

Nuclear: Ally or Enemy of Renewables?

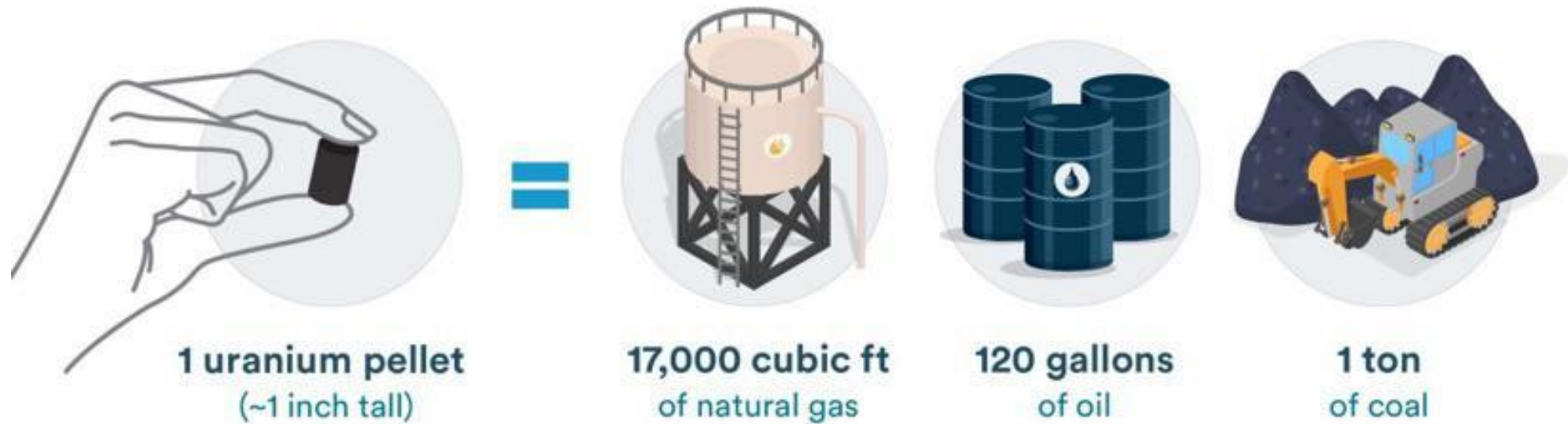
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Collegio San Giuseppe, Torino • 28/1/2022

"The most complex boiler ever made"

The diagram illustrates the complex system of a Pressurized Water Reactor (PWR). On the left, a nuclear reaction is shown: a neutron (n) strikes a $^{235}_{92}\text{U}$ nucleus, which then splits into $^{236}_{92}\text{U}$, $^{144}_{56}\text{Ba}$, $^{89}_{36}\text{Kr}$, and three additional neutrons (n). A blue arrow connects this reaction to the reactor core in the main system. The main system consists of three interconnected loops. The primary loop (red) circulates reactor coolant between the reactor and a steam generator. The secondary loop (blue) circulates feedwater between the steam generator, a preheater, a condenser, and back to the steam generator. The tertiary loop (green) circulates water between the condenser and a river. The steam generator heats the secondary loop's feedwater to produce main steam, which drives a turbine connected to a generator. The condenser cools the secondary loop's steam using water from the river, which is then pumped back to the condenser.

Energy Density



Power Density

Land Utilization

Nuclear plants in Belgium require **285** times less land than solar...



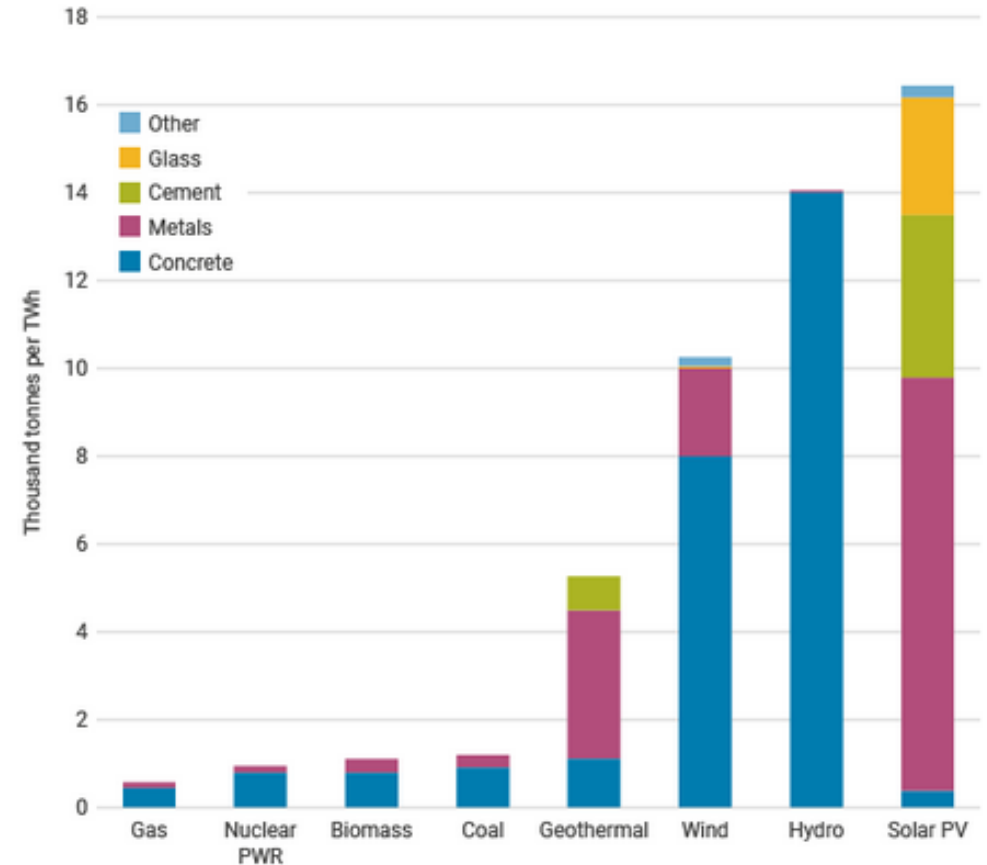
Source: Comparison between Doel Nuclear Plant and Kristal Solar Park in Lommel. If operated at 85% capacity factor, Doel's 570 megawatt (net) capacity would produce 22 terawatt-hours per year on an approximate land area of 1.1 square kilometers, for a density of 20 terawatt-hours per square kilometer. Kristal Solar Park has a power density of 0.07 terawatt-hours per square kilometer.

...and **412** times less area than wind



Source: Comparison between a facility like Doel Nuclear Plant if operated, and assumed production from Rentel wind farm. If operated at 85% capacity factor, Doel's 2.91 gigawatt (net) capacity would produce 22 terawatt-hours per year on an approximate land area of 1.1 square kilometers, for a density of 20 terawatt-hours per square kilometer. Rentel has a power density of 0.05 terawatt-hours per square kilometer.

Resource Utilization



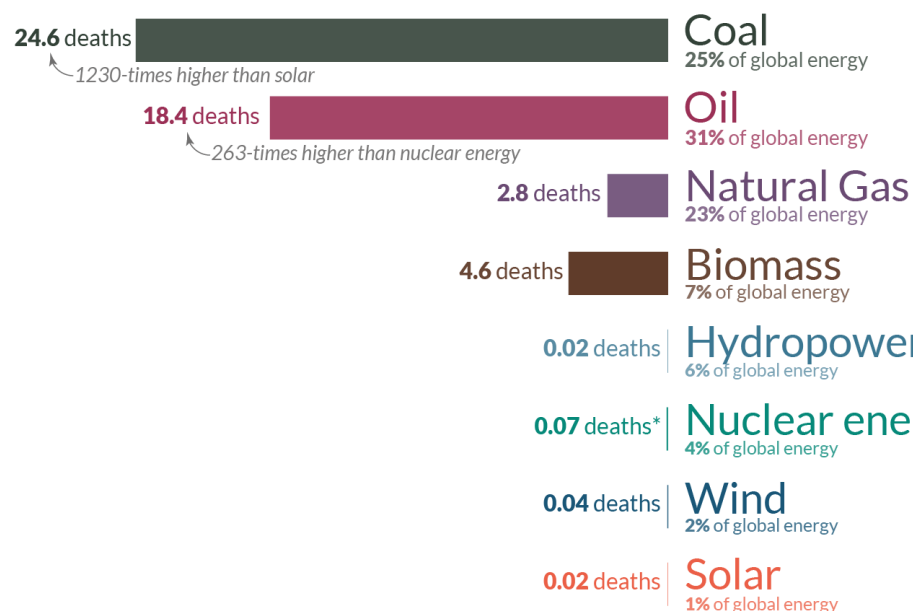
Safety and CO2 Production

Our World
in Data

What are the **safest** and **cleanest** sources of energy?

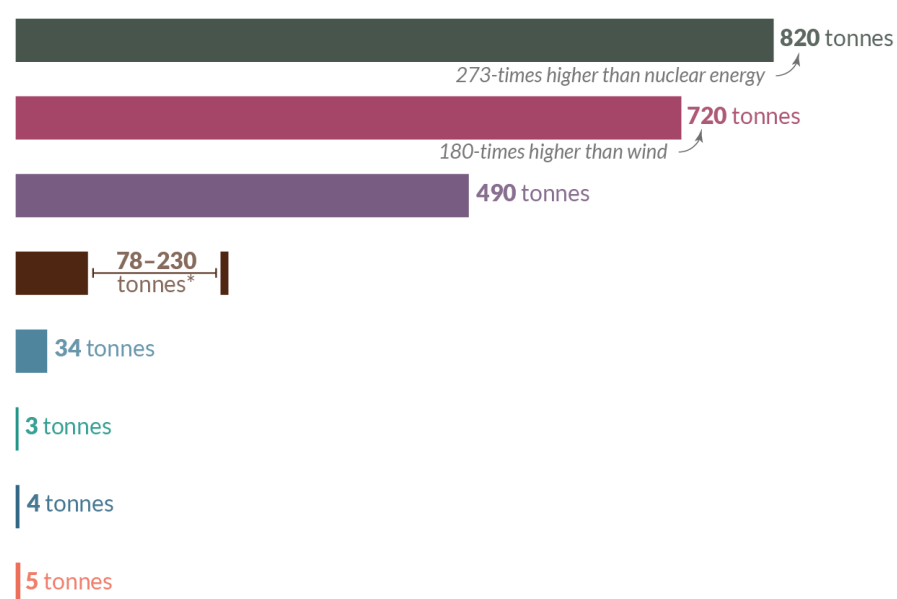
Death rate from accidents and air pollution

Measured as deaths per terawatt-hour of energy production.
1 terawatt-hour is the annual energy consumption of 27,000 people in the EU.



Greenhouse gas emissions

Measured in emissions of CO₂-equivalents per gigawatt-hour of electricity over the lifecycle of the power plant.
1 gigawatt-hour is the annual electricity consumption of 160 people in the EU.



*Life-cycle emissions from biomass vary significantly depending on fuel (e.g. crop residues vs. forestry) and the treatment of biogenic sources.

*The death rate for nuclear energy includes deaths from the Fukushima and Chernobyl disasters as well as the deaths from occupational accidents (largely mining and milling).

Energy shares refer to 2019 and are shown in primary energy substitution equivalents to correct for inefficiencies of fossil fuel combustion. Traditional biomass is taken into account.

Data sources: Death rates from Markandya & Wilkinson (2007) in *The Lancet*, and Sovacool et al. (2016) in *Journal of Cleaner Production*;

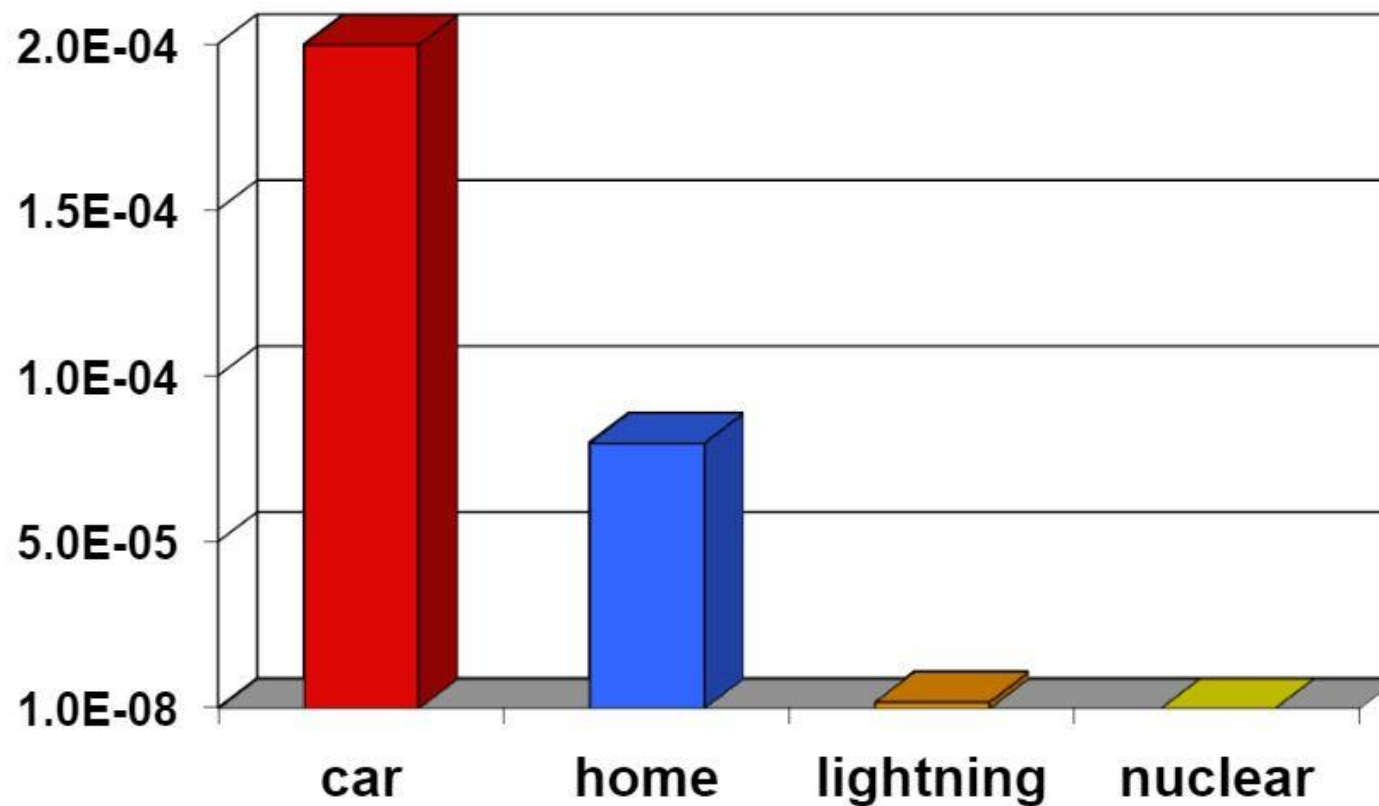
Greenhouse gas emission factors from IPCC AR5 (2014) and Pehl et al. (2017) in *Nature*; Energy shares from BP (2019) and Smil (2017).

OurWorldinData.org – Research and data to make progress against the world's largest problems.

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Risk Perception

Estimated lethal accidents frequency



Nuclear Waste Production

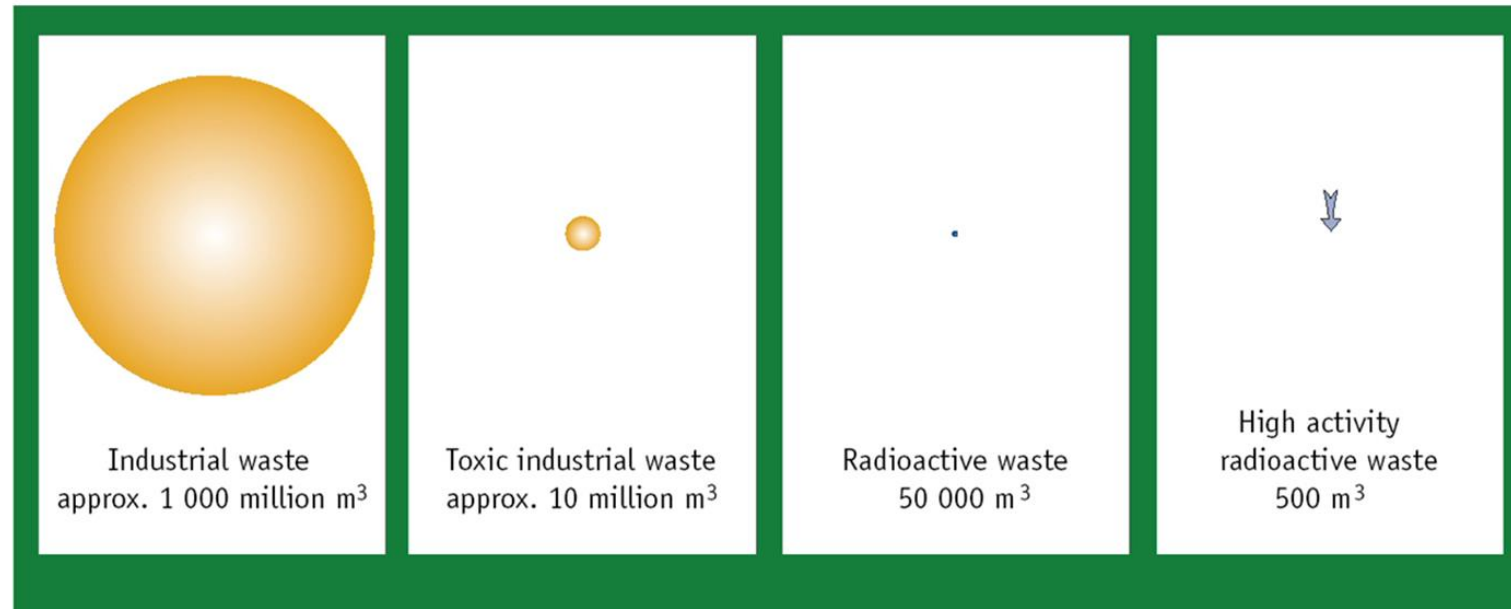
If the whole energy spent during the life of a person came from nuclear the total volume of high-level waste produced would be a 33cL can



Quantity of vitrified HLW produced by a French citizen in his / her **entire life**

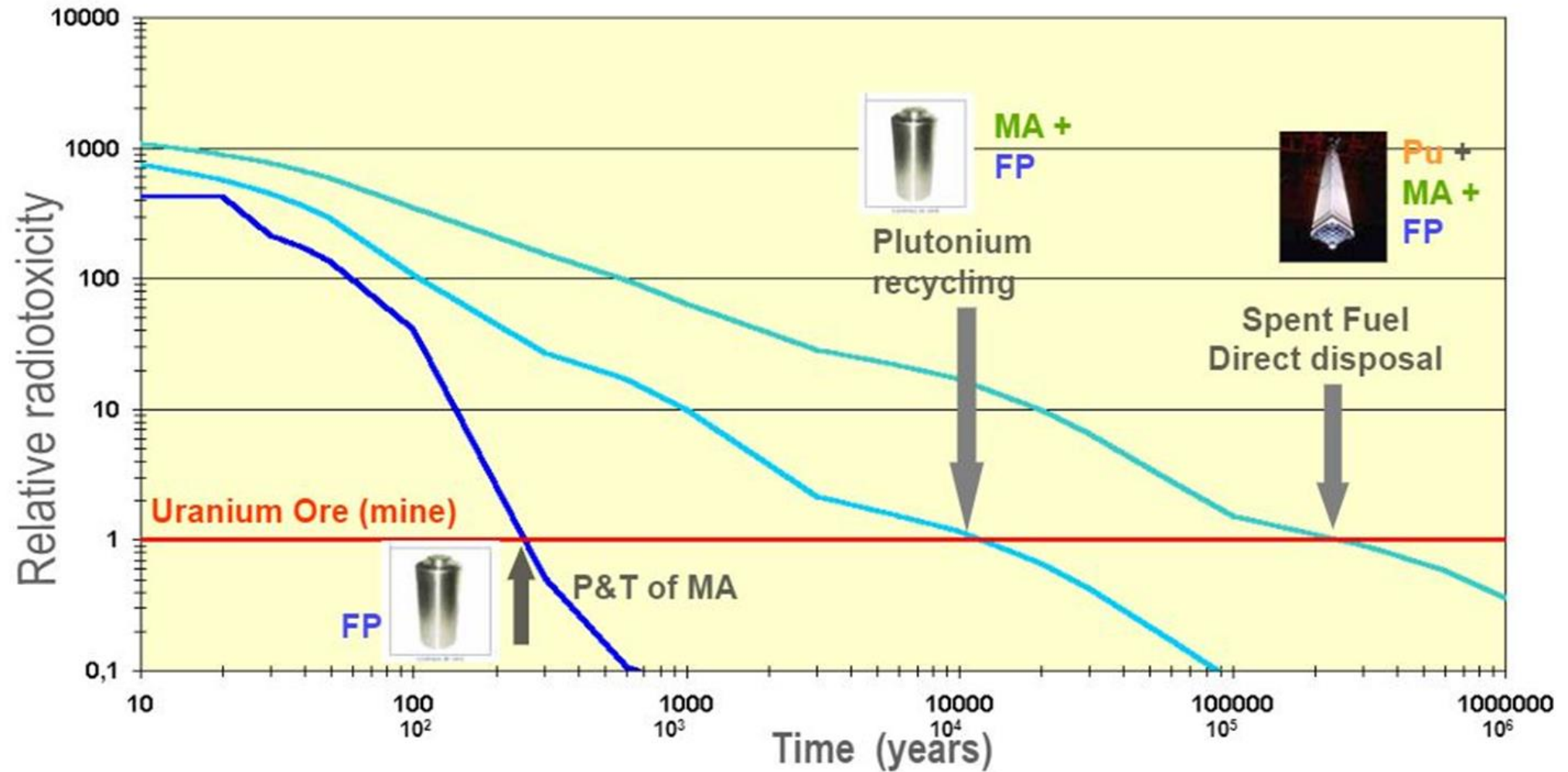


Figure 4.2: Waste generation comparison – yearly production of waste in the European Union

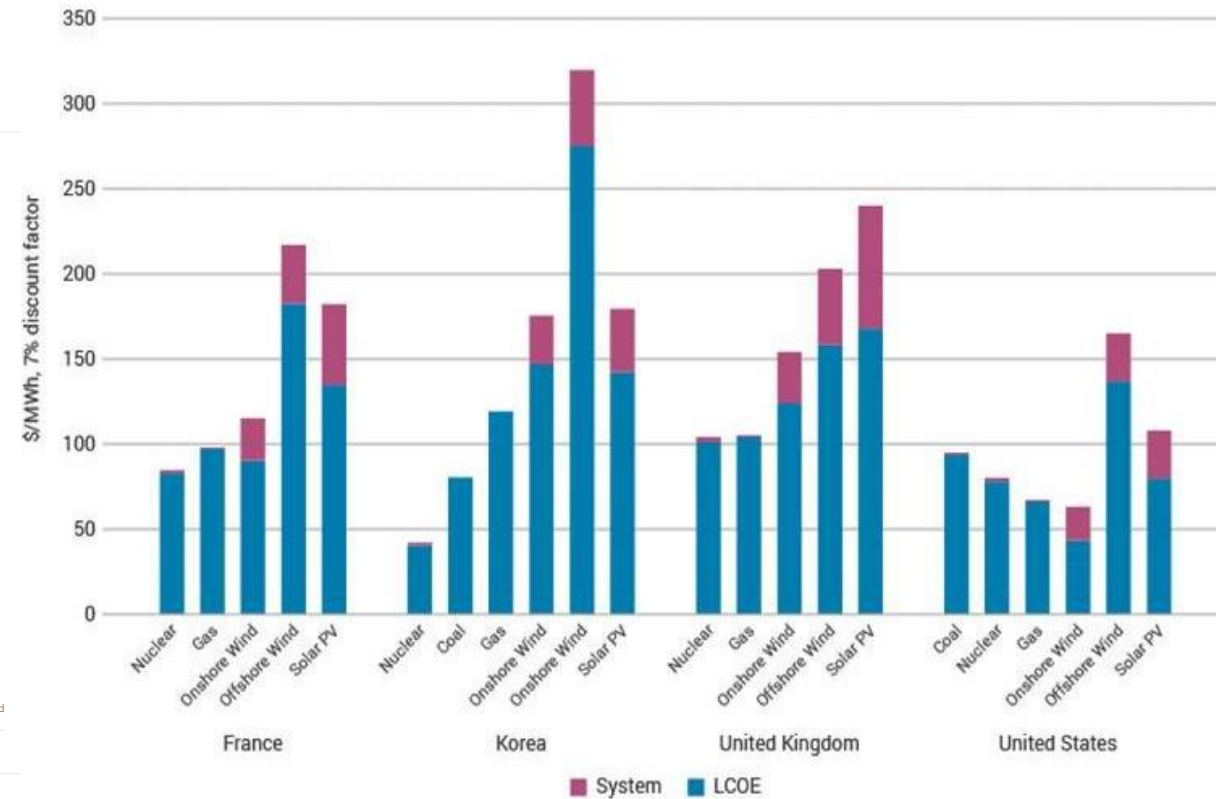
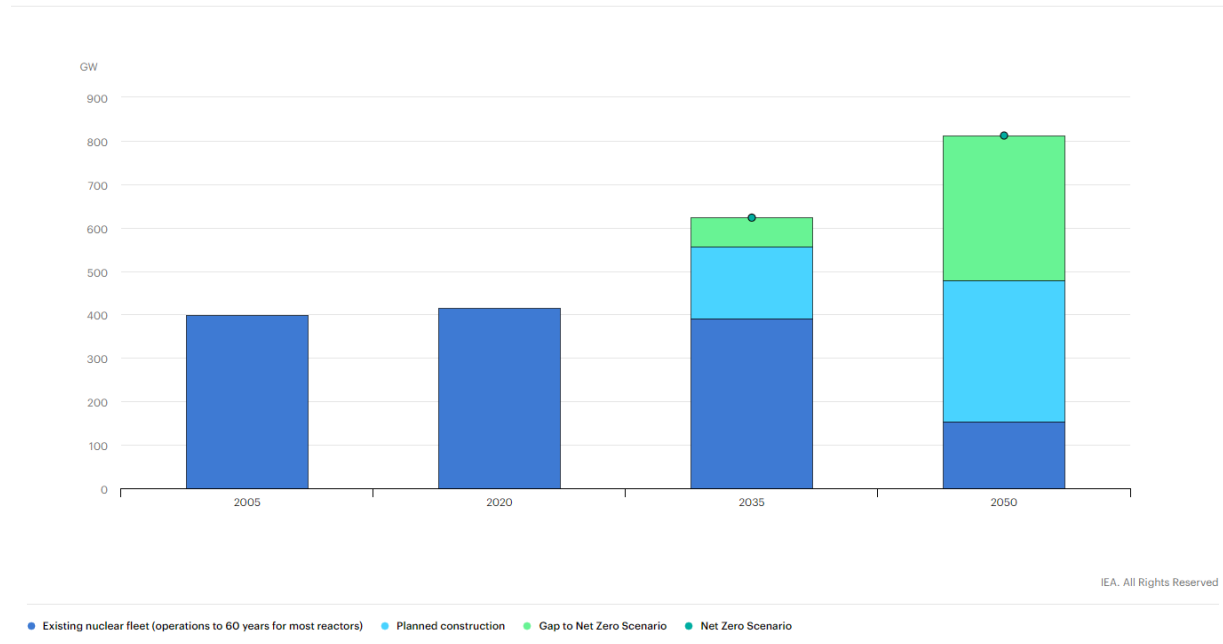


Source: *Nuclear and Renewable Energies* (Rome: Accademia Nazionale dei Lincei, 2000), updated with data from the European Commission, *Radioactive Waste Management in the European Union* (Brussels: EC, 1998).

Waste Decay Time



Economics: The Choice is Ours



On the Horizon

"A good investor has to consider the long-term"

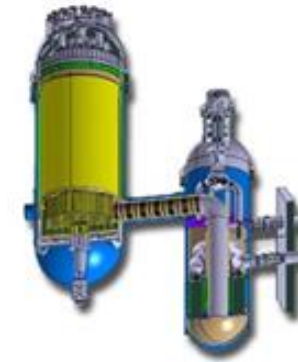
SMR

- Definition: Reactor with power output < 300 MWe
- Modularity: limited on-site preparation
- Lower capital investment
- Siting flexibility

Gen IV

- Evolutionary → Revolutionary
- Goals:
 - Waste minimization
 - Effective fuel utilization
 - Higher safety
 - Better economics
 - Proliferation resistant

GAS COOLED TECHNOLOGY



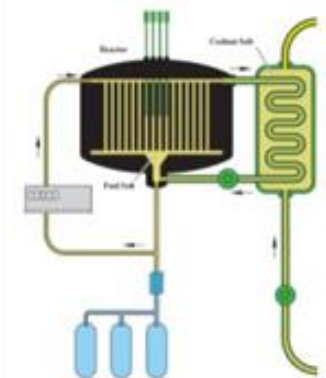
GCR

MOLTEN METAL COOLED TECHNOLOGY



SFR

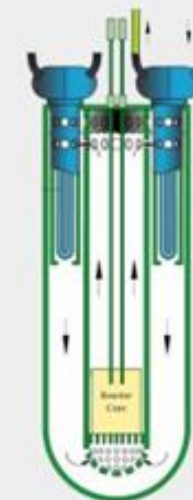
MOLTEN SALT COOLED TECHNOLOGY



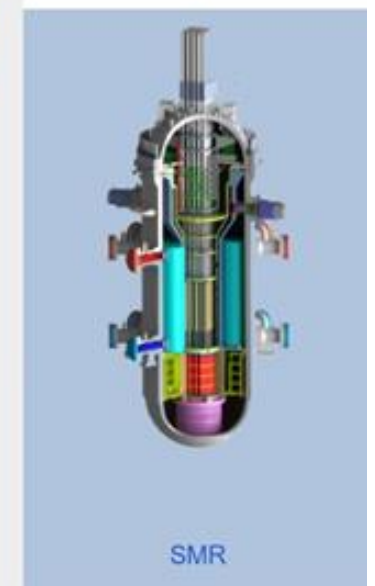
MSR



GFR



LFR



SMR



THANK YOU FOR THE ATTENTION

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