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Nuclear Waste Disposal: An Exploratory Historical Overview

Hydrogen – Important Building Block Towards Climate Neutrality

10 Years of Phasing Out Nuclear Power

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Steam generator removal in Neckarwestheim Unit 1 NPP (Courtesy of EnBW Kernkraft GmbH)

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Czech Scientists to Recycle Fuel from Operating Nuclear Power Plants to Use for District Heating

Radek Skoda

Introduction A Czech research group has come up with a design to heat cities with irradiated nuclear fuel rods from nuclear power plants, which they say can pay off better than switching from burning coal to burning natural gas.

Figure 1
The Teplator.

A team of researchers from the Czech Technical University in Prague and the University of West Bohemia in Pilsen will use spent nuclear fuel to make district heating both cheaper and more climate-friendly than current combustion techniques. The heat only producing reactor they call "TEPLATOR".

"The design is very, very simple. That means it is very unexpensive and quick to build and it, in the end, means cheap heat. The key that distinguishes our design from other nuclear technologies is that we focus exclusively on heat, not electricity", says Radek Skoda, a trained nuclear reactor operator and nuclear researcher at Czech Technical University in Prague.

He heads the team behind the Teplator design, which utilizes some of the energy left in the nuclear fuel after the nuclear power plants could not extract more energy from it. In current NPPs only less than 5 % fuel is utilized and maximal burn up is rarely achieved.

The best thing about the innovative district heating solution is that it enables the use of the spent fuel, which otherwise has to be stored for many years, which is associated with high costs.

When it is still possible to extract more energy from the nuclear power plants' spent fuel, it is because the vast majority of plants in operation today were designed about 50 years ago, when no advanced computational tools like Monte Carlo were available.

'Back in the' 70s, they sat and did their calculations on logarithm paper, simple calculators and early punch card computers. At that time, scientists could not optimize the use of nuclear fuel and utilize a maximum of five percent of energy. With the latest technology, we can take a few percent more energy out of the fuel" he says.

But not even 20 years ago it had been possible to develop Teplator technology. Calculations and simulations of the optimization of the energy of spent fuel have been performed on some of the world's modern supercomputers.

"We have spent many years optimizing this, and we have also burned some computers along the way when we have run our simulations," he says.

With the Teplator design, it will be possible, for example, to heat all the major Czech cities exclusively with the spent nuclear fuel (Teplator DEMO fuel loading is 55 fuel assemblies for 2 years; there are more than 10 000 suitable fuel assemblies in the country, and they are the current nuclear plants are still "producing" more than 250 assemblies per year), which is already stored today in warehouses around the country.

Fuel for a Teplator reactor can come from both the conventional BWR and PWR reactors, which are by far the most widely used reactor types around the world.

A Teplator district heating plant will be the size of the small nuclear research reactors, which will require an area of about 2,000 m2, half the football pitch. However, Teplator is technologically much simpler than a research or SMR reactor, because only heat and not electricity must be generated.

Figure 2
Drs Korinek, Skarohlid and Skoda of CTU Prague at the model of intermediate Teplator circle.

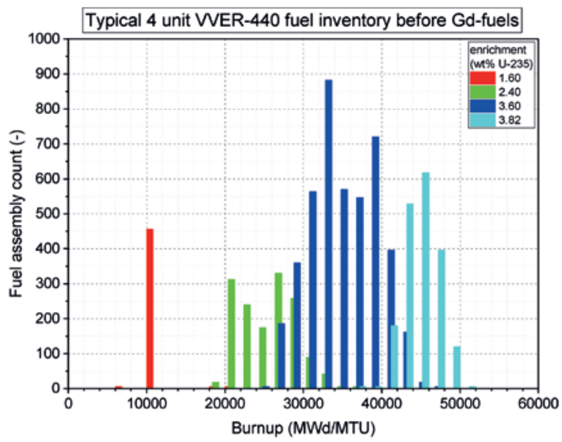
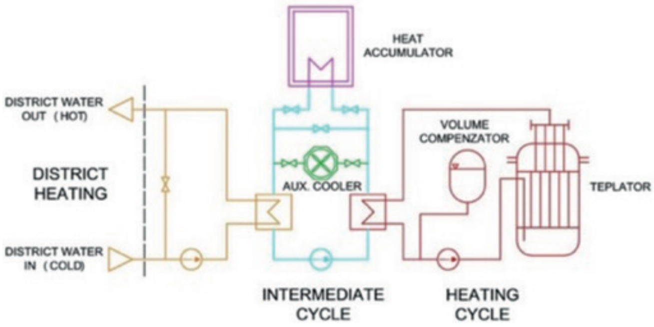


Figure 3
Typical burn up of various enrichment fuel – none reaches maximum allowed values.

| **Figure 4**
About 5,000 irradiated fuel assemblies are stored in this czech interim storage facility, enough to heat up Prague for 50 years.



| **Figure 6**
3 circuit of the Teplator design.

How it works

The simplest version of Teplator, which can be built for about 35 million euros, operates at normal atmospheric pressure and below 100 degrees Celsius, which requires fewer complicated technical solutions and materials.

This 'Teplator Demo' is a demonstration design and will have a capacity of 50 MW and a thermal output of 98 degrees Celsius. But for larger cities and industrial use, the Czech team has developed 'Teplator Full', which has a thermal output of up to 200 degrees Celsius with a capacity of 170 MW, but then works under a pressure of just under two megapascal (MPa).

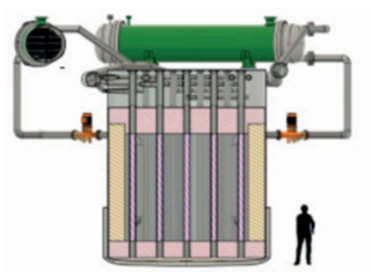
Besides this, the two designs are pretty much the same, different licensing being the greatest difference.

The Teplator core is about 6 x 6 meters large and produces heat from a total of 55 fuel assemblies (pictured in **Figure 5** in pink), which are located at a distance of about 50 centimeters.

'It would not work if we were just a little bit wrong in judging the distance between the fuel rods. If they were either too close or too far apart, the neutrons would not have the right amount of energy, and fission reaction would therefore not start", says Radek Skoda.

On contrary to nuclear power plants where the fuel is touching one another, here the space between the fuel allows releasing additional energy and also leads to smaller power density and better nuclear safety.

It is a much larger distance than at conventional nuclear power plants and research reactors, which is due to the fact that the fuel rods are surrounded by heavy water (D_2O) rather than ordinary water (H_2O), e.g. CANDU heavy water reactors also have fuel (they call it bundles) apart.



| **Figure 5**
The Teplator.

"A typical nuclear reactor uses light and not heavy water. The light water 'steals' the neutrons, and therefore the fuel rods must be placed close to each other for the fission reaction to begin. Here we use heavy water, which does not 'steal' the neutrons to the same degree. With ordinary light water, the design would not work", explains Radek Skoda.

The fuel rods are surrounded by heavy water, which is pumped up to the heat exchanger (the upper cylinder with green), which draws heat energy out of it, after which the process begins all over again.

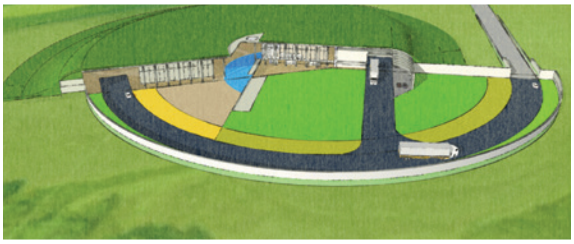
The exterior of the nucleus (with yellow) consists of graphite, which acts as a so-called neutron reflector to lower the kinetic energy of fast neutrons and return them back to release more energy.

The Teplator design is still awaiting a number of licensing permits, but the team is already discussing the technology with several Czech district heating companies, which are facing a phasing out of coal and are 'open' to the Teplator design.

"We are currently in the middle of concrete negotiations. It is cheaper than natural gas and not only with a little bit, but up to four times cheaper, and then there is no CO_2 emissions", Radek says.

In the Czech Republic, there is largely unanimous political support for building more nuclear power plants in the country. Only the Green Party which in opinion polls stands to get between two and three percent of the vote is against.

"We take these comments very seriously, the design in practice is based on very mature and tested components, because it is very similar to the Canadian CANDU reactors, which



| **Figure 7**
Architect's impression of the Teplator facility.

have been in operation since the 70s. In addition, Teplator reactors cannot be built in every small town. It would be completely meaningless with the power of 50 MW or more", he says, adding: "In the Czech Republic, we are talking about a handful of large facilities a few kilometers away from cities with at least 100,000 inhabitants. In addition, the works must be secured and protected with, among other things, armed guards."

Radek Skoda hopes that the first TEPLATOR DEMO in the Czech Republic will be in operation in 2028, while he expects that it will take longer to spread the solution in other EU countries where there is less support for nuclear power.

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Radek received his M.Sc. in Experimental Particle Physics from the University of Bergen (1998) and his Ph.D. in Nuclear Engineering from the Czech Technical University (2002). Having also a degree in economics he initially focused on quantitative finance for Dublin and London based multinational banks, followed by academic work for the Czech Technical University in Prague and University of West Bohemia in Pilsen. He is also visiting lecturer of North West University, Potchefstroom in South Africa, Polytech St. Peterburg and World Nuclear University, Oxford. Research-wise, Radek was Director of Nuclear Science Center in the Texas A&M University where he conducted experiments on the TRIGA and AGN-201 nuclear reactors and now he leads his Czech nuclear research group and co-directs Intercontinental Nuclear Institute. He published dozens of peer reviewer articles and patents in nuclear engineering and also advised the Czech government on energy strategy.