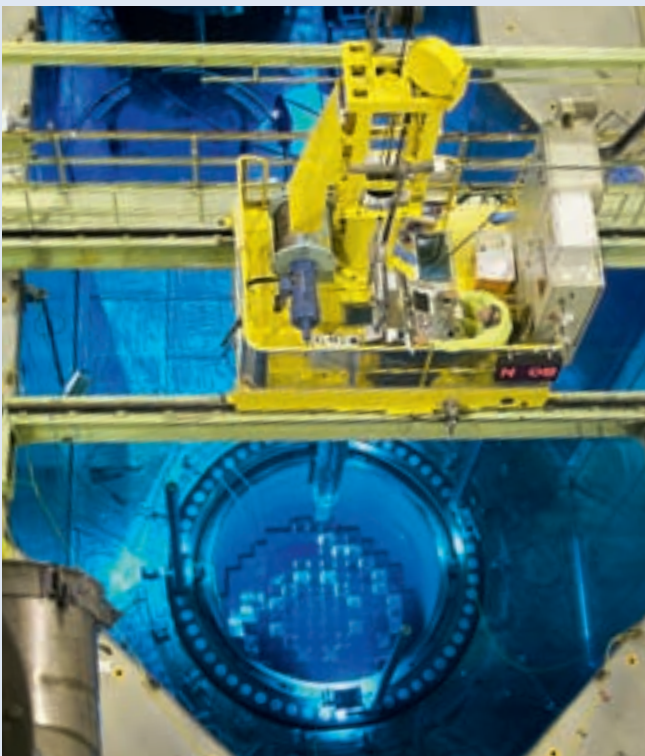


HOW NUCLEAR FUEL EFFICIENCY IS INCREASED

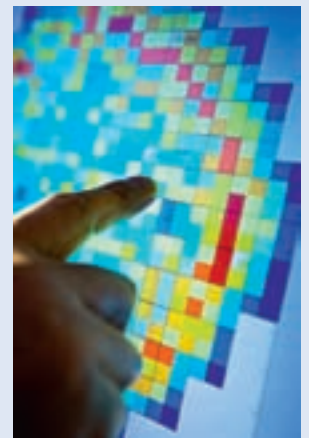
There are many technical innovations and improvements in fuel use that contribute to make nuclear power more efficient. Most of these innovations are interrelated; for example, improvements in the materials used in nuclear fuel construction make it possible to use higher enriched fuel. Higher enriched fuel contributes to a longer life span, which leads to more efficient use. Below is a presentation of the most important factors that have enabled Vattenfall to improve efficiency.



Optimised reactor core design

Nuclear power reactors are typically shut down once a year for maintenance and refuelling. Old, spent fuel assemblies with only a small amount of fissionable material remaining, are replaced by new fuel. Between 1/4 and 1/6 of the fuel is changed. The core design determines the quantity of new fuel and the location of the fuel assemblies in the reactor. The purpose is to put the fuel to optimum utilisation by appropriate locations of new and reused assemblies. Generally, fresh fuel generates more heat and is therefore surrounded by older fuel assemblies, in order to distribute the heat evenly and make the process stable.

Core design is a complicated optimisation process in which many conditions must be met. The maximum possible energy shall be extracted from the fuel, while ensuring conformance with all safety requirements. Consideration must also be given to the required operational flexibility. Good core design puts the fuel to good use and saves a great deal of money. During the past 20 years, skilled engineers, sophisticated calculation methods and computer programs have led to improved core design, thereby increasing the efficiency of the reactor process.



Improved materials and fuel construction

When nuclear fuel is fabricated, enriched uranium oxide is baked into ceramic pellets. The pellets are encased in metal tubes to form fuel rods, which are arranged into a fuel assembly ready for introduction into a reactor. Improved materials and construction of the nuclear fuel have significantly increased the reliability of the power generation process as well as fuel efficiency. Examples of construction improvements include increased accessibility of the cooling water in the fuel assembly, making the process more efficient, and improved materials that enable higher enrichment and thereby higher burn-up. Improved design of so-called "debris-catchers" has reduced the rate of fuel failure due to debris in the cooling water, thus improving fuel reliability.

Higher enrichment

Improved fuel materials and construction have contributed to a higher level of enrichment during the past 20 years, from about 3% to 4.5%. This has had a significant impact on fuel efficiency. The level of enrichment determines the amount of energy that can be extracted from the fuel. The higher the enrichment level, the more energy will be delivered by every kilogram of enriched uranium. But enrichment is costly, and a study is performed every year to determine the most economical level of enrichment for every reactor. When determining the enrichment level, consideration must also be given to the technical limitations of the fuel assembly. The aim of enrichment optimisation is to achieve the best possible overall economy. The analysis results in specification of the level to which the fuel should be enriched, and an estimate of the number of fuel assemblies that need to be purchased annually for each reactor.

Optimised fuel design

In fuel design, the properties that the individual fuel assemblies must have are determined. The aim is to produce a design that puts the fuel to maximum use for the coming years of operation. At the same time, the design must provide maximum flexibility for operating times, and it must meet all safety criteria. In order to extract as much energy as possible from the uranium, enrichment is distributed inside the assembly. This distribution ensures that the power will be more uniformly distributed and the best possible heat transfer from the uranium to the coolant will be obtained, thereby making power generation stable and efficient. Fuel optimisation is performed by Vattenfall.