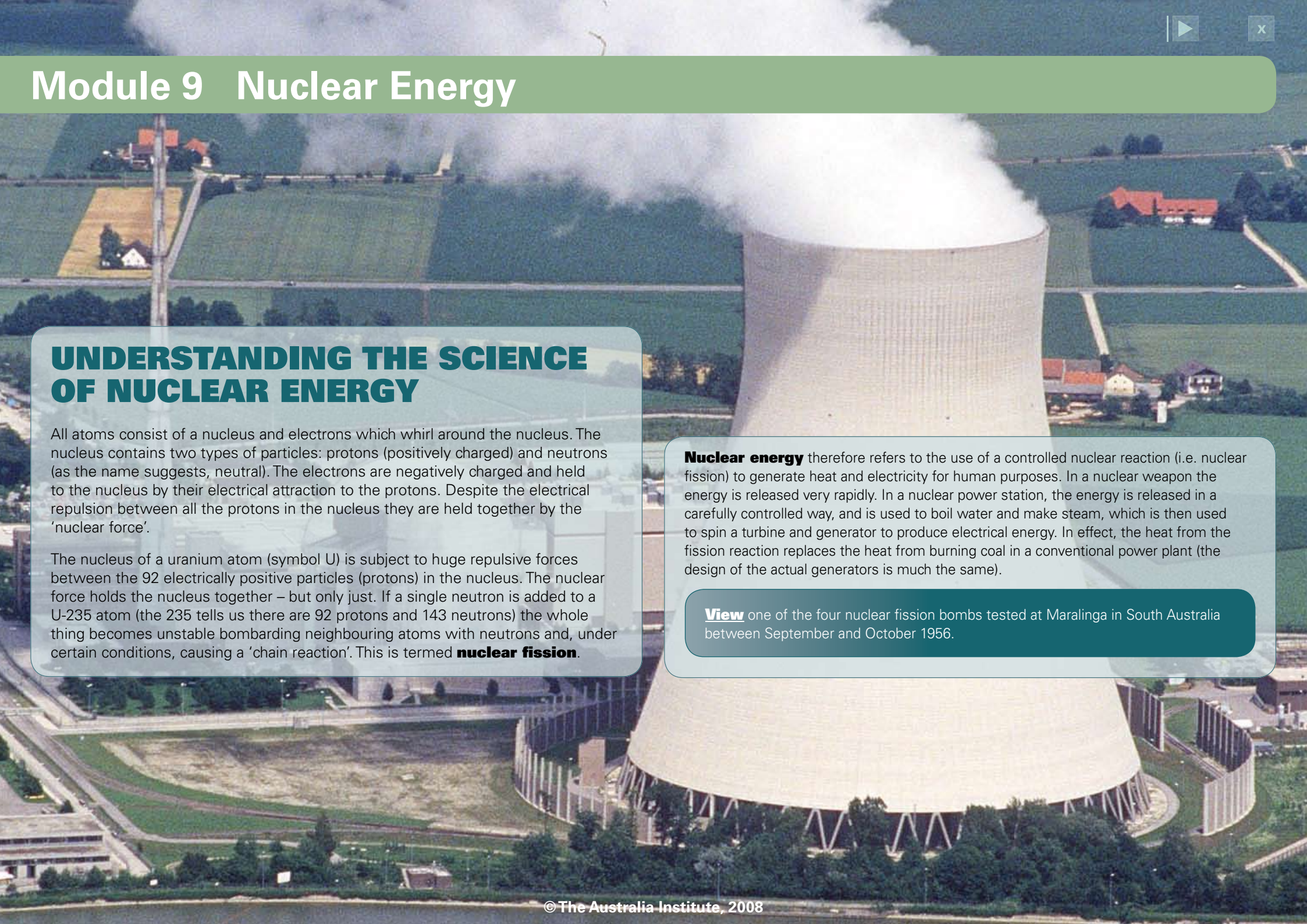


UNDERSTANDING THE SCIENCE OF NUCLEAR ENERGY

All atoms consist of a nucleus and electrons which whirl around the nucleus. The nucleus contains two types of particles: protons (positively charged) and neutrons (as the name suggests, neutral). The electrons are negatively charged and held to the nucleus by their electrical attraction to the protons. Despite the electrical repulsion between all the protons in the nucleus they are held together by the 'nuclear force'.

The nucleus of a uranium atom (symbol U) is subject to huge repulsive forces between the 92 electrically positive particles (protons) in the nucleus. The nuclear force holds the nucleus together – but only just. If a single neutron is added to a U-235 atom (the 235 tells us there are 92 protons and 143 neutrons) the whole thing becomes unstable bombarding neighbouring atoms with neutrons and, under certain conditions, causing a 'chain reaction'. This is termed **nuclear fission**.

Nuclear energy therefore refers to the use of a controlled nuclear reaction (i.e. nuclear fission) to generate heat and electricity for human purposes. In a nuclear weapon the energy is released very rapidly. In a nuclear power station, the energy is released in a carefully controlled way, and is used to boil water and make steam, which is then used to spin a turbine and generator to produce electrical energy. In effect, the heat from the fission reaction replaces the heat from burning coal in a conventional power plant (the design of the actual generators is much the same).

View one of the four nuclear fission bombs tested at Maralinga in South Australia between September and October 1956.

WHERE DOES NUCLEAR WASTE COME FROM?

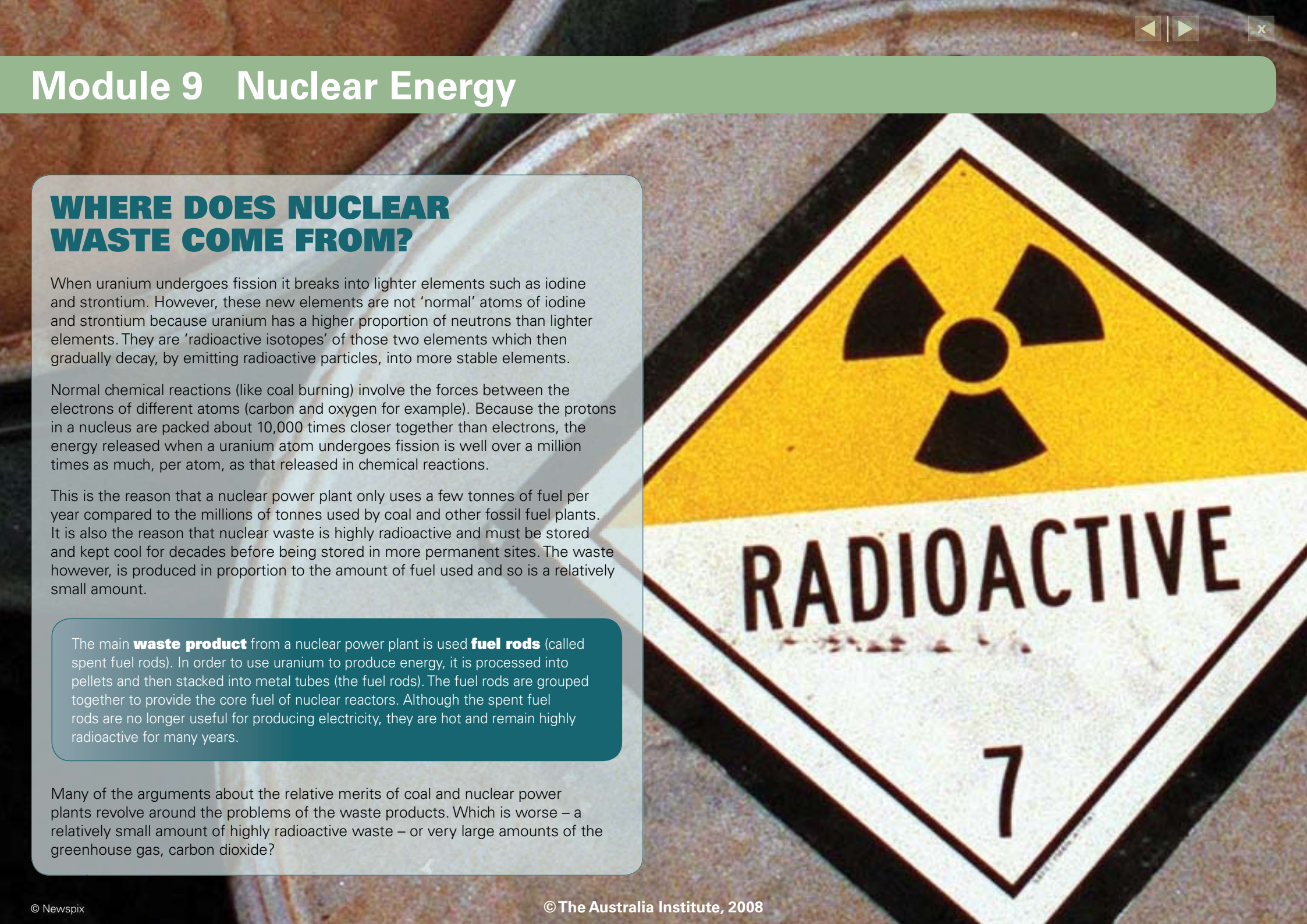
When uranium undergoes fission it breaks into lighter elements such as iodine and strontium. However, these new elements are not 'normal' atoms of iodine and strontium because uranium has a higher proportion of neutrons than lighter elements. They are 'radioactive isotopes' of those two elements which then gradually decay, by emitting radioactive particles, into more stable elements.

Normal chemical reactions (like coal burning) involve the forces between the electrons of different atoms (carbon and oxygen for example). Because the protons in a nucleus are packed about 10,000 times closer together than electrons, the energy released when a uranium atom undergoes fission is well over a million times as much, per atom, as that released in chemical reactions.

This is the reason that a nuclear power plant only uses a few tonnes of fuel per year compared to the millions of tonnes used by coal and other fossil fuel plants. It is also the reason that nuclear waste is highly radioactive and must be stored and kept cool for decades before being stored in more permanent sites. The waste however, is produced in proportion to the amount of fuel used and so is a relatively small amount.

The main **waste product** from a nuclear power plant is used **fuel rods** (called spent fuel rods). In order to use uranium to produce energy, it is processed into pellets and then stacked into metal tubes (the fuel rods). The fuel rods are grouped together to provide the core fuel of nuclear reactors. Although the spent fuel rods are no longer useful for producing electricity, they are hot and remain highly radioactive for many years.

Many of the arguments about the relative merits of coal and nuclear power plants revolve around the problems of the waste products. Which is worse – a relatively small amount of highly radioactive waste – or very large amounts of the greenhouse gas, carbon dioxide?



Module 9 Nuclear Energy

NUCLEAR POWER

Australia currently has no nuclear power stations. The only nuclear reactor in Australia is located at Lucas Heights in Sydney. This reactor is used for medical and scientific purposes rather than as a source of electricity.

Although nuclear energy is not used in Australia, it is used widely overseas. There are over 440 nuclear power reactors in the world located in 30 countries. Nuclear energy now accounts for approximately seven per cent of global energy use and 16 per cent of electricity generation. In France, it provides almost 80 per cent of the electricity. With increasing demands for electricity, more and more countries are considering building nuclear power stations.

One advantage of nuclear fission is that the reaction itself does not release any greenhouse gases. The only greenhouse gases associated with nuclear power stations are those emitted during the mining and refining of uranium; the construction of power plants; and in the manufacture and transport of nuclear fuel rods and waste. This has led some people to suggest nuclear power should be seen as part of the solution to climate change.

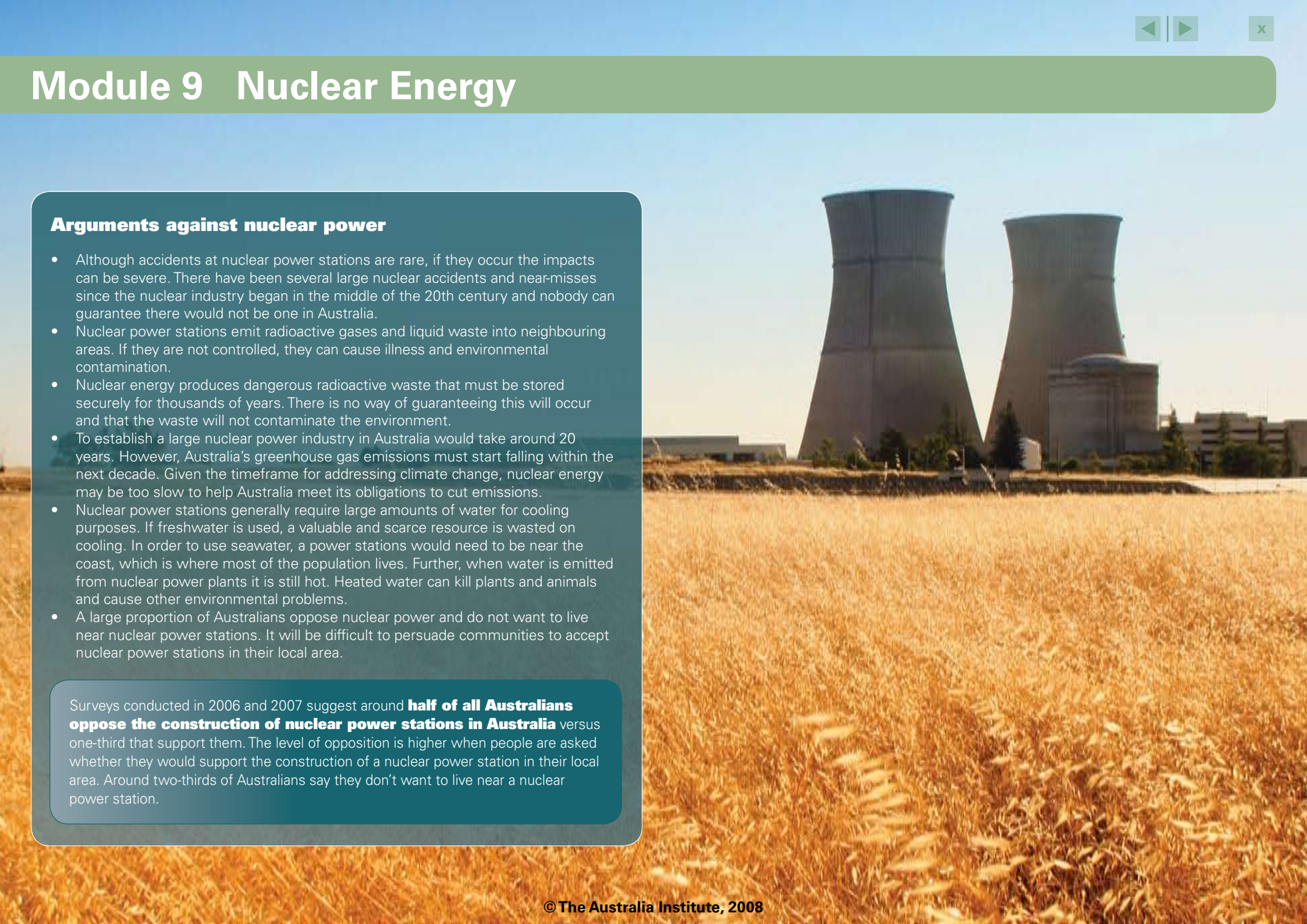
IS NUCLEAR POWER A SOLUTION TO CLIMATE CHANGE?

Australia is currently faced with the question of whether it should embrace nuclear power as one way of reducing its greenhouse emissions. The arguments for and against nuclear power are outlined on the next page.

Arguments for nuclear power

- Nuclear fission does not release greenhouse gases. Even when the emissions associated with constructing nuclear power stations are taken into account, nuclear energy is still substantially cleaner than fossil fuels.
- Nuclear power is more expensive than coal, but it is believed to be cheaper than many types of renewable energy. If Australia is going to substantially reduce its greenhouse emissions, nuclear energy may provide a cheap way of doing it.
- Australia has large stocks of uranium. It has almost 40 per cent of the world's known accessible uranium reserves and is responsible for 23 per cent of global uranium production. These reserves mean Australia would have a secure source of electricity.
- One of the problems associated with many types of renewable energy sources is that the energy output is variable. For example, the electricity supplied by a wind farm will vary depending on the speed of the wind. By contrast, nuclear power stations are able to provide a reliable, constant supply of electricity.
- There have only been a handful of major nuclear accidents since nuclear power was first used. Modern technology has reduced the risk of accidents. The chances of a major accident occurring in Australia are small.

Module 9 Nuclear Energy



Arguments against nuclear power

- Although accidents at nuclear power stations are rare, if they occur the impacts can be severe. There have been several large nuclear accidents and near-misses since the nuclear industry began in the middle of the 20th century and nobody can guarantee there would not be one in Australia.
- Nuclear power stations emit radioactive gases and liquid waste into neighbouring areas. If they are not controlled, they can cause illness and environmental contamination.
- Nuclear energy produces dangerous radioactive waste that must be stored securely for thousands of years. There is no way of guaranteeing this will occur and that the waste will not contaminate the environment.
- To establish a large nuclear power industry in Australia would take around 20 years. However, Australia's greenhouse gas emissions must start falling within the next decade. Given the timeframe for addressing climate change, nuclear energy may be too slow to help Australia meet its obligations to cut emissions.
- Nuclear power stations generally require large amounts of water for cooling purposes. If freshwater is used, a valuable and scarce resource is wasted on cooling. In order to use seawater, a power stations would need to be near the coast, which is where most of the population lives. Further, when water is emitted from nuclear power plants it is still hot. Heated water can kill plants and animals and cause other environmental problems.
- A large proportion of Australians oppose nuclear power and do not want to live near nuclear power stations. It will be difficult to persuade communities to accept nuclear power stations in their local area.

Surveys conducted in 2006 and 2007 suggest around **half of all Australians oppose the construction of nuclear power stations in Australia** versus one-third that support them. The level of opposition is higher when people are asked whether they would support the construction of a nuclear power station in their local area. Around two-thirds of Australians say they don't want to live near a nuclear power station.

Module 9 Nuclear Energy

STUDENT ACTIVITIES

Comprehension Questions

- Which is true or false?
  - Australia relies on nuclear energy for electricity.
  - Nuclear fission does not release greenhouse gases.
  - Nuclear energy is cheaper than coal.
  - It would take only 5 years to establish a large nuclear power industry in Australia.
  - Nuclear power stations require large amounts of water for cooling.

Analysis Questions

- One of the reasons that nuclear power is so controversial is that for nearly every argument in favour of nuclear power, there is a good argument against it. The reverse is also true: nearly every argument against nuclear power can be countered by a good argument in favour. Use the list of arguments above, together with any ideas you and your class mates can think of, to make a table that shows the arguments and counter arguments.

Argument in favour of nuclear power	Counter argument

Argument against nuclear power	Counter argument

Exercise 1

- If a nuclear power station was built in Australia, a decision about where to locate it would have to be made. This decision would require technical expertise, so scientists and engineers would have to be involved. But the decision also has political and economic aspects.

  As a class, brainstorm a list of things that would need to be considered. Which of these things are primarily technical, political, or economic? Which would have more than one aspect to it? Taking these factors into account, where in Australia might it be feasible to locate a nuclear power station?

Teachers Notes

To complete this excercise, students should be told that the four main factors when deciding where to locate nuclear power stations are:

- access to a reliable water source for cooling;
- access to transmission lines to transport the electricity to consumers;
- proximity to an area with high electricity demand (the further a generator gets from the place where the electricity is used the greater the amount of electricity that is lost in transmission); and
- access to transport infrastructure to import and export nuclear fuel rods.