Teaching ideas for Topic 8: Energy production

The ever-growing need for energy drives society to search for better primary energy sources and more efficient ways of transforming these into useful forms of energy. The growth of 'alternative energy' has not been uniform across the world, despite the strong persuasion of scientists. The reasons for this are both numerous and complex: political, environmental, geographical, social, ethical, cultural, technological, emotional, ecological and religious opposition have all affected how successful we have been in finding, obtaining and transforming energy for our use. This topic is designed to give students a fair, unbiased background of the availability of energy sources, the processes that are required to obtain and transform the energy, the advantages and disadvantages of the various schemes and the reasons why each scheme is, or is not, successful.

Some useful points to consider are:

- There is considerable scope for independent learning and research in this topic. What makes it so interesting, from a pedagogical point of view, is that everyone in the class, including the teacher, has the opportunity to learn more about this topic by combining students' research with the basic physics principles involved in the transformation of one form of energy into another. Collaboration with other departments within a school or college may also be a very useful way of tapping into expertise and specialist knowledge. This is to be encouraged.
- Subtopic **8.2** concerns itself with the physics of radiation and of thermal energy transfer. There are good opportunities here for experimental and investigative work.
- Since this topic was introduced some years ago, there has been a change in the meaning of some terms. For example, the term 'energy density' is now defined as the energy available from a unit volume of material, i.e. the energy per metre cubed, whereas the term 'specific energy' has been coined to define the energy available per kilogramme of a material. The sixth edition of *Physics for the IB Diploma,* by K. A. Tsokos, now includes the latest definition for the former of these two terms. (There is a TOK point here, see below.)

Ideas for teaching the topic

- A good starting point for this topic would be to research how electricity is provided in your own country. Some questions to consider might be:
  - (i) What are the primary sources of energy used and how much energy as a fraction of the total energy required is obtained from each different primary source?
  - (ii) What is the country's per capita (i.e. per person) average energy consumption?
  - (iii) How is the energy transformed from its original form into electricity? This is a vital area of learning for students, because the syllabus requires students to be able to outline these energy transformation processes. Conventional fossil fuel power stations, nuclear fission power stations, hydroelectric power stations, wind generators and solar cells should all be covered.
  - (iv) What are the relative energy densities and specific energies for various primary energy sources? How does this knowledge guide scientists towards solving the energy crisis? What are the advantages and disadvantages of each method of producing electricity?
  - (v) Once generated, how is electrical energy supplied to consumers?
- Teachers may find that giving students the opportunity to make presentations on their research is a very useful exercise. Not only does it focus the students on independent learning, it also develops their ability to work as part of a group and develops their presentation skills.
- Students should become familiar with the Sankey diagram as a representation of the efficiency of a process to transform energy. Although this is not a difficult concept, it is one that students

can make mistakes with. Attention to detail is an important teaching point that applies not only to this, but to many other areas of the course.

- Conduction, convection and radiation, as ways of transferring energy, are concepts that students may have come across before. It is worth revising these ideas if this is the case and if not then this part of the topic will provide interesting opportunities for students to investigate how good these processes are compared to each other.
- The radiation balance of the Earth is an exercise that is worth doing with students. It highlights several important factors that students should be aware of, such as the role of various atmospheric constituents. Students in Australia, for example, may be all too familiar with the role that ozone plays in absorbing incident solar ultraviolet radiation, while students from the more industrial and urban parts of China will be familiar with how particulate aerosols in the lower atmosphere block out sunlight and make the air appear brown. It is, of course, infrared radiation from the Sun that keeps our planet warm and is a concern of scientists. Students should consider the contribution to the greenhouse effect caused by the gases: methane, water vapour, carbon dioxide and nitrous oxide.
- The Stefan–Boltzmann law and Wien's law are very useful ideas for students to learn about and can be applied successfully in other areas of physics, such as astrophysics. On a more practical footing, application of these two laws and a knowledge of the inverse-square law can allow students to calculate the area of solar panels required to provide sufficient energy to run a house, a village or even a whole country!

Practical activities

- As suggested earlier, allowing students to research for themselves various aspects of this topic will produce varied and interesting facts, ideas and news about energy production around the world. The results of research projects can be presented by groups of students, giving them good opportunities to develop their presentation skills and with it their confidence.
- There is a good opportunity here to collaborate with the chemistry department in a frequently done experiment to investigate the relative effectiveness of various fuels. Students can gain valuable insight into the large values of specific energy for fossil fuels with this.
- A really interesting experiment to do with students is to find out the solar constant, i.e. the amount of solar radiation energy incident on a unit area of the Earth's surface every second. With an insulated container, such as a polystyrene box, containing a known volume of water, placed on the ground outside on a sunny day, students can measure the change in temperature of the water over a period of time, as a result of the absorption of solar radiation by the water. This will allow students to calculate how much energy was absorbed as solar radiation per second. Then, using the surface area of the box, this can be translated into how much energy would be absorbed by 1 m^2 area at the Earth's surface. Students can then compare their experimental value with the globally accepted value and discuss the reasons for any difference. For an extension to this, students can then use the inverse-square law to calculate the luminosity (i.e. the total power radiated) of the Sun.
- A circus of demonstrations to illustrate conduction, convection and radiation may be a good and quick way to get students familiar with these processes. Some suggestions for this are:

  Conduction:

  (i) Dip four equal-sized rods made of different metals in molten wax so that each end has a covering of wax, which is allowed to become solid. Now heat the other end of the four rods (with a Bunsen burner or other method) and watch to see on which rod the wax melts first. This will show students the relative conductivities of the four different metals.

  (ii) Place an ice cube on a metal sheet and another ice cube on a wooden board. The ice cube on the metal sheet will melt first because the metal is a better conductor.

(iii) Ask students to touch something made from wood in the classroom (such as a table with a wooden surface) and then to touch something made from metal. Students will quickly say that the metal is colder than the wood. In fact it is not, but it is a better conductor of the heat from their fingertips.

(iv) A nice model of the process of conduction in a solid is to get your class of students to sit in a line and pass a large bag of sweets (candy or something that the students will like to eat) from one to the next. As each student receives the bag, they can take some of the sweets and then pass the bag on to the next person. The sweets represent energy, and students should see that it takes some time before the sweets reach the end of the line, much like it takes some time for energy to be conducted along a conductor, making the process of conduction a slow process.

Convection:

(i) If you have a very large glass beaker (a 3- or 5-litre beaker is ideal), fill it with water and place it on a stand that will allow you to heat it from below using a localised heat source such as a Bunsen burner. Put some crystals of potassium permanganate into the water at one side of the beaker. Now heat the beaker underneath where the permanganate crystals are. Students will see, by the purple-coloured water, that a convection current quickly forms and that this transports hotter water around the beaker quickly. So convection, which students should consider occurring in liquids and gases, is a quick process for moving thermal energy. You can do the same thing with a glass tube that has been bent into a rectangular loop.

(ii) With an electrical heater, turned on, in one corner of your classroom, put some cologne or perfume on the surface of the heater and get your students to stand in the opposite corner of the classroom. It will not take very long before they will tell you that they can smell the cologne/perfume. You can compare this convective effect with diffusion if you repeat the experiment without the heater, although you might need to be getting on with something else while the students are waiting to smell the cologne/perfume arriving at their noses!

(iii) It may be good for students to apply what they have seen here to the large-scale convective processes that move thermal energy in the atmosphere around the globe (i.e. Hadley cells and similar). It is surprising to note that many students think that deserts occur in the equatorial regions of the Earth!

Radiation:

(i) The classic demonstration of how the ability of objects to radiate is affected by their surface colour and texture is best done with a Leslie cube. This may be a piece of equipment your department already has, but if not it is easy to make one for yourself. A thin metal box that can be filled with hot water can be painted so that each of the four vertical sides are, as an example, black and matt, white and shiny, and any two other combinations of colour and texture. Students can use a bolometer (an infrared detector) or just the back of their hands to see which kind of surface radiates the most energy. This can lead to the idea of emissivity.

(ii) If you have some metal parabolic reflectors, putting a small heat source at the focus of one reflector will allow you to 'beam' the infrared radiation across your classroom to the other reflector, at the focus of which it will be very hot!

(iii) If you live in a hot country, where there is an abundance of solar radiation, you will notice that buildings, houses and cars are frequently white or silver coloured. Their ability to reflect radiation (i.e. their albedo) is an important feature in trying to keep the insides cool. If you have ever left your dark-coloured car outside on a sunny day, you will know exactly how good darkly coloured objects are at absorbing radiation!

- Please see the available practical notes for further ideas.

ICT

- Students could watch the film of the well-known lecture on global warming by Al Gore called 'An Inconvenient Truth'.
- Some students might like to compile their own databases from the information they research on various orbits of celestial bodies in the solar system. This can be a useful exercise for students in deciding what information is useful and what is not. Such computer-based activities link directly to aim 7 of the group 4 aims.

Common problems

- Students will probably confuse the terms 'energy density' and 'specific energy', so it will be important to use these terms regularly.
- As this topic contains a large amount of factual material for students to learn, it is easy for them to forget important details. A regular review of this topic, or spreading out the presentations that students make of their research over a term's lessons might be a good way of eliminating the forgetting of important factual detail. (This can be a very effective way of utilising those lessons that occur at 'difficult' times during the week – if you have any!)

Theory of knowledge (TOK)

- When we change the meaning of words and phrases, it is worth asking the question: Why are we doing this? Does it improve our knowledge? What problems does it pose to those who had already learnt and used these expressions? How much of a link is there here to the linguistic determinism proposed by the Sapir–Whorf hypothesis?
- As outlined in the practical activities, touching wood and metal that are at the same temperature produces two very different sensations, leading us to believe that the metal is cold and the wood is warm. When can we trust our sensory perception and when do we have to accept that our senses can get it wrong? How fooled can we be by illusion? How do we deal with counter-intuitive sensory perception?
- The long list of possible arguments against various energy production processes suggests that it is not an easy task for those that make important decisions about how we obtain our energy. Quite frequently it is the interaction between emotion and reason that ultimately allows decisions to be made. When emotional responses are so easily heightened (as they are, for example, with the topic of nuclear energy production) how can we know that the right decisions are being made – and for the right reasons?
- The time aspect of energy production projects often means that a project begun now may take a decade or more before it is fully functional. During that time, technological advance, political change and other factors such as economic prosperity can alter drastically what countries think and feel about such energy projects. To what extent should we be concerned with what we cannot know is going to happen?
- The interpretation of data is a subjective thing. Scientists, even with the same levels of knowledge and training, can frequently interpret data in different ways. We have seen this already with the various arguments for and against global warming. How then is it possible to decide between different interpretations of the same data?

International-mindedness

- The demand for energy is not going to stop and will, in all probability, continue to increase. As countries develop, so their need for more and more energy also develops. This is a global problem and must be solved globally. This will require greater collaboration between countries (and the people that run them). Perhaps the greatest need right now is for better education about the physics and the other aspects of energy and its exploitation, so that better-informed decisions can be made. Though there has been a big drive to make this happen over the last few years, it seems clear that there is still a need for an internationally agreed set of protocols for how the world looks to solve the energy crisis. Appreciation and understanding of different cultures and philosophies will be vital if this is to happen.

