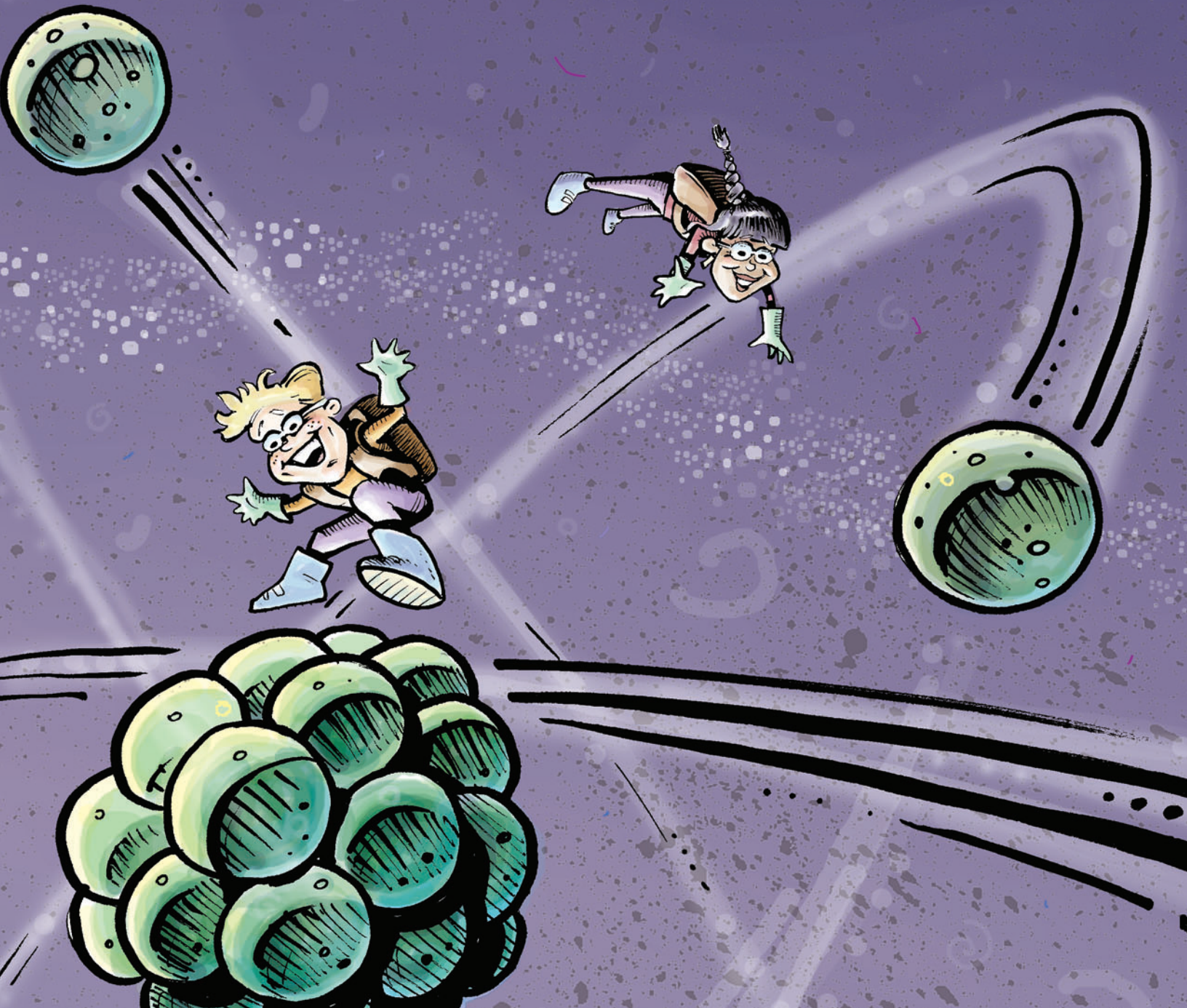


Let's Learn About...

URANIUM

A Teacher's Guide



WHAT IS URANIUM



URANIUM IS A METAL LIKE GOLD OR LEAD. IT IS UNIQUE BECAUSE ITS PHYSICAL PROPERTIES GIVE IT THE POTENTIAL TO GENERATE INCREDIBLE AMOUNTS OF ENERGY. IT IS A VERY COMMON AND ABUNDANT ELEMENT FOUND IN MOST OF THE EARTH'S ROCK, SOILS, RIVERS AND OCEANS. THE SOIL OF A TYPICAL CANADIAN BACKYARD LIKELY CONTAINS ABOUT HALF A POUND OF URANIUM. TRACE AMOUNTS OF IT CAN BE FOUND IN FOOD AND IN YOUR OWN BODY.

THE CHEMICAL SYMBOL FOR URANIUM IS "U."

WHERE DID IT COME FROM?

Physicists believe uranium originated in supernovae in space billions of years ago. Uranium is a common element and scientists believe heat from its radioactive decay deep underground helps keep the Earth's core in its molten state.

URANIUM DISCOVERED

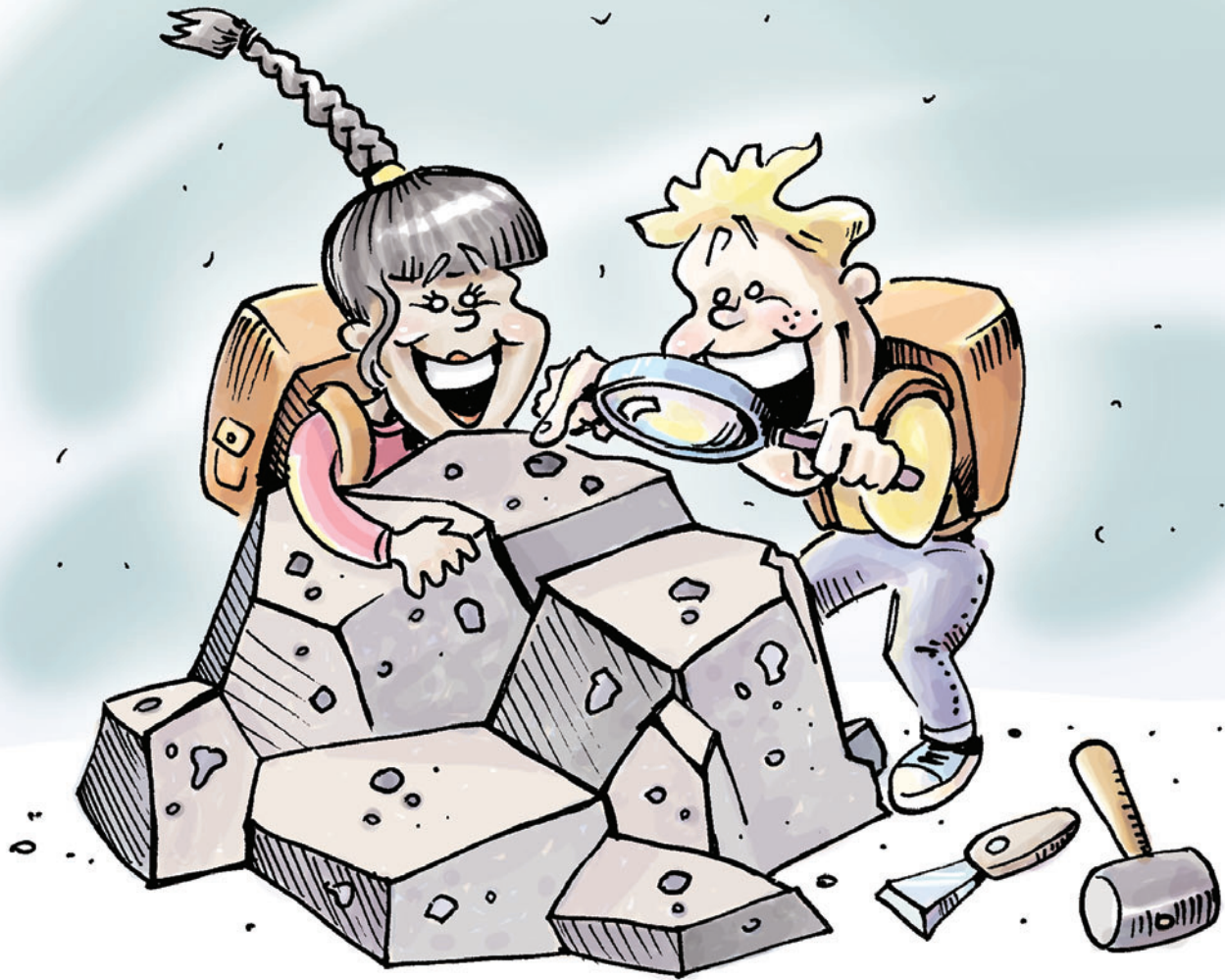
Uranium was discovered in 1789 by German chemist Martin Klaproth while he was studying a mineral known as pitchblende. It was named after the planet Uranus which had been discovered eight years earlier. Uranium's unique properties were uncovered by succeeding generations of scientists including Polish-born physicist Marie Curie who coined the term "radioactive."

URANIUM AS ENERGY

Uranium's most useful property is that its atomic structure can be changed in a process that releases energy in the form of heat. Inside a nuclear reactor, this heat is harnessed to generate electricity without producing greenhouse gases.

BENEFITS OF URANIUM

Generating electricity is not the only benefit uranium offers. Uranium and other nuclear materials are also used for space exploration, food safety, medicine and other non-energy uses. Some remarkable medical uses for uranium and radiation in the treatment of cancer were pioneered right here in Saskatchewan.



THE URANIUM

URANIUM IS ONE OF THE HEAVIEST OF ALL NATURALLY OCCURRING ELEMENTS WITH 92 PROTONS. ISOTOPES DIFFER FROM ONE ANOTHER BY THE NUMBER OF NEUTRONS IN EACH ATOM. ISOTOPES HAVE THE SAME NUMBER OF PROTONS AND NEUTRONS IN EACH ATOM. THE URANIUM FOUND IN THE EARTH'S CRUST IS A MIXTURE OF ISOTOPES. THE ISOTOPE U-238 IS A VERY STABLE FORM WHICH MAKES UP ABOUT 99.3 PER CENT OF ALL URANIUM. IT CAN BE SPLIT UNDER CONTROLLED CIRCUMSTANCES TO PRODUCE A LOT OF ENERGY.



ATOM

2 PROTONS IN EACH ATOM. IT EXISTS IN 16 DIFFERENT FORMS OR ISOTOPES THAT ARE IDENTIFIED BY ATOMIC WEIGHT, WHICH IS SIMPLY THE TOTAL NUMBER OF. IT IS PRIMARILY A MIXTURE OF TWO ISOTOPES – URANIUM-238 AND URANIUM-235. NT OF ALL NATURALLY OCCURRING URANIUM. MOST OF THE REST IS U-235 WHICH CAN

WHAT IS FISSION?

The process of splitting atoms is called nuclear fission. Under certain circumstances, U-235 atoms will absorb extra neutrons and consequently divide, releasing additional neutrons and generating heat. When additional neutrons are released, they collide with other U-235 atoms and in turn cause them to split and release more neutrons. When enough U-235 atoms divide, a chain reaction of fission is created which can produce a great deal of heat from a small amount of uranium. This is the process that occurs inside a nuclear reactor.

WHAT IS RADIATION?

Radiation is energy travelling through space. Sunlight, radio waves and microwaves are forms of radiation on the low-frequency end of the energy spectrum. The type of radiation created by uranium is called “ionizing” radiation. We are all exposed to naturally occurring ionizing radiation from space, and from radioactive atoms in the air, the Earth and even our own bodies, called background radiation.

Most atoms are stable and will never change, but certain atoms are always changing or decaying in a process by which they eventually become stable as completely different elements. Uranium, for example, will naturally turn into lead after billions of years. As an unstable atom decays, its atomic structure changes releasing radiation in the form of gamma rays and alpha and beta particles.



MINING URANIUM

URANIUM ORE TO REACTOR FUEL

Before uranium can be used to fuel a nuclear reactor it must be extracted from the ground and processed into a useable form. It begins as rock containing an unusually high concentration of uranium called uranium ore.

The ore is mined underground or in open pits depending on how deep the deposit is. It is then transported to a mill where it is ground up and a chemical process is used to separate the uranium from other elements in the rock. The final product from milling is U_3O_8 or "yellowcake." It is a fine powder that is packaged in steel drums for shipping.

After mining and milling, yellowcake is shipped to a refinery and is then sent for further processing to prepare it for use as fuel in nuclear reactors.

WHO MINES URANIUM?

Large deposits of uranium ore have been found on all of the Earth's continents except Antarctica. The largest known deposits of high-grade uranium ore in the world are found in northern Saskatchewan. **About 14 per cent of the world's known uranium reserves are located in northern Saskatchewan where four mines produce about 30 per cent of the world's supply.**

Other countries such as Australia and Kazakhstan have large reserves of uranium, but **Canada remains the world's main supplier due to the richness and size of the ore bodies here.**

Uranium is only sold to countries that uphold the international Nuclear Non-Proliferation Treaty by which countries agree to use uranium for peaceful purposes only.





WHO USES NUCLEAR POWER?

Nuclear reactors now generate more than 16 per cent of the world's electricity.

In Canada, nuclear generating stations provide more than 14 per cent of our electricity and additional capacity is planned to meet rising demand, particularly in Ontario.

France relies on nuclear reactors for three quarters of its electricity. The United States – the world's largest energy consumer – has more than 100 nuclear reactors that meet 20 per cent of its electricity needs. Germany, Japan, Belgium, Bulgaria, Finland, Hungary, South Korea, Lithuania, Slovakia, Slovenia, Sweden, Switzerland and Ukraine each generate more than 30 per cent of their electricity at nuclear power plants.

Nuclear energy will play an increasing role in meeting the world's appetite for electricity in the future. Demand is projected to grow by 2.8 per cent annually to 2010 and double by 2020. At the same time, the world is struggling to reduce emissions of greenhouse gases. Nuclear is the one of the cleanest methods of producing large amounts of electricity. Generating the electricity now produced by the world's nuclear power plants with coal would increase carbon dioxide emissions by about 2.4 billion tonnes per year.

THE NUCLEAR

In simple terms, a nuclear reactor is the vessel that contains and controls a nuclear reaction for the generation of electricity. Fuel bundles made of uranium pellets are loaded in the reactor and configured in a way that enables the reaction. Pressurized coolant is pumped through the tubes that hold the fuel bundles to pick up heat from the reaction and deliver it to steam generators. This steam drives turbines that spin large generators to produce electricity.

The greatest potential for a serious accident is a mechanical failure that disrupts the flow of water that carries heat away from the reactor core. The chance of this happening is remote because reactors are designed to automatically shut down if they become too hot. If the cooling system does fail, a reactor core can overheat causing an intense fire. The accident at Chernobyl in 1986 is the only incident of this degree in the history of nuclear energy.

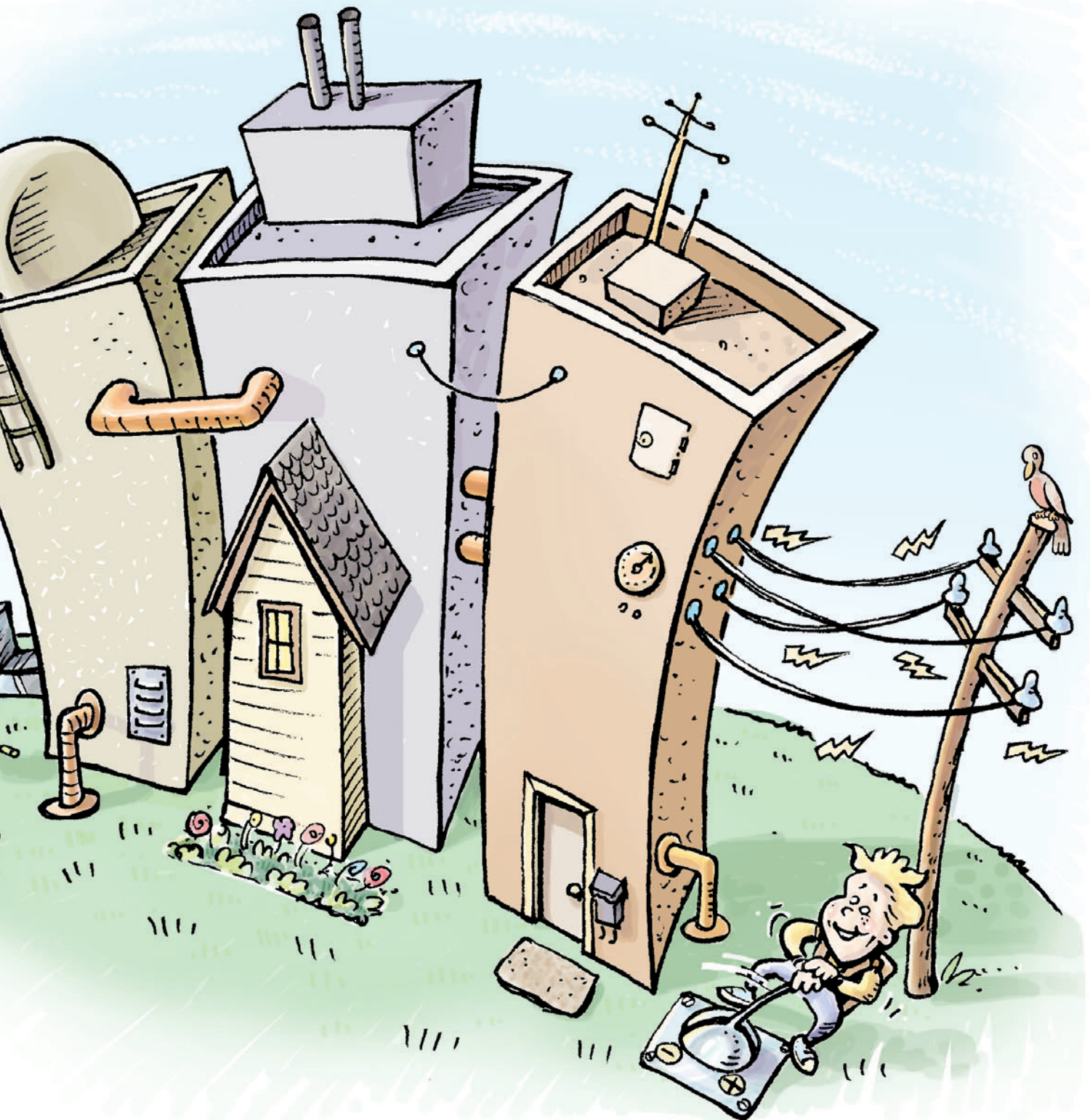
CANADA'S CANDU REACTOR

CANDU reactors were designed and continue to operate in Canada and are among the safest, most efficient and cost effective nuclear power stations in the world. As with all reactors, safety and environmental risks including human error, equipment failure and external risks such as plane crashes and earthquakes have been addressed right from the design phase. The CANDU reactor has two separate shutdown systems and also an emergency core-cooling system to backup the main system. All of the systems are tested regularly to ensure they are available should the need arise.

And just in case, the cores of Canadian reactors, and all other modern reactors, are surrounded by air-tight containment buildings with walls nearly two metres thick to prevent the release of radioactive material in the event of an accident.



REACTOR



OTHER USES FOR URANIUM



FUELLING NUCLEAR POWER STATIONS IS THE MOST WIDELY KNOWN USE OF URANIUM, BUT IT HAS MANY OTHER APPLICATIONS THAT BENEFIT PEOPLE.

URANIUM HAS ALLOWED SCIENTISTS TO CREATE NEW MATERIALS CALLED RADIOISOTOPES BY BOMBARDING DIFFERENT ELEMENTS WITH NEUTRONS. THE RADIOACTIVE MATERIALS CREATED BY THIS PROCESS HAVE BECOME IMPORTANT TOOLS IN PROTECTING HUMAN HEALTH AND FOOD SUPPLIES.

1. MEDICINE

Radioisotopes are especially useful in medicine to both detect and treat illness. Radioactive isotopes are used in the treatment of diseases such as cancer and are commonly used to sterilize medical equipment. Canada is a world leader in the production of medical radioisotopes providing about 60 per cent of the world's supply.

2. FOOD SAFETY

Radioisotopes can be used to preserve food and control bacteria and pests. The shelf-life of fruit, vegetables and meat can be greatly extended by exposing it to radiation. Irradiation is commonly used to inhibit sprouting in potatoes and onions and to control the parasites and pests that infest some commodities. Irradiated foods do not become radioactive. Radioisotopes are also useful to researchers in the development of new crop varieties with greater resistance to disease and adverse weather conditions.

3. SAFETY & RESEARCH

You may be enjoying the benefit of a radioisotope at this very moment. There is likely a tiny amount of one in the smoke detector in your home or office. Radioisotopes are also used by police to investigate crimes, and by researchers analyzing pollutants in the environment or studying the movement of surface water.

4. NUCLEAR POWERED VESSELS

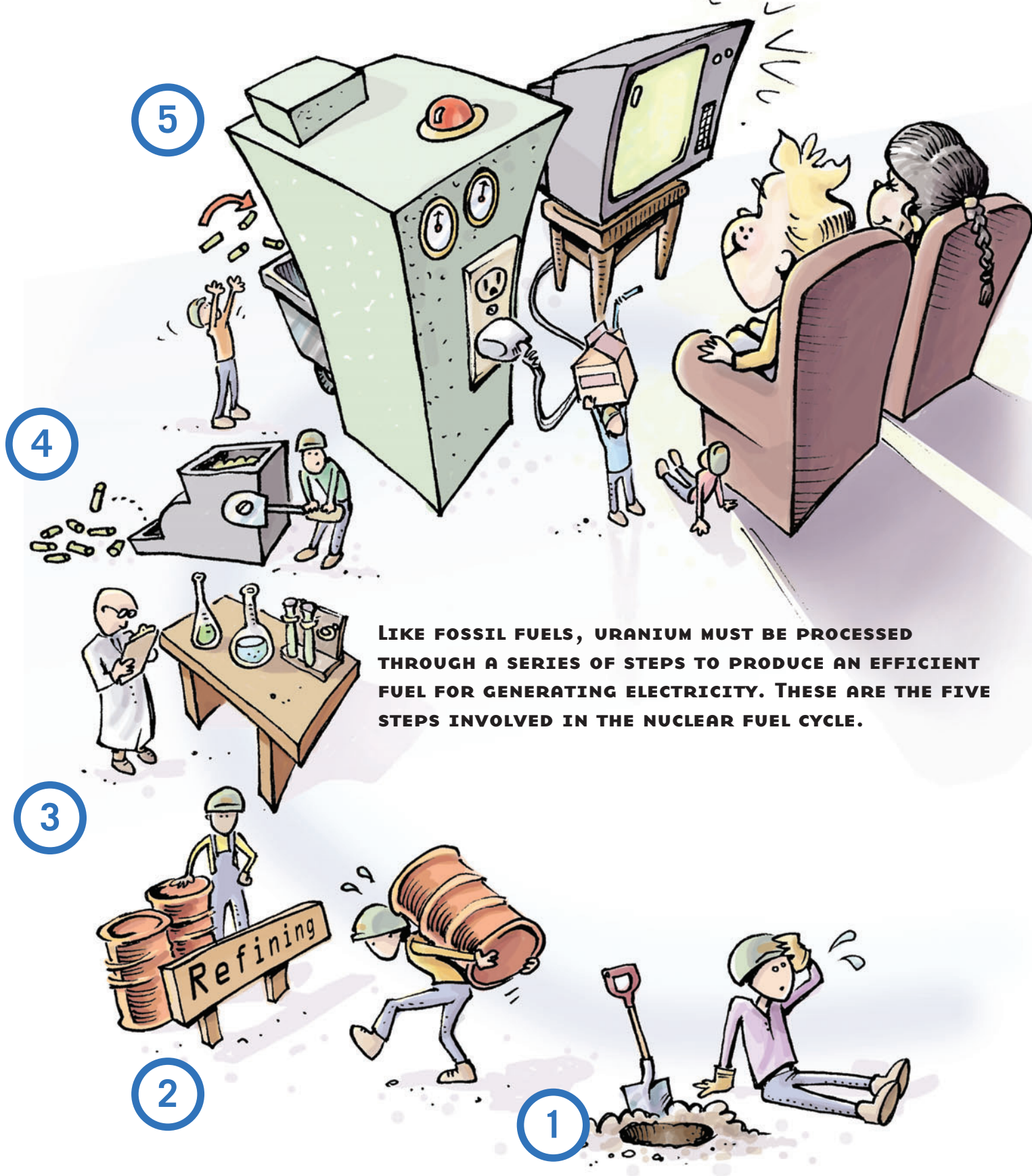
Uranium also provides fuel for the smaller nuclear reactors that power submarines and other ships such as ice-breakers and aircraft carriers. Nuclear-powered vessels can remain at sea for longer periods without refuelling. Nuclear energy is also used to power different types of space craft exploring our solar system.

5. MILITARY USES

Shortly after uranium's energy potential was discovered, uranium was used to make weapons. Near the end of the Second World War, scientists working in the United States first developed a way to harness nuclear energy for destructive purposes. To prevent the spread of nuclear weapons and weapons technology, the Treaty on the Non-Proliferation of Nuclear Weapons came into force in 1970.

TODAY, UNDER A GROWING MOVEMENT TO REDUCE THE NUMBER OF NUCLEAR WEAPONS IN THE WORLD, COUNTRIES WITH SIGNIFICANT NUCLEAR CAPABILITY ARE DISMANTLING THEIR WEAPONS AND USING THE HIGHLY ENRICHED URANIUM AND PLUTONIUM FROM THEM TO GENERATE ELECTRICITY.

THE NUCLEAR



LIKE FOSSIL FUELS, URANIUM MUST BE PROCESSED THROUGH A SERIES OF STEPS TO PRODUCE AN EFFICIENT FUEL FOR GENERATING ELECTRICITY. THESE ARE THE FIVE STEPS INVOLVED IN THE NUCLEAR FUEL CYCLE.

FUEL CYCLE

1 MINING AND MILLING

Uranium is extracted from the ground using a variety of different mining techniques. In Canada, uranium is mined using both open pit and underground mining technology. The extracted rock is then milled to recover the uranium in the form of a dry powder called yellowcake. Yellowcake is packaged in metal drums at the mill for shipping.

2 REFINING AND CONVERSION

Yellowcake is shipped to a processing facility where it is prepared for use in different types of nuclear reactors.

In Canada, the process occurs at two facilities in Ontario – a refinery at Blind River and a conversion facility at Port Hope. The yellowcake is purified and changed into a new powder form called uranium trioxide (UO_3). Uranium trioxide can then be converted into either a gas called uranium hexafluoride (UF_6) for export to other countries for enrichment or a uranium dioxide powder (UO_2) which is the fuel used in Canadian-designed CANDU reactors.

3 ENRICHMENT

Most nuclear reactors require enriched uranium fuel. Enriched fuel is created by separating U-235 isotopes from U-238 isotopes to increase the concentration of U-235 from about 0.7 per cent to between three and four per cent. The enriched uranium is then converted into UO_2 and passes to the next stage of the fuel cycle.

4 FUEL FABRICATION

At this stage, the uranium dioxide powder, both enriched and natural, is pressed into small pellets about the size of a two-centimetre stack of dimes. Seven of these pellets will produce enough electricity to meet the annual needs of the average Canadian home.

The pellets are then placed in thin zirconium alloy steel tubes to form fuel rods. The fuel rods are arranged in bundles that are designed to be inserted into a nuclear reactor.

5 THE NUCLEAR REACTOR

Once inside the reactor, the elevated levels of U-235 isotope inside the fuel bundles are activated to begin a process called fission. The heat produced by the fission reaction creates steam that drives a turbine to run a large electric generator. A 1,000-megawatt reactor will consume about 25 tonnes of fuel in a year and generate enough electricity to supply a city of one million people.

WASTE MANAGEMENT

Byproducts from the mining and milling process are called tailings. Tailings are contained in regulatory approved, monitored facilities at the minesite where the highest environmental and safety standards are applied.

Reactor waste is the used fuel bundles. Spent fuel continues to give off a lot of heat after it is removed from a reactor. Consequently, spent fuel bundles are temporarily stored at the reactor site in special pools until their heat and radioactivity decreases. Bundles remain under water for several years before being transferred to dry storage.

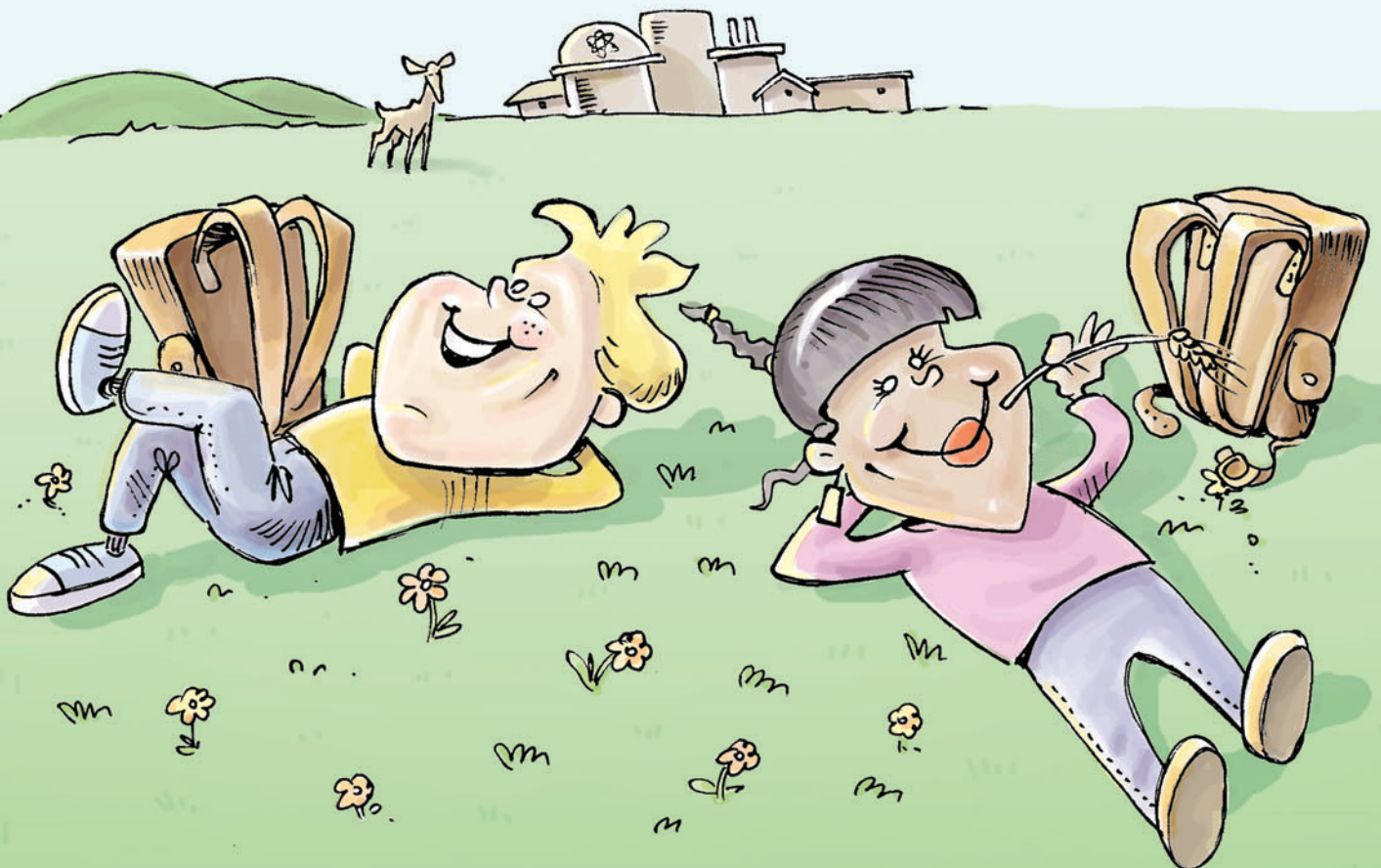
Currently, about 30,000 tonnes of spent reactor fuel is being stored at Canadian nuclear facilities awaiting reprocessing or permanent disposal. All of this material would fit into two Olympic-sized swimming pools.

CLEAN POWER

Meeting rapid growth in demand for electricity without damaging the environment will be a major challenge in the future. Over the next 50 years, world demand for electricity is expected to double or triple.

Nuclear power will be necessary to meet that demand. Most of the world's potential for hydroelectric generation is already harnessed. **That leaves nuclear as the only efficient and reliable method of generating large amounts of electricity that doesn't contribute to air pollution, global warming or acid rain.**

Nuclear plants consume a tiny fraction of the fuel used by coal- or gas-fired plants to produce the same amount of electricity. Nuclear plants also create very little waste and none of it is released into the environment.



GLOSSARY

ALPHA PARTICLES

Positively charged particles consisting of two protons and two neutrons that are emitted by the nuclei of radioactive elements as they decay. Alpha particles are relatively large and can be stopped by skin or a sheet of paper.

BETA PARTICLES

Fast moving electrons ejected by radioactive element as they decay. Beta particles are relatively small and can penetrate up to two centimeters of water or human flesh. They can be stopped by a sheet of aluminum a few millimeters thick.

CANDU REACTOR

The Canadian designed nuclear power reactor that uses natural, unenriched uranium for fuel and heavy water as a moderator.

ENRICHED URANIUM

Is uranium that has been processed to increase the concentration of fissionable uranium-235 isotope to prepare it for use in some types of reactors. Natural uranium is about 0.7 per cent U-235. Enriched uranium is about three per cent U-235.

FISSION

The splitting of the nucleus of an atom which is accompanied by the release of energy in the forms of heat and radiation.

GAMMA RAYS

A wave form of ionizing radiation that is emitted from the nuclei of some radioactive elements as they decay.

IRRADIATION

The use of ionizing forms of radiation to kill bacteria and pests in human food and animal feed or to slow the ripening process in fruits and vegetables after harvest.

ISOTOPES

Various forms of atoms of the same chemical element which are distinguished by the number of particles in the nucleus. Uranium has 16 different isotopes.

NEUTRON

A particle found in the nucleus of atoms with no electrical charge. Neutrons are released from the nuclei of Uranium-235 atoms during fission.

RADIATION

Is energy travelling through space in the form of waves or particles including sunlight and radio waves. The type of radiation emitted by uranium is ionizing radiation which is potentially harmful or beneficial to people.

RADIOISOTOPE

Unstable atoms of various chemical elements that emit radiation. They are widely used in medicine to treat diseases such as cancer or to diagnose injuries and disease. Radioisotopes can also be used to kill pests and bacteria in food and to slow the ripening process in fruits and vegetables after harvest.

URANIUM ORE

Is rock that contains unusually high concentrations of natural uranium which can be extracted through the mining and milling process.

YELLOWCAKE

Is the name given to the final product of most uranium mills including those in Canada. A common type of yellowcake is uranium oxide (U_3O_8).

MORE INFORMATION:

