Nuclear Energy
Support notes

DVD OVERVIEW

MAIN PROGRAM

Basic version (22 min)
Suitable for all secondary levels. Could also be shown to upper primary students.
The program includes the following sections:

- Introduction (the basics of how a nuclear power plant works*)
- What fission is
- The role of cooling water in nuclear reactors
- The nuclear fuel cycle:
    - Mining
    - Milling
    - Enrichment
    - Fabrication
    - Spent fuel: storage and reprocessing
- Other uses of nuclear energy, including 'non-power' uses

Advanced version (27 min)
Suitable for senior secondary/ tertiary science students.
Covers all the topics in the basic version. Also includes:

- A specific example of a fission reaction
- The use of water to vary reactor power
- Different methods of mining uranium
- A more detailed discussion of enrichment, including:
- Structure and properties of Uranium Hexafluoride
- Two methods of enrichment: centrifuging, and gas diffusion
- Decommissioning of nuclear power plants

Extras
Short sequences designed for student enrichment/ teacher background:

- Breeder reactors
- Fusion and fusion reactors
- Fission (the example shown in the advanced program)

* There are various kinds of nuclear power plants. This program describes one of the common designs: a boiling water reactor.

The issues raised by nuclear energy are explored in a separate DVD: ***Nuclear Energy: the Issues.***

USING THE DVD

The main program is presented in clear-cut sections. The DVD can be stopped at any point, for discussion and questions. Alternatively, the entire program can be viewed without break, with questions at the end.

The worksheet questions are presented in the same order as the topics are dealt with in the program. They vary in complexity from straightforward points of fact to questions where the response requires application and synthesis.

INTRODUCTORY ACTIVITIES

The DVD does not necessarily need an introduction, but useful activities before showing the DVD could be to discuss with students any of the following:

Their current knowledge of nuclear energy/ nuclear power:

- Does their country/state use nuclear energy to produce electricity?
- What is the fuel
- What is the essential element in the fuel for nuclear power plants?
- Which countries are the main suppliers? [Canada, Australia, Kazakhstan]
- How much of the world's electricity is produced by nuclear power plants? [a little under 20%]

Issues raised by nuclear power:

- What advantages are claimed for nuclear power generation?
- What are some of the objections raised to the use of nuclear power?

What else is nuclear energy used for (besides electricity generation)?

You could also discuss a current newspaper article/ TV news story related to nuclear energy (eg countries developing nuclear power but suspected of developing nuclear weapons).

Nuclear power plants vs other kinds of power plants: you could discuss with students:

- What other kinds of power plants they have heard of that produce electricity
- What do they have in common (eg do they know both nuclear and fossil-fuel power plants boil water to drive turbines)?
- What differences are there? (eg different kinds of waste products)

STUDENT WORKSHEET

INTRODUCTION

What are the two basic components needed to make electricity?

In a nuclear power plant, what is the purpose of a turbine?

What is used to spin the turbines?

In the program, a model is used to generate electricity. Draw a diagram of the model, and label the main parts.

What is the most common fuel used in a nuclear reactor?

What is the heat released from the fuel used for in the reactor?

What is fission?

What is the difference between U235 and U238? (hint: think about the particles in an atom's nucleus)

What is a chain reaction?

What is used to 'kick-start' the chain reaction in a nuclear reactor?

What is produced by the fission of U235?

What is the purpose of control rods in a nuclear reactor?

How do control rods work (hint: they do it by absorbing something)

Why do nuclear power plants need to move massive amounts of water through a condenser?

What happens to the cooling water as it moves through the condenser?

How is this problem dealt with?

How can weather conditions affect the operation of a nuclear power plant? (hint: there are two examples in the program)

What goes into the air from the nuclear power plant cooling towers?

What substances are produced by coal and gas-fired power plants that are not produced by fission in a nuclear reactor?

What is the problem about the fission products that build up in a reactor?

What is the nuclear fuel cycle? (hint: it's made up of a number of steps)

What is open-cut mining?

What is the common name given to uranium oxide once it's been separated from the rest of the mined rock?

What are 'tailings'?

Why do tailings have to be handled carefully?

Why is nuclear fuel enrichment a controversial process?

In the final stage of fuel preparation, the enriched uranium is converted back from a gas into solid fuel pellets. How are these prepared to use in a reactor?

What is spent fuel?

Why does spent fuel need to be handled and stored with great care? (hint: there are two main reasons).

What are some examples of 'low-level' radioactive waste?

What does 'high-level' radioactive waste mainly consist of?

Most high-level waste is currently stored at power plants and other sites. What is the current long-term plan to deal with this waste?

What are some of the difficulties that these plans have met with? (you may need to do some research eg on the internet).

How much of the world's electricity is currently supplied by nuclear power plants?

ADDITIONAL QUESTIONS (ADVANCED VERSION)

Fission
Complete the missing numbers in this example of fission:

$$^{235}_{92}U \longrightarrow {}^{144}_{56}Ba + {}^{\cdots\cdots}_{\cdots\cdots}Kr + 3\,n$$

In this case, what are the fission products (ie what elements?)

What kind of radiation do they emit?

What does 'n' stand for?

Enrichment
Why is it necessary to enrich the uranium fuel to at least 3% U235 for use in nuclear reactors?

For the enrichment process, uranium oxide is first converted to uranium hexafluoride. Fill in the blanks to balance this equation:

$$U_3O_8 + \ldots HF + F_2 \longrightarrow \ldots . UF_6 + \ldots . H_2O$$

Find out what HF is. Is it an easy material to handle?

Why is uranium hexafluoride a useful compound for the enrichment process? (hint: there are two main reasons).

What are the two methods described in the program for carrying out uranium enrichment?

Breeder Reactors

What is a breeder reactor? How is it different from a conventional reactor?

Are any breeder reactors currently producing electricity on a commercial basis?

Fusion reactors

How is a fusion reaction different from fission?

Have fusion reactors actually been built?

Are any fusion reactors yet producing electricity on a commercial basis?

Note to teachers:

Conversion of uranium oxide to uranium hexafluoride gas

Uranium oxide is dissolved in hydrofluoric acid and excess fluorine gas to form uranium hexafluoide gas as follows:

$$U_3O_8 + 16HF + F_2 \longrightarrow 3UF_6 + 8H_2O$$

ADDITIONAL RESOURCES

Websites

http://www.worldenergy.org/wec-geis/publications/reports/ser/overview.asp
Comprehensive site of the World Energy Council

http://www.world-nuclear.org/sym/1998/frost.htm
Waste Management in the Uranium Mining Industry. Detailed outline of the different categories of waste produced – from a *Uranium Institute* symposium in 1998.

www.wvic.com/how-gen-works.htm
More detail on how an electric generator works, including interactive animation showing generation of both DC and AC current.

http://www.nuc.umr.edu/nuclear_facts/history/history.html
History of nuclear energy – US Department of Energy.

http://www.cekert.kth.se/nuclear_power/virtual/nobel_showcase/reactor_site.html
Virtual Nuclear Reactor tour - produced by the Nobel foundation.

MINING
http://chemcases.com/nuclear/nc-06.htm
Outlines the chemistry involved in extracting uranium oxide from the mined ore.

http://www.uranium1.com/indexu.php?section=uranium%20projects&page=6
Details of 'in situ leaching' mining of uranium on *Uraniumone*'s company website.

http://www.royal-navy.mod.uk/server/show/nav.2549
British Ministry of Defence page with diagrams and explanations of the power systems in their nuclear submarines.