Service life extension for Paks Nuclear Power Plant Ltd

Technical and financial background information

mvm

paks nuclear power plant

Contents

The service life extension in brief	1
Summary	2
Why Paks Nuclear Power Plant is needed for the country?	3
What does service life extension mean?	4
International trends	5
Ageing management at Paks Nuclear Power Plant	6
Safety during the extended operation	8
Environmental issues of the service life extension	9
Economical energy source	10
What about the radioactive waste?	11
Why the nuclear power plant can not be replaced with renewable energy?	12
The service life extension is supported by the public	13
A critical question: Will sufficient qualified personnel be available?	14

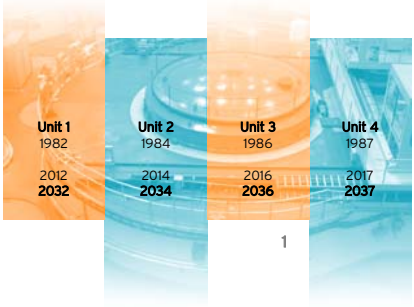
The service life extension in brief

The four reactor units of Paks Nuclear Power Plant, each with an initial capacity of 440 MW, started to operate between 1982 and 1987. Thanks to the modifications undertaken during the past years, two Units (1 and 4) were power upgraded up to 500 MW. The power enhancement of other two Units (2 and 3) will be finished in 2009. Since the initial designed lifetime of the units was 30 years, their operation should be ceased between 2012 and 2017.

In 2000, a feasibility study was carried out on the extension of the service life of the power plant by 20 years. The feasibility study resulted in a conclusion that there was no technical objection or safety limit that would prevent the extension of the service life to 50 years. The feasibility study also confirmed the return of capital investments required for the service life extension work.

After the owner had issued its letter of intent, a complex ageing management program was launched by the power plant with the purpose of monitoring the technical condition of the items of equipment, wich may potencialy prevent the service life extension, and to intervene in the ageing process, if required.

On 21 November 2006, a proposal was carried by the Hungarian Parliament with a vote rate of 96.6%, in wich the Parliament accepted the report of Paks Nuclear Power Plant on the service lifetime extension concept and the way of implementation, at the same time, granted its basic approval to the service life extension. Of course, the legal licencing process for the service life extension has not been concluded yet; the permits of the competent authorities (environmental, nuclear, safety, etc.) are also required.



The start and end of service life of the four units of Paks Nuclear Power Plant (assuming a service life of 30 to **50** years).

Summary

Why Paks Nuclear Power Plant is needed for the country?

Because it cleanly and safety produces electric energy, with high confidence, at the lowest price in the country.

What does service life extension mean?

The use of the equipment and the operation of the units of Paks Nuclear Power Plant in compilance with the specified regulations until this can be achived in a safe and economically effective manner.

Is it safe?

Yes. The level of safety is equivalent to the safety level of western units of similar age. The widening of our knowledge and the use of international experience is enforced by Paks Nuclear Power Plant, in the everyday life, with the help of safety enhancement measures. The units have been operating safely for more than 20 years.

Is it environment friendly?

Yes, because it does not discharge green-house gases, nitrogen oxide or sulphur dioxide, and consequently, it does not contribute to the global warming and occurence of acid rain.

Is it cheap?

Yes. It produces the cheapest electric power in the country and thus, has an overall price rise prevention effect.

Is service life extension accepted by the public?

Yes. As shown by the result of national public opinion polls, nearly 65% of the population agrees with the service life extension.

What are the international trends?

International experience and technical reviews undertaken by other nuclear power plants around the world show that the service life of such type of nuclear power plant units can safely be extended.

What about the radioactive waste?

A relative small amount of waste is produced during the operation of the nuclear power plant, wich is collected, treated and monitored until final disposal. In 2005, the Parliament granted its basic approval for the construction of the low and middle level radioactive waste repository in Bátaapáti, and the construction is in progress now. The potencial site for the high level radioactive waste repository in Boda region, Mecsek Mountain, has been recently explored. The spent nuclear fuel is not considered as nuclear waste. The spent fuel assemblies are currently stored in a special store facility at the site of the power plant (for a specified period of 50 years). Later, the fuel assemblies can be reprocessed and recycled, or disposed in the high level waste repository.

What does ageing management mean for Paks Nuclear Power Plant?

Monitoring of the structural materials, replacement of obsolete items of equipment, and condition preservation and preventive maintenance of all other items of equipment.

Why the nuclear power plant can not be replaced with renewable energy?

One hand, because renewable energy sources are not capable of providing continuous and bulk electric energy supply matched to the demands and, on the other hand, the production of electric energy is much more expensive with the use of renewable sources. Of course, the use, to the possible highest degree, of renewable energy sources is necessary for environment and sustainable development, but the realities shall also be kept in wiev.

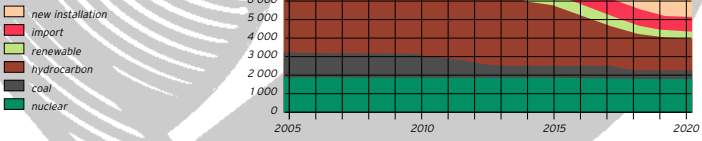
Will sufficient qualified personnel be available?

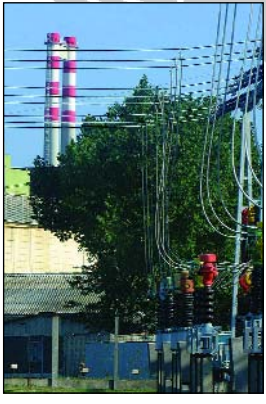
The close co-operation with the secondary and higher educational institutes is integral part of the human policy of our nuclear power plant, to ensure the required supply of professionals.

Why Paks Nuclear Power Plant is needed for the country?

Paks Nuclear Power Plant is the most significant component of the Hungarian electric power production: it supplied 36,8% of the total domestic production in 2007.
The 30 years design service life of the four reactor units will expire between 2012 and 2017. The closure of this power plant would cause a capacity loss of some 2000 MW in the energy system. An additional loss of some 4000 MW is anticipated due to the closure of old and obsolate conventional power plants during the period until 2020.
In addition, according to the forecast, the average annual increase of the electric power consumption will be of 2% during the next 15 years, which will require the installation of some 2000 MW electric power generation capacity up to 2020.

The stucture of the total installed production capacity for the anticipated energy sources up to 2020. (The blue line represents the anticipated trend of the domestic consumption.) /www.mavir.hu/





This means, that a capacity deficit of some 5-6000 MW needs to be compensated even with Paks operating further, but a new capacity of 7-8000 MW needs to provided by construction of new power plants or from import, if Paks Nuclear Power Plant is closed.

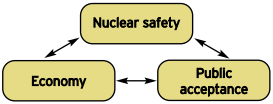
Paks Nuclear Power Plant has a particular role in the energy policy. The diversity of the electric power production (coal, hydrocarbon, nuclear) has been achived and can be sustained with the help of Paks Nuclear Power Plant.

Paks Nuclear Power Plant, as a dominant state owned energy producer, is a potential tool for the market regulation and economic policy inventions, and may retain this role for long term.

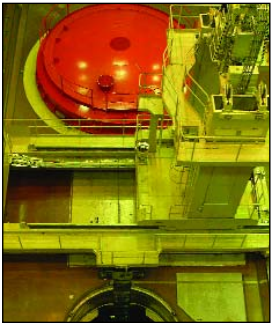
Paks Nuclear Power Plant significantly reduces the risk arising from the one sided import dependence of the national economy, since the nuclear fuel, contrary to natural gas and crude oil, is supplied from from countries outside the crisis regions of the world, and can easily been stockpiled for several years ahead. (The power plant keeps fuel reserves for two years at present. If it necessary, this reserved stock could be easily increased with relative low additional expenses, while the stockpiling of the gas or crude oil for several years would need enormous costs.) Several sources are available for the purchase of nuclear fuel elements: at present a Russian and a British company are capable of manufacturing nuclear fuel assemblies for Paks Nuclear Power Plant.

Paks Nuclear Power Plant significantly contributes to maintaining the security of the domestic electric power supply.

What does service life extension mean?



A precondition for the service life extension is that, during the extended life, the nuclear safety shall not diminish below the presently valid level specified in the authority regulations. In addition, it is of primary importance to ensure, that the service life extension has sufficient public acceptance and that the owner can be in anticipation of remunerative investment.

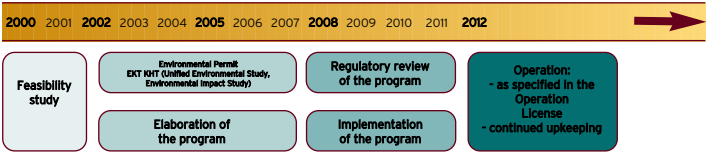


In order to ensure that the Paks units can operate for further twenty years after the expiry of the design service life, the Operation License needs to be renewed. This shall be preceded by the elaboration of a complex lifetime management program.

The aquisition of several various permits is required for the planned service life extension work. The process of licensing is primarily specified by the Nuclear Act, the Environmental Act, the Act of Electric Energy, and other associated degrees.

First, in 2008, ie. 4 years before the expiry of service life of Unit 1, a technical implementation program will need to be submitted to the nuclear regulator, the Hungarian Atomic Energy Agency. Parallel to this, the environmental permit for the service life extension shall also be obtained for all four units. Finally, for Unit 1, the Operation License will be required for the extended service life from 2012. For the other units, the licensing procedure will take place in a similar manner.

The renewal of the Operation License requires that effectiveness and suitability of lifetime management program and adequacy of the technical/safety assessment is demonstrated by the power plant as early as during the design lifetime.



Schedule for the implementation of the service life extension.

(The new Operation License can be issued following the acceptance of the Environmental Impact Study Report and the issuance of the Environmental Permit. However, the elaboration of the service life extension program is under way, parallel to having Environmental Permit.

The implementation schedule of program, as presented in the figure above, was accepted by the Parliament in its resolution in November, 2005.)

International trends

Fort Calhoun - USA

The practice used by Paks Nuclear Power Plant for the service life extension is not unique. The United States has great experience in license renewal work, where new operation permits have been issued to more than sixty nuclear power plant units since 2000, thus extending the 40-year original design lifetime to 60 years. The application for license renewal of further units are under processing at US Nuclear regulator, and several other units plan to submit their application during the next years. In addition the power upgrading of the units is also a generally accepted practise in the USA: during the last 30 years, power upgrading of some 4000 MW has been implemented in the USA, and the availability of nearly 1000 MW additional capacity is expected for the next 5 years. Furthermore, an act was accepted in 2006, for which, several big companies showed their interest.

Dukovany - Czech Republic

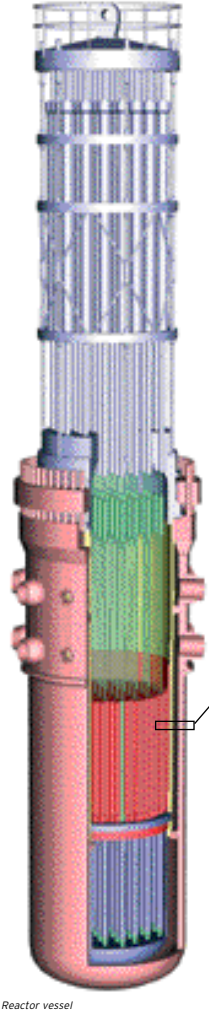
In Europa, the previous anti-nuclear trend seems to taken an opposite direction. In Finland, a new 1600 MW EPR (European Pressurized Reactor) type reactor, the Olkiluoto 3, is under construction now, and France has also started to construct a new demonstration EPR unit.

There are also examples for the service life extension of the VVER-440 units (which is the type of units of Paks) in Russia.

In the Czech Republic, preparations are being made now for the 40 years operation of the four VVER-440 units of Dukovany power plant, and even more, the operator set a target in 2005 to operate these units, which are of the same type as the Paks's ones, for further 20 years, i.e. for a total period of 60 years.

Kola - Russia

Olkiluoto 3 EPR - Finland



Reactor vessel

Ageing management at Paks Nuclear Power Plant

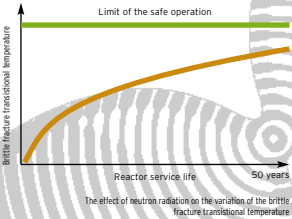
Ageing management of the major items of equipment of the power plant is a key technical issue for the service life extension. The ageing processes may be influenced by the design and manufacturing features of the major items of equipment, the technical reviews and the maintenance practice used in the power plant, and the reconstruction and renewal works.

The preservation of the functionality of the ageing equipment is managed by both the operation and maintenance practice of Paks Nuclear Power Plant, and the nuclear safety regulations, as a key issue. The power plant had to demonstrate as early as 1997-1999, during the Periodic Safety Review, that the safety related items of equipment are serviceable even in spite of the ageing process. Due to this requirement, the systematic ageing management work commenced already that time at Paks Nuclear Power Plant. The ageing processes for the critical items of equipment, the methods of monitoring the condition changes, and the possible corrective actions were identified within this work. It was concluded that the ageing characteristics of the major items of equipment remained below the anticipated values.

In accordance with the results of the review, the ageing management of the reactor pressure vessel and the steam generators are of special importance, since they can not be replaced. The dominant ageing process of the reactor pressure vessels is the embrittlement of the steel material due to neutron radiation. During this process, as a consequence of the neutron dose explosure to the material, the mechanical properties of the reactor vessel sructural material changes in the course of time, thus causing the reduction of the material toughness and the increase of the so called transitional temperature at the boundary between the tough and the rigid range.

The embrittlement of the reactor vessel material is identified by calculations, with the use of neutron detectors and so called surveillance specimens. These test pieces are made of the same steel as the reactor vessel, and are installed within the reactor, close to the active zone, thus ensuring that the neutron radiation exposure to the test pieces is surely higher than to the vessel material. The surveillance specimens are removed from the reactor to a specified schedule, and the degree of their ageing is identified by material testing procedures.

To our present knowledge, the brittle fracture transitional temperature of the reactor vessel wall will not exceed the safe operation limit even during 50 years operation. With regard to this, comprehensive analysis and calculations are in progress at present. The implementation of the so called low leakage core also serves for reducing the radiation exposure to the reactor wall. This means, that the fuel assemblies are loaded into the reactor core in a configuration that partly spent fuel assemblies are loaded in the circumferential positions, to ensure that the intensity of the neutron radiation towards the reactor vessel wall is smaller.



The effect of neutron radiation on the variation of the brittle fracture transitional temperature

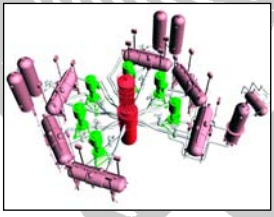
The reactor vessels are slightly different at each unit, thus the extension of their service life will also be subject to different conditions.

The reactor vessels of Unit 3 and 4 can be operated for 50 years with no special intervention.

For Unit 1 and 2 the coolant of the emergency cooling system will need to be heated-up to a small degree. (Thus, if the emergency core cooling system needs to be operated, the temperature of the coolant injected into the vessel is higher than the critical temperature, that helps avoid the occurance of the so called pressurized thermal shock.)

For the case, in which the transitional temperature would even reach the safe operation limit, a so called reactor vessel heat treatement could be undertaken, during which the major part of the material defects caused by radiation is eliminated by heating the vessel wall to high temperature, thus causing a significant reduction in the brittle fracture transitional temperature. With the use of this method it is possible to achieve that the material of the reactor vessel wall has favourable properties again close to the original conditions after the manufacture.

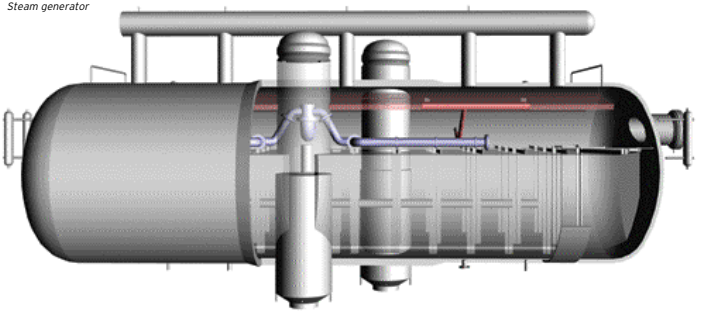
Arrangement of the steam generators around the reactor vessel



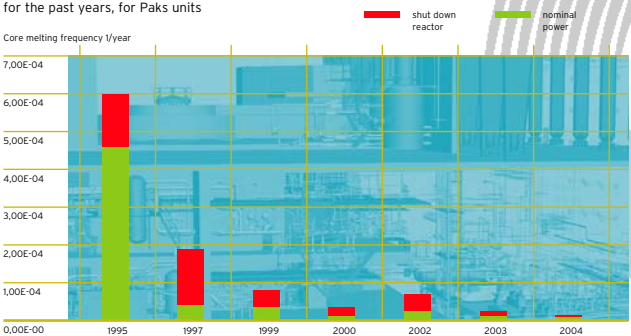
This heat treatment technique has been tested and proven good in other VVER power plants (Finland and Slovakia).

For the steam generators, the attention shall be focused on the stress corrosion of the heat exchange tubes. Nearly 5500 U-shape tubes are installed in the steam generators of the VVER power plants. To reduce the corrosion of these tubes, measures (new water regime, condensor replacement, copper removal, etc.) were adopted and implemented to protect the secondary side of the steam generators. As a result of these actions, to our present knowledge, no steam generator replacement will be required even during the 50 years service life.

Steam generator



The expected core melting frequency
for the past years, for Paks units



The most important precondition for the service life extension is that the safety of the units shall not be decreased even under the entire service life.In this work, and in the improvement of the safety, we can make use of some 5000 reactor-years experience, that accumulated to date all over the world in the field of the operation of pressurized water reactors.

In the nineties, a comprehensive safety enhancement program was launched by Paks Nuclear Power Plant, which included the improvement of the management of accident situations, the improvement of the reliabiity of the safety systems, the reduction of loads on the equipment, the review of the containment condition, the improvement of the earthquake resistance, the enhancement of the fire safety, and more effective training of the operational staff.

As a result of these safety enhancement measures, the safety of Paks Nuclear Power Plant is equivalent, at present, to that of the western power plants of similar age. (The anticipated core melting frequency, which is the mot important safety performance indicator, is 10-5/year order of magnitude at present).

The seriuos incident of Unit 2 on Apryl 2003 had no inpact on the process system of Unit 2 consequently, the incident does not qualify the safety and the process systems of the unit and had no effect on the technical/safety conditions and the chances of the service life extension and thus, on the permissibility either. The accident called the attention to the safety culture of all persons involved in the work, to the safety conscious management and to the importance of quality work.

In accordance with the international recommendations, both the nuclear power plant and the regulatory body launched a comprehensive program for the improvement of the safety culture and the more effective training of the personnels, the results of which were confirmed by recent reviews (eg. review of the International Atomic Energy Agency in February 2005).

Environmental issues of the service life extension

The surface temprature of the Danube on 13 February 2003.

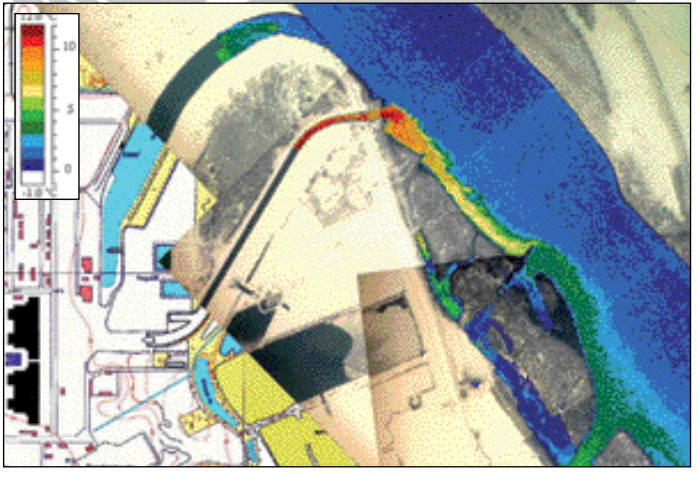
(Dark blue indicates 0°C, while the red one 12°C. It can bee seen that the warm water discharged from the power plant causes a temperature increase of some 3°C in a narrow zone close to the right bank. Due to mixing and evaporation, this difference fully disappears within the distance to the Sió mouth.)

The permission of the competent environmental authority (ADVKTVF - Lower Danube Valley Environment and Water Inspectorate) will also be required for the service life extension. The power plant can apply for this permission with reference to the Environmental Impact Study Report prepared in early 2006.

It had to be demonstrated in the this document, that the operation of the nuclear power plant during the extended service life will not cause any change in the today prevailing environmental conditions.

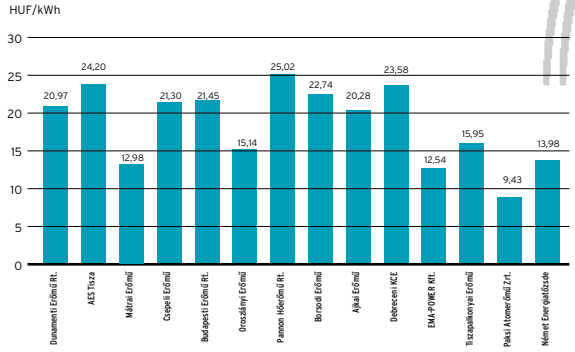
The environmental impacts during the longer service life can be well predicted upon the so far abtained operational experience:

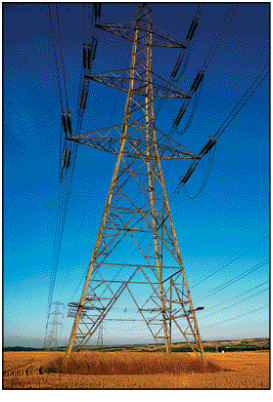
- The power generation process is not accompained by discharge of any dust, flying ashes or air polluting gases (CO_2, SO_2, NO_x).
- If the nuclear power plant was replaced with conventional power plant, the CO_2 emission of the country would increase by 6 or 10 million tonnes, depending on the fuel type. Thus, the carbon dioxide free operation of the nuclear power plant greatly helps Hungary in saving the climate conditions and in fulfilment of the Kyoto Protocol. The carbon dioxide saving is comparable to the absorption capacity of all Hungarian forests.
- The radioactive discharges of Paks Nuclear Power Plant are, by several order of magnitude, below the authority limits.
- The largest normal operation impact is the heat load to the Danube but, according to the results of the Environmental Impact Study Report, there are significant margin in this area too.



Economical energy source

The electric power generation cost of domestic producers in 2007.





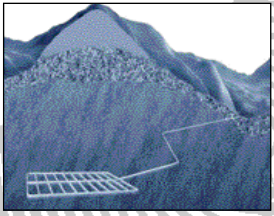
At present, Paks Nuclear Power Plant is the largest and cheapest domestic electricity producer. In 2007, it sold the power to the wholesaler at a price of 9,43 HUF/kWh.

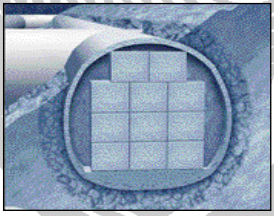
From economical considerations, the service life extension is well substantiated, if the electric power production in the nuclear power plant is competitive even under deregulated market conditions. This was demonstrated by the feasibility study report and is supported by western free market experience as well.

The stability of the price of energy produced by the nuclear power plant is supported by the fact that the price of the fuel represents only a very small ratio in the total production costs, thus the doubling of the price of urane would only cause a 10-15% increase in the cost price.

The price of the imported electric power is lower, at present, than that of the energy generated by the nuclear power plant; however, this difference is expected to decrease in the future. The quantity of cheap energy sources decreases, and Paks Nuclear Power Plant has also committed itself to cost reduction. The planned service life extension also helps achieve this goal. By this means, the price advantage of Paks electric power in the domestic production will be ensured.

What about the radioactive waste?





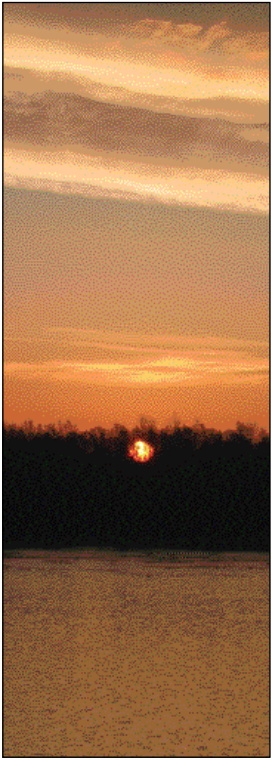
Together with the service life extension, the Parliament issued its basic approval to the construction of the low and middle level radioactive waste repository in Bátaapáti. The opening of the repository is scheduled to 2008. Currently, the project is in finishing phase. The selection of the site complies with all international standards. The scientific, technical, economical and social support is provided to the implementation.

An amount of 180 - 190 m³ solid, and 250 - 280 m³ liquid low and middle level waste is generated annualy by Paks Nuclear Power Plant, which will be completed by further 18500 m3 during the decommissioning of the power plant. The Bátaapáti repository is constructed for the final disposal of this amount of waste, and to ensure the safe storage of these wastes for 600 years, as specified by the design requirements.

The interim storage of the spent fuel assemblies has been safely solved for 50 years at the Interim Spent Fuel Store. During the interim storage period, researching is performed by Hungarian researchers to identify the optimal way of disposal (near-surface or deep geological disposal facility) and to select the host rock. The site of the final disposal facility for the spent nuclear fuel and the high level wastes has not been selected yet, but the exploration work is in progress in the Boda clay stone in Mecsek, that was found acceptable by the previous exploration work.

The financial sources for the interim storage and the final disposal are provided by Paks Nuclear Power Plant by paying an annual amount of HUF 20 - 25 billion in the Central Nuclear Financial Fund, as early as during the service life. In addition, Hungary takes part in international projects launched to assess the possibilities of exploiting the remaining energy production potential of the spent fuel assemblies.

Why the nuclear power plant can not be replaced with renewable energy?



The most frequently delivered statement of green organisations is, that Paks Nuclear Power Plant could be replaced with 'cheaper, cleaner and more flexible' small power plants based on renewable energy sources, thus, in their opinion, the service life extension is unnecessary. Let us see what the figures show!

In 2005 some, 1700 GWh electric power was generated in Hungary from renwable sources (including the hydro plants, that are not supported by the environmentalists), which gives 4.5% of domestic electric energy consumption. This ratio will, in all probability, increase in the future, but will not even be enough for the replacement of the nuclear power plant.

Efforts should be made to achive that the renewable sources are involved in the replacement of obsolete and rather environment polluting fossil fuelled power plants. The replacement of the nuclear power plant is impossible, because Paks operates as a base load plant, while the renewable sources, except the water and biomass ones, can not be used for this purpose due to the variation of the meteorological conditions and the load fluctuations during the different parts of the day. For example, the average laod factor of wind turbines in Germany in 2003 was 16%, and showed a fairly uneven distribution: during some hours period, a production change of even several thousands MW may occur due to weather variations.

The wind and sun power plants are available as allowed by the meteorological conditions rather than in accordance with the actual consumption demands. The increase of their capacity does not allow the reduction of the capacity of conventional, particularly the fossil fuelled power plants. A reserve capacity of 80 - 90% should be kept on standby to ensure, that the power demands can be supplied even under unfavourable weather conditions. As a result of this, the constructions costs per kW, which are not low anyway, would also increase the power production costs, if renewable sources are used.

Hungary is in very favourable position with regard to the geothermal energy sources: the temperature of the ground beneath the country is the double of the world average. However, this may have significance primarily in heating of homes and could be used for electric power generation up to some hundred MW only, with a very low efficiency.

The biomass fireing could play a more significant role in the power generation in Hungary, which, although, is more expensive than the 'nuclear electricity', the construction of such plants is worthy of considering in the middle and long term plans. According to the calculations, this would not even be enough to achieve a capacity increase that could reasonably and economically be capable of replacing the Paks units.

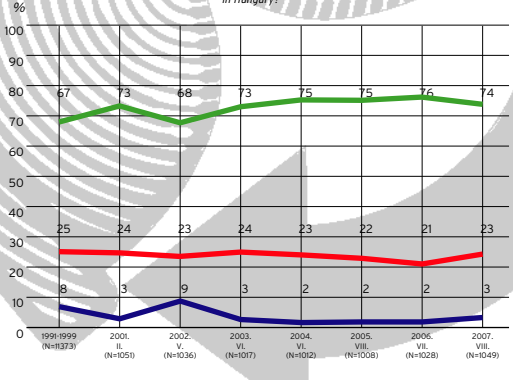
A great role is devolved upon the renewable energy sources in the future, not instead of, but rather **besides** the nuclear.

The service life extension is supported by the public

The confidence and the support of the public are inevitable for the service life extension. According to the results of a representative survey performed on behalf of Paks Nuclear Power Plant Ltd., the acceptance of the nuclear power in Hungary is prominently high, and has been around 70% for years, and did not decreased even after the incident in April 2003 (75% in 2004 and in 2005). The support and confidence of the public is a good basis for the continuation of the nuclear energy production.

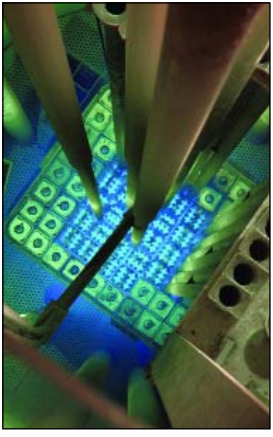
Public acceptance
of the nuclear power plant as resulted
from the public opinion poll.

Question asked during the survey: Do you agree that a nuclear power plant operates in Hungary?

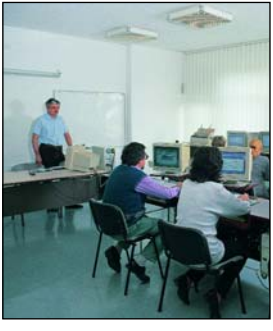


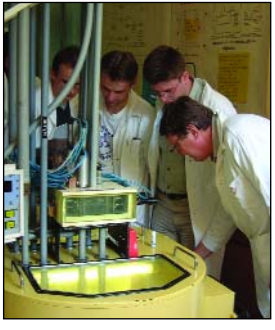
This high acceptance rate is also confirmed by the public opinion poll 'Eurobarometer' performed for the European Union, which resulted in a statement, that Hungary has one of the highest public acceptance for the nuclear energetic. (The energy generated by nuclear power plant is 'fully accepted' or 'rather accepted' by 65% of the pollees. The public acceptance is similarly high in Sweden, Czech Republic and Lithuania, while some 80-90% of the Austrians, Greeks and Cyprians are against the nuclear energy.) It was also indicated by this large scale survey, that the rate of acceptance was higher for gruops of population, which are kept better informed in the field of nuclear power generation.

A critical question: Will sufficient qualified personnel be available?



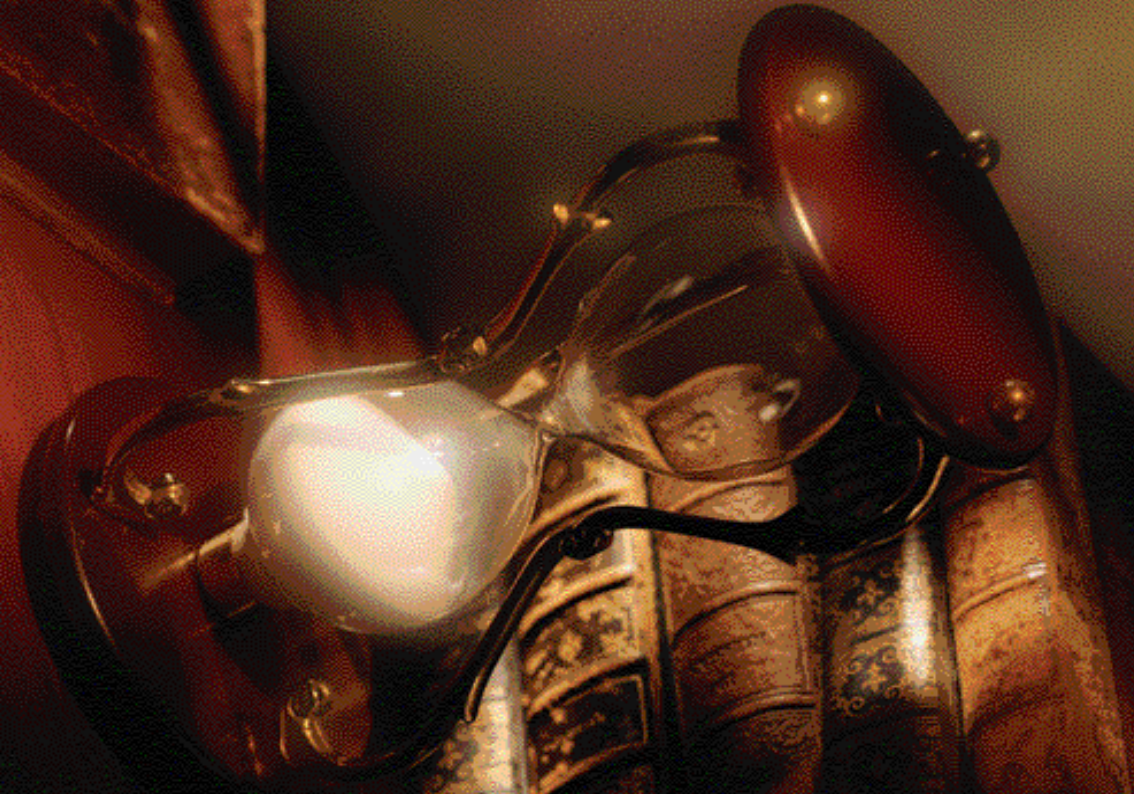
Not only well functioning items of equipment, but highly qualified and motivated professionel team is also required for the safe operation of the nuclear power plant.
It is clearly visible from the age composition of professionals, who constructed, and since then have been operating the power plant, that full generation change is necessary to ensure the safe operation of the Paks units during next 30 years.
It is shown by an age tree analysis, that 400 engineers will retire up to 2015, the replacement of whom will be necessary. Further demand on professional staff will arise in the background industry, at the authorities, the vocational education and in the field of the research work.
The qualification and the experience of the first generation, the so called 'Colt Team' is unique, but this knowledge and experience need to be transferred to the young generation, to enable them to successfully operate the power plant during the extended service life.
The continuous learning, which can be implemented, on one hand, by 'in house' training and, on the other hand, by postgraduate education, is an essential part of the professionel development, for the staff of the power plant.
One of the own training/education facilities of the nuclear power plant, the Maintenance Training Centre, is worthy of mentioning, where professionals are trained and instructed, uniquely even at international levels, for the operation and the maintenance of the items of equipment under inactive conditions.





On the unit simulator equipment of Paks Nuclear Power Plant, the reactor operational staff (eg. reactor operators, unit supervisors) can practice the control operations with the use of an exact copy of the Control Room equipment. Here can also be practised the needed operations of the control room staff, which are very rarely or perhaps never occuring situations during the normal regime. The planned design modifications can also be tested with the use of this simulator equipment, since the simulator equipment itself should also be subjected to modifications to reflect the actual design configuration of equipment.

Another important place for the training of nuclear professionals is the training reactor at the Budapest University of Technology and Economics, where young people can acquire the most important and up-to-date knowledge, from the basic principles to the practical use of experimental and measuring tools.



Imprints:

Issued by Paks Nuclear Power Plant Ltd

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Graphics and typography: Bálint Vincze

Printed by Páskum Printery, Szekszárd

2008