Lecture 1.2  Energy and non-power applications of nuclear technology

Dr. Alexey Ubeev

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Pro and Contra of the use of nuclear technologies

Nuclear Fuel Cycle and Conversion of materials

Nuclear energy and technologies for sustainable development

Non-power nuclear applications for industry, medicine, agriculture, food, environment, etc.
Pros of Nuclear Energy

✓ **Low Pollution:** Nuclear power has a lot fewer greenhouse emissions. The amount of greenhouse gases have decreased by almost half. Nuclear energy doesn’t discharge any gasses like methane and carbon dioxide, which are the primary “greenhouse gasses.”

✓ **Low Operating Costs:** Nuclear power produces very inexpensive electricity. The cost of the uranium as a fuel is low. Even the expense of building up NPP is high, the expense of running it is quite low. The normal life of nuclear reactor is anywhere from 40-60 years.

✓ **Reliability:** enough uranium for another 80 - 100 years. NPP can run uninterrupted for even a year. As solar and wind energy are dependent upon weather conditions, NPP has no such constraints and can run without disruption in any climatic condition.

✓ **More proficient than fossil fuels:** amount of fuel required by NPP is comparatively less and energy released by nuclear fission is approximately ten million times greater than by fossil fuel. Highly efficient power source.
Cons of Nuclear Energy

✓ **Nuclear Accidents:** The Three Mile island incident (1979) in Pennsylvania, the Chernobyl disaster (1986) and Fukushima Daiichi (2011). Nuclear meltdown is the result of reactor core overheating, due to failure of cooling systems.

✓ **Non-proliferation concerns:** targets for terrorists. If these materials fall in the wrong hands, it can spell disaster for the world.

✓ **High Cost of NPP construction:** The high safety standards requirement along with maintenance of radioactive waste treatment facilities add to costs further.

✓ **Radioactive Waste and Spent Fuel management:** The safe disposal of radioactive waste and spent fuel is a major problem. Radioactivity cannot be turned off and therefore, there is no way but to safely store radioactive waste. Many techniques of disposal have been suggested including geological disposal, transmutation and reprocessing, but...
CURRENT STATUS OF NPP (Sept. 2019):

450 NPPs IN OPERATION in 31 States
399,7 MWe TOTAL NET INSTALLED CAPACITY
4 NPPs IN LONG-TERM SHUTDOWN
52 NUCLEAR POWER REACTORS UNDER CONSTRUCTION
Nuclear Power Economics

✓ Nuclear power plants are cheap to operate, **BUT** high initial capital costs can be difficult to finance*

✓ Stable & predictable generating costs, **BUT** sensitive to interest rates

✓ Supply security (insurance premium), **BUT** long lead times (planning, construction, etc.)

✓ Low external costs (so far no credit applied), **BUT** long payback periods, market risks

* Up to 70% of new plant lifetime costs can be due before the date of first operation, making nuclear power sensitive to interest rates and financing costs.
Safety and Security – priorities for NPP operation

Technological (Safety) improvements
- Active and passive safety systems
- High-quality design
- New composite and Nano-materials

Nuclear Security measures
- Physical Protection of nuclear materials and facilities
- Cyber security
- Nuclear security culture and others

Safeguards measures
- Accountancy & Control of NM SG Agreements and Additional protocol in force
- International and National legal framework
- Treaties, conventions, codes, recommendations
- Increased role of Regulatory body
Conversion of materials in NFC

- 50,000 t ore (0.32%)
- 160 t U
- 140 t U tails
- 20 t 4% enriched U
- 18.9 t uranium
- 0.9 t RW in ~5 t glass
- 6 t LLW and ILW
- 0.2 t plutonium
- Reactor 1000 MWe
- 20 t SNF
- 20 t SNF
- 1000 MWe
- 7 billion kWh
OTHER NUCLEAR ENERGY APPLICATIONS

✓ **Hydrogen production**: for oil refining and for fuel cell vehicles. NE may be used to make hydrogen electrolytically and HTR for thermochemical production;

✓ **Desalination**: NE is already being used for and has the potential for much greater use (ex. BN-350 at Aktau, Kazakhstan, produced up to 135 Mwe of electricity and 80,000 m/day of potable water during 27 years);

✓ **Nuclear-Powered Ships**: marine and submarine propulsion ships, floating NPP;

✓ **Space**: Radioisotope thermoelectric generators (RTGs) used in Space since 1961 (Pu-238, Po-210, U-Mo fuel rods, etc.)

✓ **Research reactors for radioisotopes**: 243 RRs in operation in around 60 countries (totally 774 RRs, IAEA RRDB)
Nuclear energy and technology for sustainable development

Sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs." - World Commission on Environment and Development (Brundtland Commission), 1987

- **17 Sustainable Development Goals (SDGs), adopted at the United Nations’ 2015 Sustainable Development Summit**
- Nuclear energy and nuclear technics play an active part in helping the international community with the achievement of SDGs
Nuclear Energy input to SDGs

✓ Nuclear energy sector is generally consistent with the fundamental sustainable development goal. Over 60 years of experience in Nuclear Power demonstrates that responsibly managed nuclear power programs have a very low safety risk and much smaller impacts on the environment and public health than other sources of energy especially with respect to emissions and air pollution.

✓ The nuclear option internalizes a large part of its external costs, such as the decommissioning of the plant at the end of its life and the management and disposal of the radioactive waste.

✓ The social dimension of nuclear energy's contribution to sustainable development is ambivalent. While nuclear energy contributes to the security of energy supply, local employment and technological development.
Isotopes are different forms of an atom of the same chemical element. They have identical chemical properties but different relative atomic masses.
Most of the isotopes which occur naturally are stable. A few naturally occurring isotopes and all of the man-made isotopes are unstable. Unstable isotopes can become stable by releasing different types of particles. This process is called radioactive decay and the elements which undergo this process are called radioisotopes/radionuclides.

A sealed **radioactive source** is an encapsulated quantity of a radioisotope used to provide a beam of ionizing radiation. Industrial sources usually contain radioisotopes that emit gamma or X-rays. The radioactive decay process of each type of radioisotope is unique and is measured with a time period called a **half-life**.
Nuclear Applications

- Diagnosis and Treatment of Disease
- Changing Environment
- Water Resources
- Food Safety
- Human Health
- Sustainable Agriculture
Nuclear Applications in Food and Agriculture

Insect Pest Control
by Sterile Insect Techniques

Plant Breeding & Genetics
by Mutation Techniques

Animal Production & Health
by RIA, ELISA, PCR, etc.

Soil & Water Management & Crop Nutrition
by Isotopic and Nuclear Techniques

Food & Environmental Protection
by Food Irradiation and Radio-analytical Techniques
Nuclear Applications, cont’d

Food and Agriculture:
✓ Fertilizers N-15 and P-32 allowing better management of fertilizer application; Increasing Genetic Variability some 1800 crop varieties have been developed by gamma or neutron irradiation
✓ Insect Control: Crop losses caused by insects in developing countries is 25-35%. Sterile Insect Technique (SIT) involves rearing large numbers of insects then irradiating their eggs with gamma radiation before hatching, to sterilize them, then released in large numbers in the infested areas.
✓ Food Preservation: In over 40 countries health and safety authorities have approved irradiation of more than 60 kinds of food. Irradiation of food does not make it radioactive.
Water Resources: Above 60 countries have used isotope techniques to investigate their water resources (tracing and measurement of the extent of underground water).

Medicine: Over 10,000 hospitals worldwide use radioisotopes in medicine. In the USA there are over 20 million nuclear medicine procedures per year, and in Europe about 10 million. The use of radiopharmaceuticals in diagnosis is growing at over 10% per year. Only $^{99m}$Tc is employed in some 40 million diagnostic procedures per year worldwide.

Industry: Environmental and industrial tracers, instruments. Gauges containing radioactive (usually gamma) sources are in wide use in all industries where levels of gases, liquids and solids must be checked.
Radioisotope instruments have three great advantages: measurements can be made without physical contact with the material or product. Very little maintenance of the isotope source is necessary. The cost/benefit ratio is excellent - many instruments pay for themselves within a few months through the savings they allow.

Radiography: Radioisotopes which emit gamma rays can be used to check welds of new gas and oil pipeline systems. Other forms of radiography (neutron radiography/ autoradiography) can be used to gauge the thickness and density of materials or locate components that are not visible by other means.

Radioisotope power sources: Some radioisotopes emit a lot of energy as they decay. Such energy can be harnessed for heart pacemakers and to power navigation beacons and satellites.
Summary:

➢ Before construction of NPP or Nuclear research reactor it is necessary to analyze “pro’s and cons” of the use of nuclear energy in every particular case. The pro’s outweigh the cons?

➢ A lot of technologies and materials are involved in NFC operations, some of them are sensitive for environment, health and proliferation risks

➢ Nuclear energy meet the main objectives for sustainable development goals (SDGs)

➢ Non-power nuclear applications can play a significant role in achievement of many SDGs
Thank you for your attention!

Questions?