bedding, 2 Mt for animal feed, 0.04 Mt for making compost, 0.4 Mt for winter storage of carrots and 0.6 Mt for making biofuel There was a surplus of approximately 1.6 Mt that could have been used for making more biofuel rather than remaining unused and wasted.[1]

Natural straw can be made into fuel pellets by grinding, drying and forming it into pellets using a binding agent such as molasses. These pellets may be used in power stations to generate electricity or in specialised domestic boilers to provide hot water and central heating for homes. Alternatively, straw can be fermented to make bioethanol which can be added to petrol. Bioethanol is also used as a fuel in some power stations in Brazil and in the future, it may be used in special domestic boilers in the UK.

In this lesson, children investigate burning natural straw to try and measure the energy released during combustion. They compare their results with the energy released from ethanol using a spirit burner. Using their results and a conversion table, they make comparisons of the two biofuels.

Equipment needed:

- Natural straw
- Copper calorimeter (or aluminium beaker)
- Thermometer or temperature sensor / data logger
- Precision balance (to 0.01 g)
- Measuring cylinder
- Ethanol spirit burner (containing methylated spirits or denatured alcohol)
- Bunsen burner
- Heatproof mat
- Stand, boss and clamp
- Eye protection

Safety information:

Standard safety procedures should be followed. Children should wear suitable eye protection Spills should be cleared up immediately and children should avoid getting ethanol on their skin.

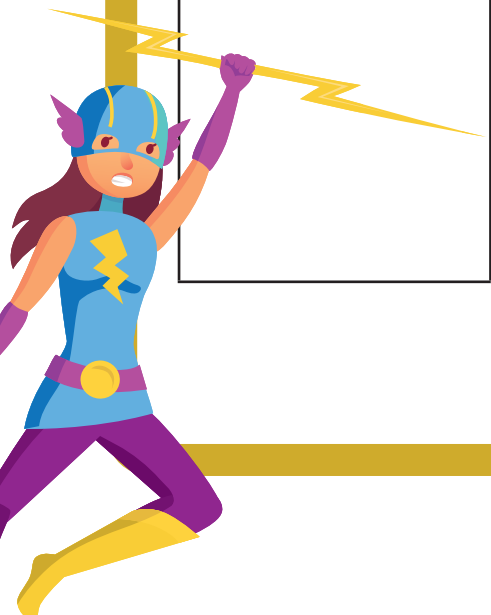
Ethanol burners should have a volume of 50 ml or less and be made for lab use. They should be filled to more than half-full to avoid explosive ethanol / air mixtures forming. The wick should be a good fit in the nozzle and the nozzle a good fit in the burner neck. Burners should only be filled by the teacher or a lab technician. Lighted burners should not be moved when lit. The teacher must be vigilant during use to ensure children do not misuse burners.[2] Teachers should carry out a risk assessment before children carry out the investigation.

[1] Source: Crops grown for Bio-energy in England and the UK: 2016, December 2016, DEFRA.

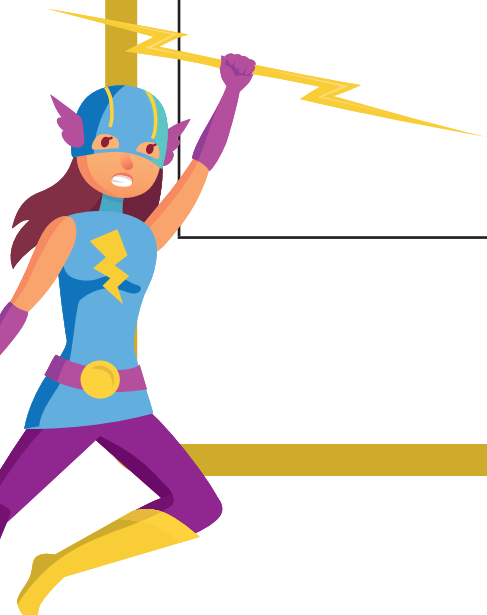
[2] See CLEAPSS Handbook Section 9.4.3 for more detailed guidance.

Presentation guidance:

Slide 2:	Explain that the UK is a major grower of cereal grain - wheat and barley. Some cereal grain is used to make flour for bread and other baked goods. Some is used to make animal feedstock and some by the brewing industry.
Slide 3:	Many children will be familiar with the word 'cereal' in the context of a breakfast food. They may be unaware that the origin of the word is 'a grain to make food'. They may also be unaware that straw is the stalk from cereal crops such as wheat and barley and drinking 'straws' were originally made from rye grass straw.
Slide 4:	Modern round bales come in a variety of different diameters from about 1.2 m (weighing about 200 kg) to 1.8 m (weighing about 400 kg).
Slide 5:	Most cereal straw is used for animal bedding - 5.8 Mt (about 55%). Although about 400 000 tonnes (about 6%) was used to make biofuel in 2016, another 1.6 Mt (about 15%) could have been used to make biofuel.
Slide 6:	Straw contains about 15% water when harvested and it needs to be dried. Explain that molasses is a by-product from sugar refining. Although some molasses is used as a food additive there is a surplus and some is used as a natural 'glue' to bind the straw powder and make pellets.
Slide 7:	Explain that cellulose is a polymer made from long chains of sugar molecules. Straw is not easy for cows and sheep to digest and, if used as food for them, it needs to be supplemented with other foodstuffs. Explain that enzymes are protein molecules that act like a catalyst to make a biochemical reaction happen. Digestive enzymes are a good example – they break large complex molecules into smaller molecules that organisms can use. Enzymes similar to cows' digestive enzymes are used industrially to 'digest' the straw, converting it into simpler sugar molecules. The second part of the process is fermentation (anaerobic respiration). Yeast contains a different enzyme that breaks down sugars into ethanol. Children should be familiar with the process of simple distillation form other work in KS3.



Slide 8:	Explain that our Government makes decisions about science and technology based on advice they are given by expert scientists. The children use an investigation to collect evidence to provide that advice.
Slide 9:	Introduce the basic equipment to children using this slide and the real equipment if possible. Emphasise the safety precautions required during the investigation. Children must: • Wear eye protection • Make sure the metal beaker is securely clamped and near the middle of the bench • Not move the spirit burner when it is lit. They should move the metal beaker to the burner or light the burner when it is in position. A student sheet is available to guide children through controlling variables, reducing errors and recording and processing data.
Slide 10:	The investigation often gives poor results because of the design of the calorimeter (metal beaker). Heat losses by convection around the sides of the beaker are significant and the straw is unlikely to burn cleanly: soot (unburnt carbon) will doubtlessly be deposited on the metal beaker. It would be helpful for children to see the variation in results between groups. The better results from the class can be combined results to determine a reasonable mean value for both fuels. It would also be helpful to discuss the class results after the investigation, identifying sources of heat loss and other possible errors. As an extension activity or homework, children could research or design a better calorimeter.
Slide 11:	Explain that a report to government has two distinct parts: the data collected, and recommendations based on the data. The energy content from straw varies but is quoted as around 19 MJ/kg. The energy content of ethanol is around 25 MJ/kg. However, as the process of making bioethanol is only 35-55% efficient, it is more energy efficient to make fuel pellets. The main reason for making bioethanol is that it can be used as petrol additive or substitute.



Key Stage 3 Curriculum Links:

Subject	Topic	Objective
Science	Working Scientifically (Experimental skills and investigations)	Make predictions using scientific knowledge and understanding. Select, plan and carry out the most appropriate types of scientific enquiries to test predictions, including identifying independent, dependent and control variables, where appropriate. Use appropriate techniques, apparatus, and materials during fieldwork and laboratory work, paying attention to health and safety. Make and record observations and measurements using a range of methods for different investigations; and evaluate the reliability of methods and suggest possible improvements.
Science	Working Scientifically (Analysis and evaluation)	Present observations and data using appropriate methods, including tables and graphs. Interpret observations and data, including identifying patterns and using observations, measurements and data to draw conclusions. Present reasoned explanations, including explaining data in relation to predictions and hypotheses. Evaluate data, showing awareness of potential sources of random and systematic error.
Science (biology)	Cells and organisation	The functions of the cell wall, cell membrane, cytoplasm, nucleus, vacuole, mitochondria and chloroplasts.

Science (biology)	Nutrition and digestion	Plants making carbohydrates in their leaves by photosynthesis and gaining mineral nutrients and water from the soil via their roots. The tissues and organs of the human digestive system, including adaptations to function and how the digestive system digests food (enzymes simply as biological catalysts).
Science (biology)	Photosynthesis	The reactants in, and products of, photosynthesis, and a word summary for photosynthesis.
Science (chemistry)	Pure and impure sub-stances	Simple techniques for separating mixtures: filtration, evaporation, distillation and chromatography.
Science (chemistry)	Chemical reactions	Combustion, thermal decomposition, oxidation and displacement reactions.
Science (chemistry)	Energetics	Exothermic and endothermic chemical reactions (qualitative).
Science (physics)	Energy	Comparing amounts of energy transferred (J, kJ, kW hour). Fuels and energy resources. Heating and thermal equilibrium: temperature difference between two objects leading to energy transfer from the hotter to the cooler one, through contact (conduction) or radiation; such transfers tending to reduce the temperature difference: use of insulators. Other processes that involve energy transfer: changing motion, dropping an object, completing an electrical circuit, stretching a spring, metabolism of food, burning fuels.