SNETP
Sustainable Nuclear Energy Technology Platform

Nr. 1

The production of electricity with nuclear energy is CO_2 free and therefore an option for the fight against climate change. European research plays a vital role when developing new innovative technical and technological solutions focused on nuclear fission.

Nuclear Energy Factsheets

What is nuclear fission?

• Historical background on nuclear energy

Nuclear fission is the commercial way to produce energy from a nuclear reaction. The roots of today's technologies are based on the first scientific achievements dating the end of 19th century.

In 1896, while investigating phosphorescence in uranium salts, a French scientist Henri Becquerel accidentally discovered radioactivity. This discovery led him to investigate the spontaneous emission of nuclear radiation. On the basis of these findings Marie Sklodowska Curie followed the investigation on uranium. One of her achievements was the creation of a theory of radioactivity, and techniques for isolating radioactive isotopes. Enrico Fermi, an Italian physicist, is particularly known for his work on the develoment of the first nuclear reactor, Chicago Pile-1.

The geopolitical realities in the beginning of the second half of the 20th century led to several studies into the prospects of nuclear energy use in Europe. The conclusion was that further nuclear development was needed to fill the deficit left by the exhaustion of coal deposits and to reduce dependence on oil producers. Founding of EURATOM in 1957 had the aim to foster co-operation in the nuclear field, and support the creation of a serious basis for further European investigation, and potential political and economical integration.

• Nuclear Power comes from Fission

Most power plants, including Nuclear Power Plants (NPPs), use heat to produce electricity. Instead of burning fossil fuels to produce the heat, NPPs produce heat through fission of nuclear fuel. In principle during this process atoms are split apart to form smaller atoms while releasing energy.

The main material required to generate electricity from nuclear power is uranium. Naturally-occurring uranium, as extracted form uranium ore, contains only about 0.7 fissile uranium 235. The remaining 93,9 per cent is non-fissile uranium 238 which needs to be enriched to be used in the fission nuclear reaction as a fuel. Nuclear fuel must contain a sufficient quantity of fissile material to initiate the chain reaction. To achieve this result, the proportion of isotope uranium 235 in the fuel must be increased from 0.7 found in natural uranium to 3 to 5%. This process is done in an enrichment facility[1].

• Nuclear chain reaction

During a nuclear reaction elements (or isotopes) are converted from one form to another. It can involve all three types of subatomic particles: protons, neutrons and electrons. Reactions are accompanied by absorption or release of energy. The rates of reaction are normally not affected by temperature, pressure or catalysts.

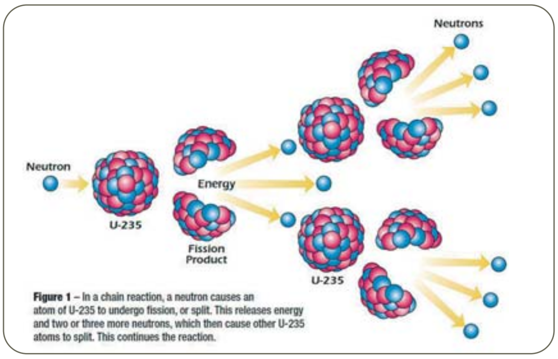

Figure 1 – In a chain reaction, a neutron causes an atom of U-235 to undergo fission, or split. This releases energy and two or three more neutrons, which then cause other U-235 atoms to split. This continues the reaction.

How Fission Splits the Uranium Atom (Source: National Energy Education Development Project (Public Domain)

It is possible to overcome the nuclear binding energy in some large atoms, such as uranium, causing them to split apart. Fission occurs when a free neutron enters the nucleus of a fissionable atom. The nucleus quickly becomes unstable, vibrates, and then splits into fragments that are propelled apart

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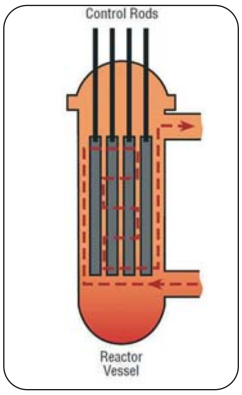
at a high speed. These neutrons go on to hit other uranium atoms, and the process repeats itself over and over again, thus giving rise to a "chain reaction".

The rate at which the "free" neutrons are emitted is the key to sustaining and controlling a nuclear chain reaction. When the population of neutrons remains constant the nuclear chain reaction is maintained and controlled - the chain reactions reaches equilibrium[2].

• Industrial use – a Nuclear power plant

The fission takes place inside the reactor of a NPP. At the centre of the reactor is the core, which contains the enriched uranium fuel, formed into ceramic pellets. These pellets are stacked end-to-end in metal fuel rods (typically about five meters).



A Nuclear Fuel Assembly (source CEA)

A bundle of fuel rods – about 200 – is called a fuel assembly. A reactor core contains fuel assemblies (about 150 – 200), control rods and coolant, the pressure vessel surrounds this core[3].

• The pressurized and boiling water reactors (PWR/BWR)

The heat given off during fission in the reactor core is used to boil water into steam, which is transferred under high pressure to a turbine that mechanically turns an electric generator producing electricity. Both PWR and BWR reactors are called light-water reactors, because they use ordinary water to transfer the heat energy from reactor to turbine. In the case of boiling water reactors (BWR), the coolant is used directly to drive the turbine. In the pressurized water reactor (PWR) the heat from the coolant is transferred to another fluid through a heat exchanger (steam generator).

Light-water reactors are the predominant technology worldwide (in terms of the number of reactors currently in operation). But there are other reactor types in commercial operation around the world, i.e. Pressurized Heavy-Water Reactor "CANDU" (PHWR) a Gas-cooled Reactor (Magnox&AGR),

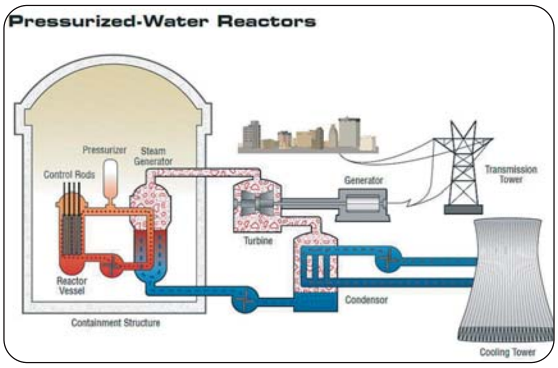


Image from the Teacher`s guide 051508

a Light-Water Graphite Reactor (RBMK) and a Fast Neutron Breeder Reactor (FBR)[4]. According to the International Atomic Energy Agency (IAEA) in 2010 there were 441 commercial nuclear power reactors in operation in the world with a total net installed capacity of 374.633 GW(e)[5].

• Reactor Safety

Nuclear safety is above all designed to confine radioactivity under all circumstances. The safety is based on a defence-in-depth principle according to which all systems are considered vulnerable and must be backed up by other systems. The IAEA has established several different levels of defence. The modern reactor designs involve placing three strong physical barriers: (1) metal fuel rod cladding, (2) primary circuit housing made of thick steel, and (3) containment enclose around the buildings[6].

• Future prospects

Further research and development is needed in order to (1) improve performance of existing nuclear fleet, (2) explore the Fast breeder Reactors and (3) enhance the use of nuclear systems for other application than electricity generation, e.g. delivering process heat.

Indications of international agencies and organisations show that the nuclear electricity sector is competitive compared with other electricity generation solutions. Some of the European countries have lately reconsidered their policy towards nuclear energy production. In 2010 there are 60 reactors under construction worldwide with net electrical capacity of 58, 6 GWe.

References

1. Synopsis from Teacher`s guide 051508
2. Le fonctionnement d'un réacteur nucléaire: www.cea.fr
3., 4. Synopsis on reactor types: www.westinghousenuclear.com, www.areva-np.com, www.eon-kernkraft.com
5. NUCLEUS, Power Reactor Information System: www.nucelaus.iaea.org
6. The IAEA Department of Nuclear Safety and Security: http://www.iaea.org/OurWork/SS/index.html