Centuries of Non-Fossil Nuclear Energy from "Waste"

US nuclear reactors have created 27,000 terawatt-hours of fossil-free electricity since 1951 from 90,000 tons of uranium fuel. Using fossil fuel that amount electricity would have required almost 100,000 times as much coal, 7,800 million tons, and produced 23,000 million tons of CO2.

To produce those 27,000 terawatt-hours of electricity the energy was extracted by splitting only 3,600 tons of the uranium fuel atoms into two smaller atoms each in a process called fission. The two smaller very energetic atoms immediately fly apart at great speed and release their energy of motion to the surroundings. That's nuclear energy. The other 86,400 tons of uranium fuel still remain unused and are now considered part of the 90,000 tons of highly radiotoxic long-term used fuel "waste", as are the 3,600 tons of small atoms created by fission.

But nuclear power can do even better, about 25 times better, by recycling the unused 86,400 tons of fuel through fast-spectrum fuel-breeding reactors. Such reactors were developed in the USA and operated here for over 30 years starting already in 1951. Russia has such power reactors since 1973, at 350 and 600 MW, and since 2016 at 800 MW levels, the latter now refueled with recycled used fuel.

To achieve that energy potential from the fuel we have to build that type of reactor again, here. We have the know-how.

The advantages are at least two-fold.

First is a 25 times additional non-carbon energy yield compared to the gargantuan amount already extracted with our current thermal reactors. The fleet of all current US power reactors would have accumulated the 90,000 tons of used fuel in about 35 years. A fleet of fast-spectrum fuel-breeding reactors of the same power recycling those same 90,000 tons would be able to operate 25 times as long, or 875 years.

Second, as a huge bonus, the preferential splitting of the highly radiotoxic heavy atoms in the used fuel "waste" can eliminate their million-year radiotoxicity in decades.

What is left is a residue of smaller atoms created when uranium is "fissioned". About 70% of these are stable, non-radioactive atoms immediately. The others lose their radioactivity in days, months, or a few years. Non-radioactive, they are very valuable, such as platinum-group metals that occur at higher concentrations than in the best ores in Africa, or costly noble gases, or rare earths use in solar panels and in wind turbine. Only two atoms, strontium and cesium, at 9% of the split atoms, have half-lives of 30 years, much much shorter than the million years of the untreated "waste". And their radioactivity makes them valuable even now as gamma ray sources in industry (Cs-137) or as long-lived thermoelectric power sources (Sr-90) in space or arctic applications similar to Pu-238.

How does one realize this potential? Only with two complementary US-developed technologies:

1) use of fast-spectrum fuel-breeding reactors,

and 2) recycling of the used fuel, e.g. by electro-refining (pyroprocessing) to remove the split-atom fission product "ashes".

There is no other way.

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Neutrons at the Core: Energy for Millennia – A Gentle Introduction to Nuclear Energy from Neutrons to Fast-Spectrum Reactors