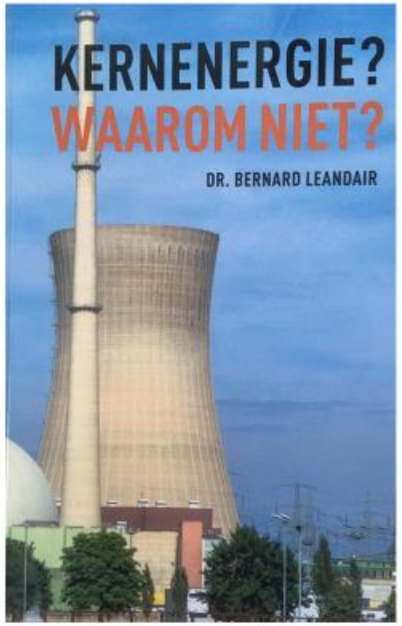
Nuclear Energy today and in the future

Leen Bevaart


KERNENERGIE?
WAAROM NIET?
DR. BERNARD LEANDAIR

The book deals with:

- The history, the present situation, and the future of (military and) peaceful applications of nuclear energy
- Radioactivity and radiation
- Safety, security and safeguards
- International treaties, agreements and conventions
- Some observations
  - Incidents
  - Future energy- and electricity supply

This presentation covers:

- The role of nuclear energy in the present and future energy- and electricity supply
- The effects of radiation
- The long-term storage of high-level radioactive waste

References

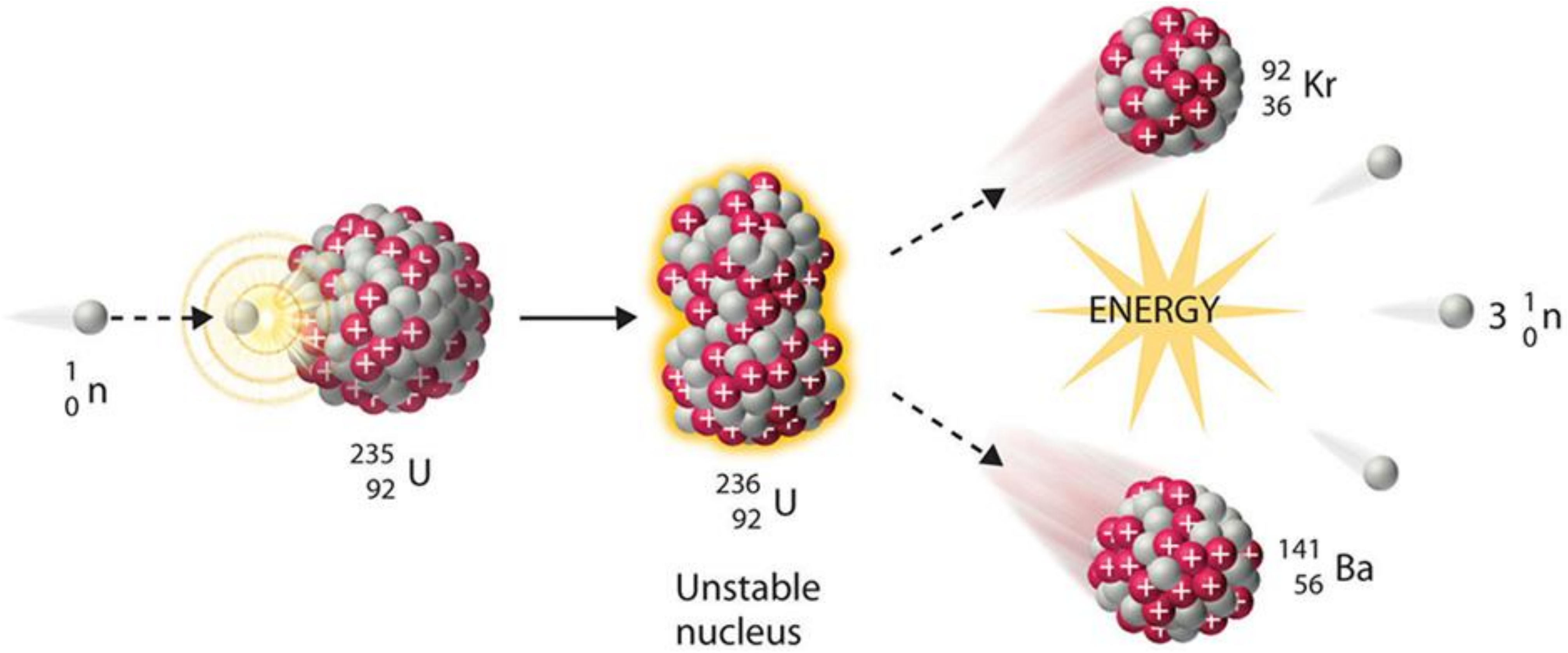
- International Commission on Radiological Protection (ICRP)
- United Nations Scientific Commission on the Effects of Atomic Radiation (UNSCEAR)
- Intergovernmental Panel on Climate Change (IPCC)
- Organisation for Economic Co-operation and Development (OECD)
  - Nuclear Energy Agency (NEA)
  - International Energy Agency (IEA)
- International Atomic Energy Agency (IAEA)
- World Nuclear Association (WNA)
- Energy Information Administration (EIA, US government)
- World Health Organisation (WHO)
- Food and Agricultural Organisation (FAO)
- Sustainable Energy for All (SE for All)
- https://www.forbes.com/sites/jamesconca/2021/06/28/the-international-energy-agencys-bizarre-roadmap-for-global-decarbonization/
- https://www.thearticle.com/the-100-trillion-dollar-question-how-will-the-world-pay-for-net-zero

Global energy- and electricity production in 2019 in TWh

	Energy	Electricity
• Total	170000	25000
• oil	50000 (~30%)	1130 (~5 %)
• coal	45000 (~27%)	8700 (~35%)
• gas	40000 (~23%)	5900 (~24%)
• fossil	135000 (~80%)	16000 (~64%)
• nuclear	6900 (~4%)	2600 (~10%)
• renewables	16500 (~10%)	6600 (~26%)
• others	10000 (~6%)	

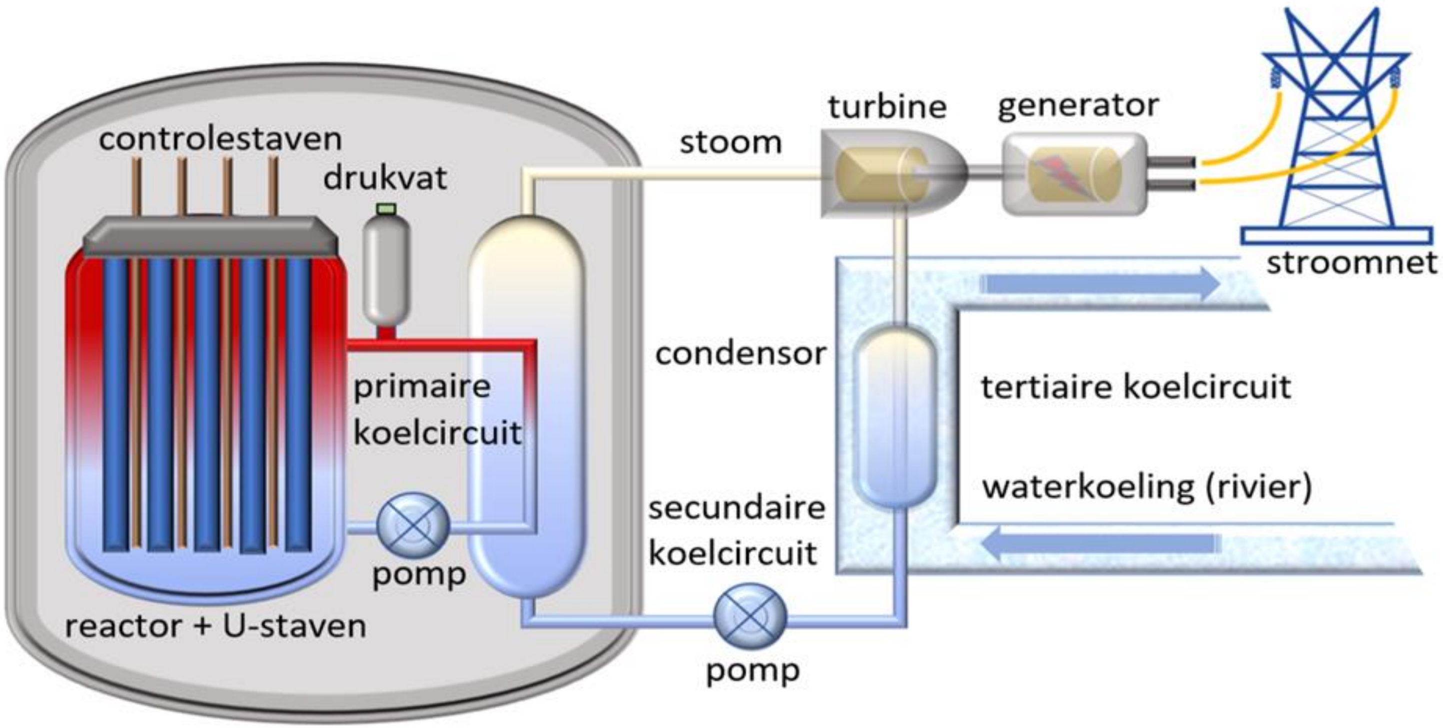
Predicted global energy- and electricity production in 2050 in TWh

	Energy	Electricity
• Total	250000	50000
• oil	85000	8
• coal	30000	11000
• gas	40000	10000
• fossil	155000 (~62%)	21000 (~42%)
• nuclear	15000 (~6%)	5000 (~10%)
• renewables	73000 (~30%)	29000 (~48%)



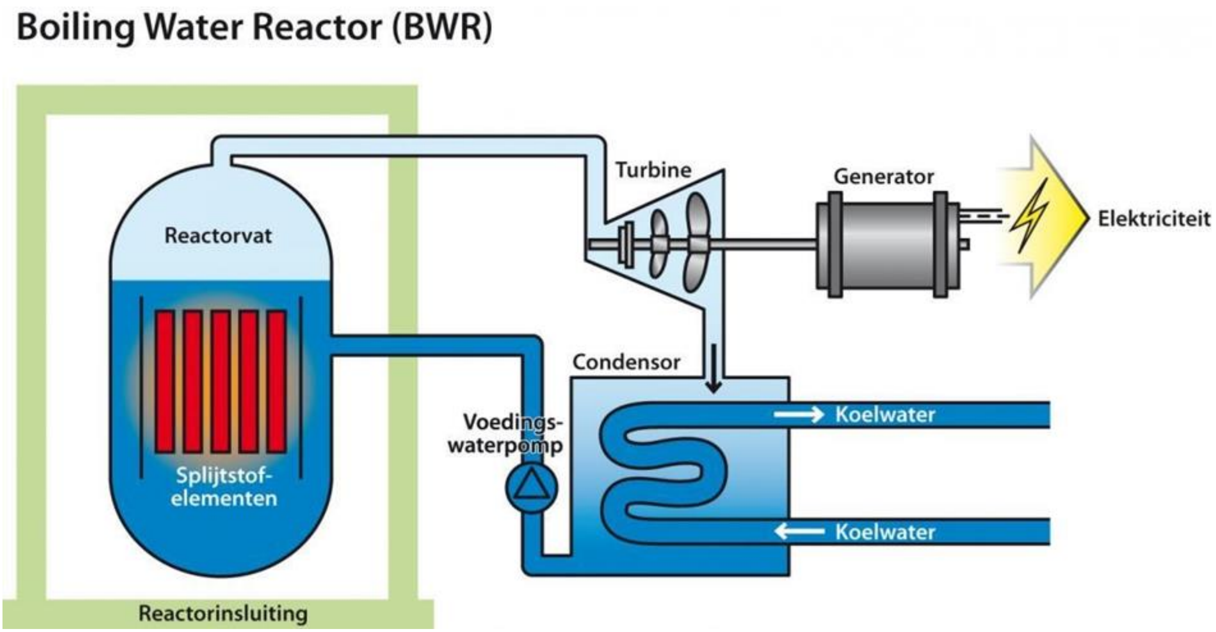
$^{1}_{0}n$
$^{235}_{92}U$
$^{236}_{92}U$
Unstable nucleus
$^{92}_{36}Kr$
ENERGY
$3\ ^{1}_{0}n$
$^{141}_{56}Ba$

Schematic view of a Pressurised Water Reactor (PWR)



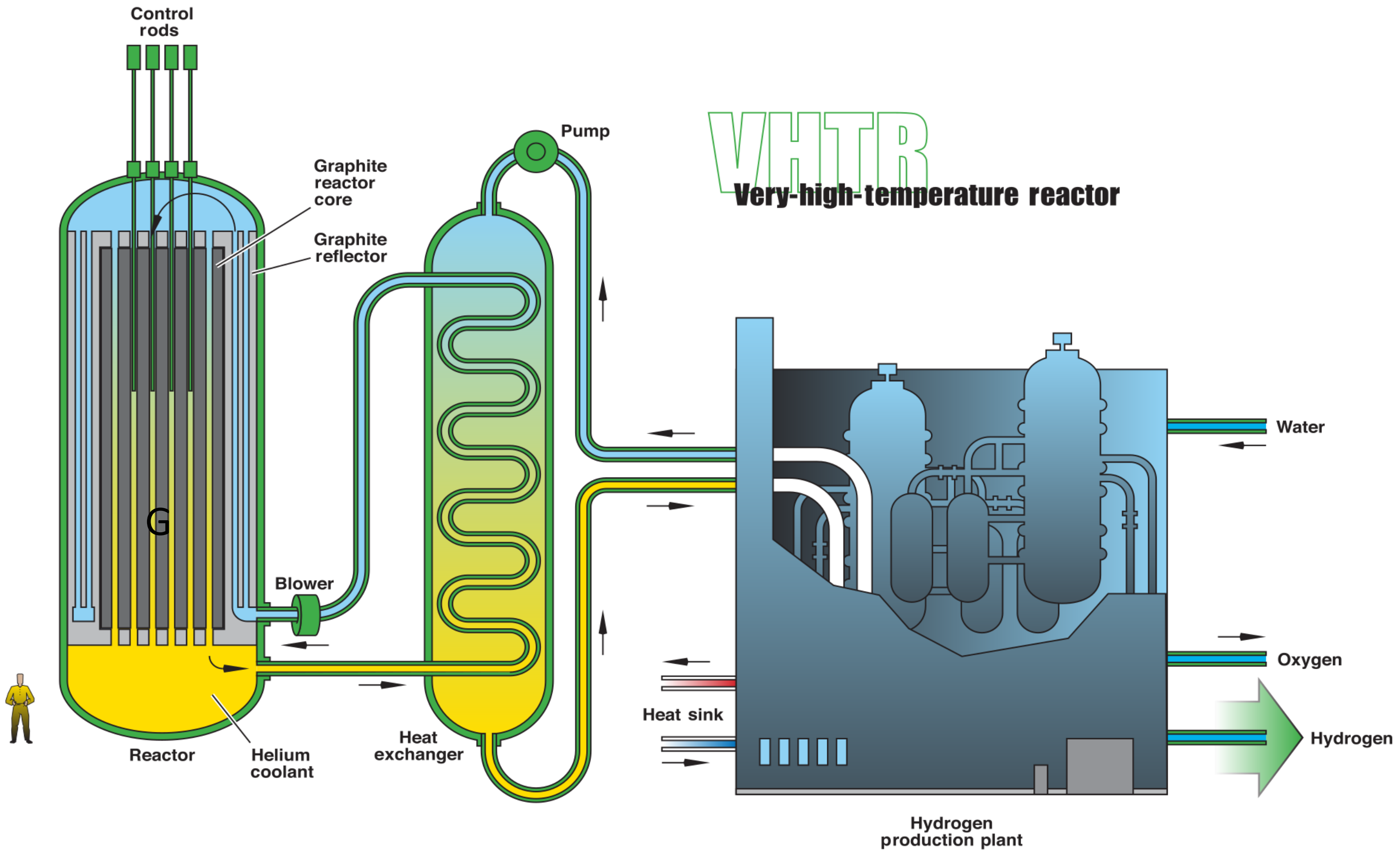
Water under pressure is heated in the core, and circulated in the primary loop. The steam generated in the secondary loop operates the turbine which in turn operates the generator. The steam is condensed in the third loop with surface water.

Schematic view of a Boiling Water Reactor (BWR)



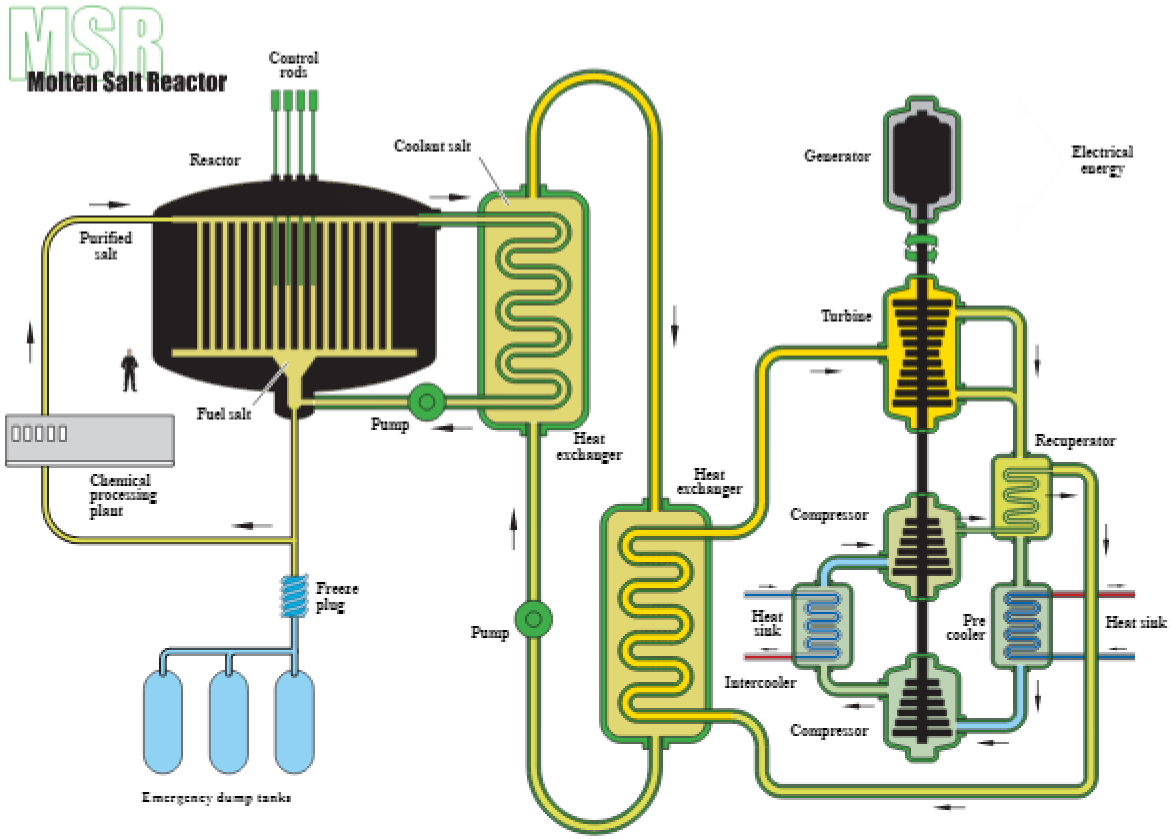
Steam is produced in the reactor vessel. It operates the turbine and indirectly the generator. The rest is similar to the PWR.

Generation III reactors. 1. Standardised, more efficient licensing. 2. Some parts are modular (shorter construction time, less concrete). 3.More robust and passive safety features (e.g. several independent cooling systems, using temperature and pressure). 4. long lifetime 5. Core catchers. 6. more economical.



Generation IV reactors: 1. High temperatures. 2 Burns highly radioactive isotopes. 3 Fuel not suitable for nuclear weapons. 4 Longer lifetime (70-80 years). 5 Intrinsic safety systems.

Malten Salt Reactor



Small Modular Reactors

The first SMR: the AKADEMIK LOMONOSOV.

Radioactivity and radiation

Radioactivity is the phenomenon that energy in the form of radiation is released when unstable nuclei decay to other stable or unstable nuclei.

There are several types of radiation:

- α-radiation (He nuclei);
- β-radiation (electron or positron);
- γ-radiation (electromagnetic waves, short wavelengths);
- neutrons

Most of the radiation produced by radioactive processes is so-called ionizing radiation , i.e. its energy is high enough to transform molecules into ions and damage the tissue or cause mutation in the human body, and this could in turn cause illnesses or change genetic material.

Radioactivity is measured in Becquerel (Bq), the number of disintegrations per second;

The amount of energy from ionizing radiation absorbed by matter is called the absorbed dose D, and is measured in Gray (Gy), that is one joule per kilogram of matter;

The absorbed dose that could cause damage in the human body is called the equivalent dose H and is measured in Sievert (Sv). It has the same units as the absorbed dose. The health effects are depending not only on the energy and the intensity of the radiation but also on the type of radiation. $H = W \cdot D$; for β- and γ-radiation $W=1$, for α-radiation $W=20$, and for neutrons $5<W<20$.

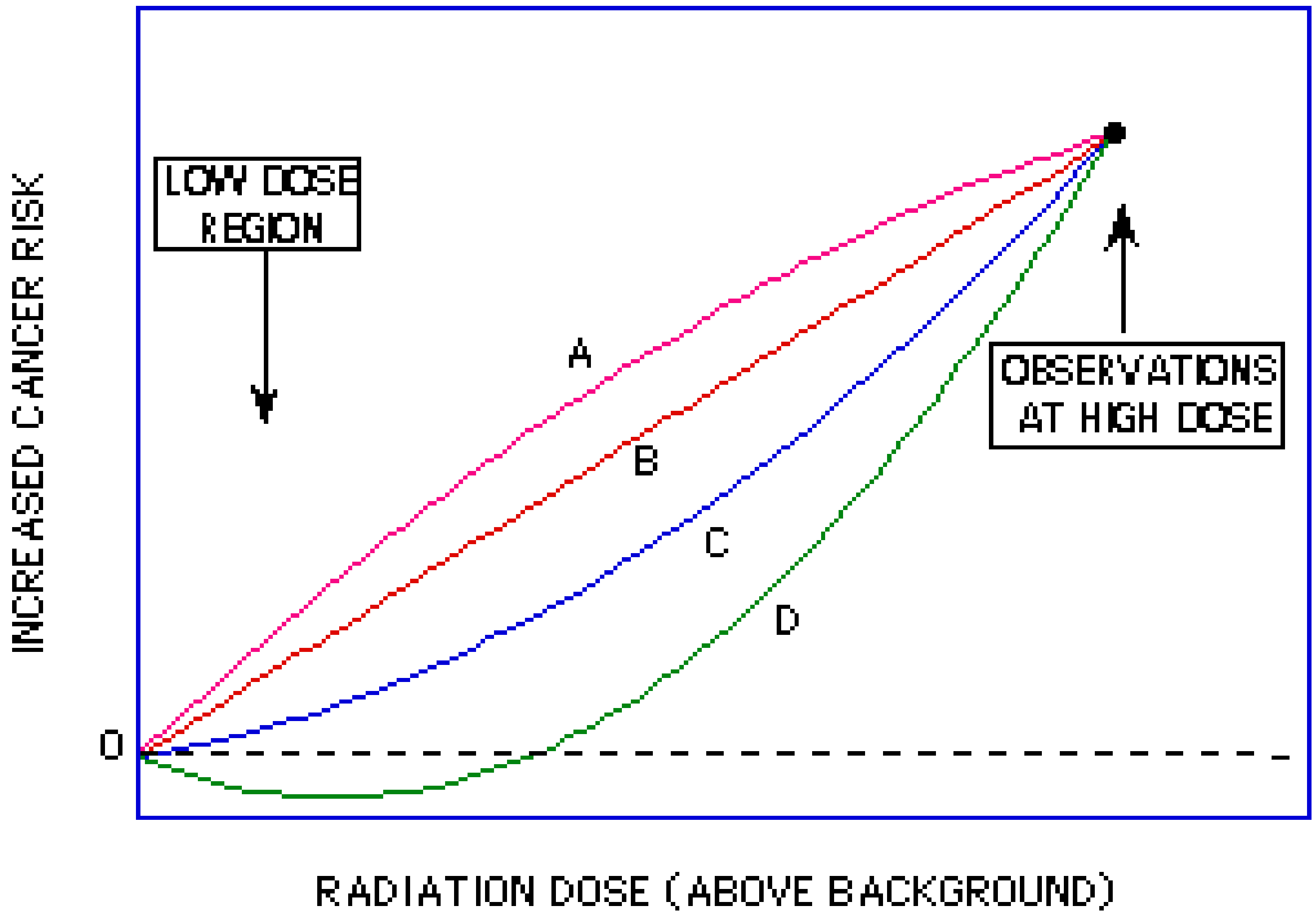
Causes of background radiation

- radioactive isotopes present in surrounding nature, e.g. radium;
- cosmic radiation;
- medical treatments.

In the Netherlands is the background radiation about 3 mSv per year.

In Ramsar, Iran the background is roughly 250 mSv per year.

The dose limit for employees in the nuclear industry is 20 mSv per year on average over a period of 5 years with a maximum of 50 mSv in one year. This limit is solely based on the ALARA principle (as low as reasonably achievable) and not on eventual negative health effects.


LOW DOSE REGION
OBSERVATIONS AT HIGH DOSE
A
B
C
D
0
INCREASED CANCER RISK
RADIATION DOSE (ABOVE BACKGROUND)

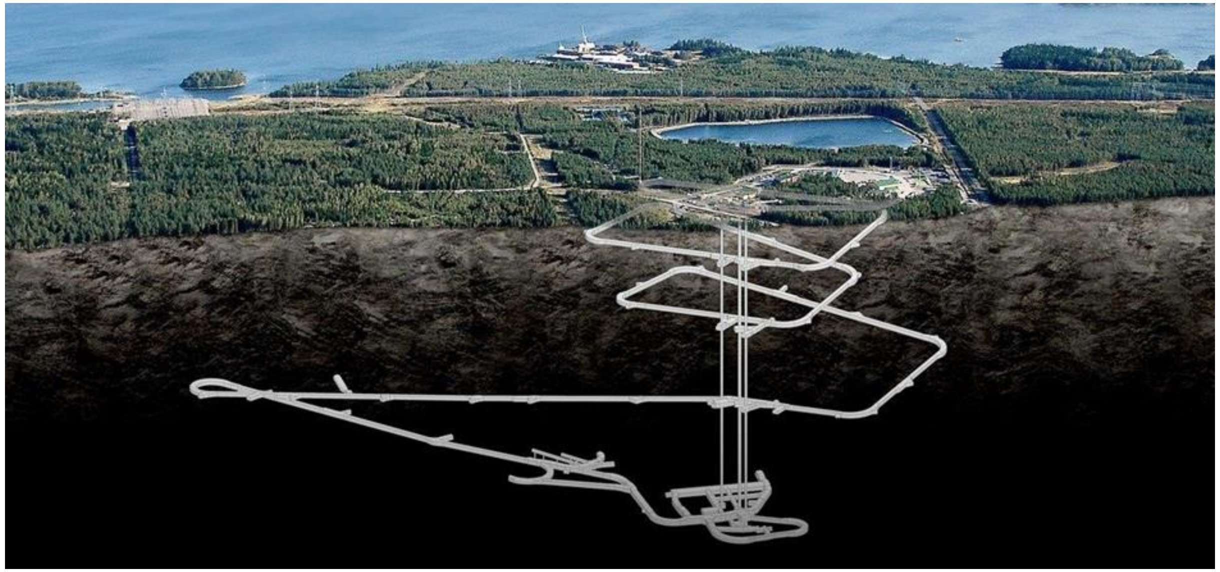
Three types of radioactive waste:

- Low level waste; this contains mostly short-lived radioactivity and can be handled safely with simple precautions.
- Intermediate level waste; this is more highly radioactive and consists primarily of used reactor core components and resins and filters used to purify reactor water systems.
- High level waste; this is basically the used nuclear fuel.

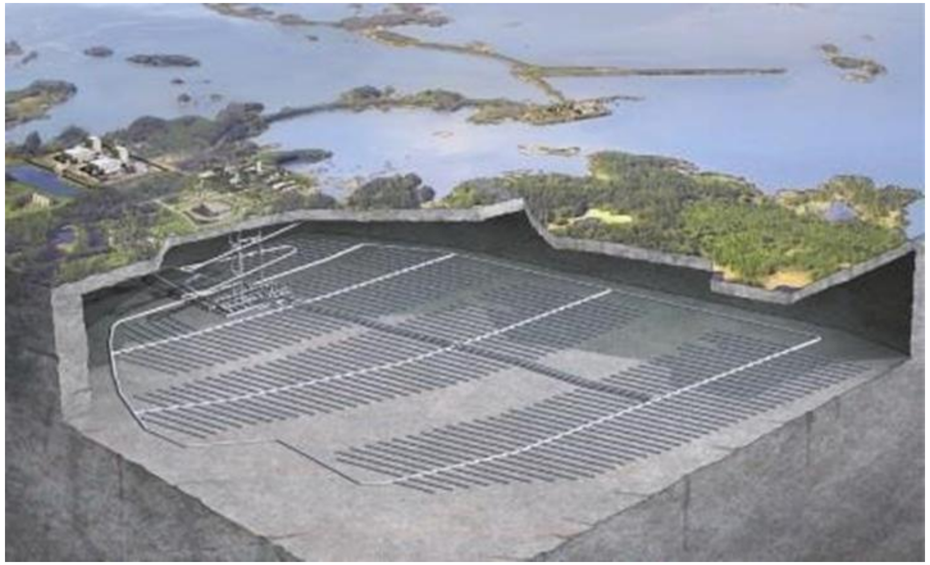
Currently, deep underground storage locations are being explored in stable, impermeable geological formations, e.g., graphite, marble, clay or salt.

One storage in operation: Carlsbad in New Mexico, 650-meter-deep ancient salt formation. Pilot plant, only waste from weapons programme.

Schematic view of the long-term Storage in Olkiluoto



Swedish Repository in Forsmark approved



Nuclear energy could substantially contribute to the decarbonization the world urgently needs, and hence to a limited warming up of the planet.

Thank you for your attention.