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Nuclear energy in Hungary

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Abstract

Options for the development of electric power generation industry in Hungary are considered. The Paks Nuclear Power Plant Ltd. is a stable element of the energy system of the country. Its significance in power supply is demonstrated and preparatory works for new nuclear projects are presented. The feasibility of construction of a new plant is outlined. Basic aspects of preparatory work and its results are presented in the paper.

Keywords: energy mix, diversification of energy sources, Paks NPP, operation safety, extension of capacities, preparation for a new project

Introduction

Development of Hungarian economy during the past two decades was accompanied with a growing consumption of electric energy: in 2008 about 40 billion kWh gross was generated, nevertheless per capita use remained low i.e. about 3,300 kWh/a. The demand probably will continue to rise modestly even in case of low economic growth scenario. Energy supply of Hungary is import-dependent therefore the economy is highly sensitive to security of supply and market volatility. More than 70% of total primary energy demand is covered by import. The share of import may reach the level of ca 90% within ten years if the recent tendencies are to dominate in the future. There is a high share of natural gas within energy mix and import from a single source is overwhelming. The disturbances in the gas supply coming from Russia via Ukraine became a regular event occurring practically every winter.

In the energy policy approved in 2008 the Hungarian Parliament recognised the priorities of sustainable development and environmental and climate protection, while the security of supply and economic aspects have also been emphasised. These goals might be achieved by increasing the share of renewables and low-emission technologies in the energy system, improving the efficiency of end-use and energy saving, diversification of energy sources, gas supply lines, and also by the diversification of import markets.

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The electric power generation industry of Hungary is being diversified considering the technologies. Gas, nuclear and coal are to remain the main sources but the share of renewable technologies is bound to grow. Nuclear power plant at Paks has an important contribution to secure cheap and clean energy supply of Hungary.

The power generating system needs further development since a large portion of the existing capacities is obsolete. The average age of plants is over twenty years, and two thirds of them are older than 20 years. After the recent temporary drop in power consumption a moderate economic growth is expected and predicted in the long run with an annual increase of electric energy consumption between 0.5 to 1.5%. The growing demand shall be covered in line with energy policy aimed at the operation of low-emission capacities. While considering the options for the development of power industry, nuclear power should be taken into account: both the existing nuclear power plant at Paks as well as the construction of a new plant *(Photos 1–2).*

Basic features of the Paks NPP

Paks NPP with four Soviet-designed WWER-440/V213 type power generation units was constructed between 1974 and 1987. It was the largest industrial project of Hungary in the 20th century.

The WWER-440/V213 type reactors are pressurised, light-water moderated light-water cooled reactors representing the second generation of WWERs. Basic technical data of the plant are shown in *Table 1*.

Table 1. Basic technical data of the Paks NPP

Unit	Connected to the grid	Net capacity at the start of operation, MW	Net capacity before recent power uprate, MW	Capacity, MW (2008)	
				Net	Gross
1	1982/12/28	410	437	470	500
2	1984/09/06	425	441	473	500
3	1986/09/28	427	433	443	470
4	1987/08/16	425	444	473	500

The reactors are equipped with a six cooling loops, with one horizontal steam generator per loop, main isolating valves on the cold and hot loop legs, and one main circulation pump. The WWER-440/V213 has threefold redundant safety system, and bubbler condenser-type pressure suppression containment, capable of maintaining containment function even after large break loss-of-coolant accident. The WWER-440/V213 has essentially inherent safety features: robust design, low heat flux in the core, large water inventory in the primary system and a large containment volume. At Paks NPP, the

Photo 1. Bird's-eye views of Paks NPP

Photo 2. The site for the two new blocks (above) and visual plan of the NPP after extension (below)

safety deficiencies known for this reactor type had been addressed by comprehensive safety upgrading programme, which resulted in decreasing of the annual frequency of core damage by an order of magnitude up to the level of 10^{-5}/a. The overall safety of Paks NPP is comparable with the PWR plants of the same vintage.

The operation of the plant is very smooth; there were no reactor scrams in 2008. The average number of reactor scrams was less than 0.4/a over the past decade. During the operational history of the plant a serious incident occurred in 2003 at the Unit 2 during the cleaning of fuel assemblies in the service shaft, which did not affect the safety of basic technology of the Unit 2 and there was no harmful effect on the environment. Unit 2 was returned to normal operation in 2004.

The value of Paks NPP in the energy system of Hungary

The importance of nuclear power generation for Hungary and particularly the value of Paks NPP can be assessed in economic and environmental dimensions and also from the point of view of security of power supply. Other positive impacts of the plant operation, e.g. the social ones are obvious; therefore these will not be considered here. The analysis will demonstrate that, Paks NPP is an unavoidable element of the Hungarian electricity system.

Economic dimension

In 2008, the four reactors of the NPP had a gross electricity output of 14,814 GWh, providing a 37.2% share of the national total. The plant is a reliable producer; the cumulative load factor of the plant is 84.39% (details of operational performance see in *Table 2*).

Table 2. Paks NPP operational performance (2008)

Unit	Energy (GWh)	Energy Availability Factor (%)		Load Factor (%)		Annual Time On Line (hours)	Operational Factor (%)
		Annual	Cumulative	Annual	Cumulative		
1	3,670.291	88.9	85.52	89.15	86.33	7,824	89.32
2	2,993.793	76.18	78.87	76.7	79.52	6,669	76.13
3	3,530.425	90.6	86.5	90.97	87.36	7,962	90.89
4	3,671.437	88.36	87.59	88.61	89.13	7,854	89.66

Electricity generated by the NPP is the cheapest in Hungary. During the history of plant operation the rate of increasing of unit generation cost was always below the average price index. Being the cheapest and largest producer on the market, Paks NPP has an essential impact upon the average power production price in Hungary.

Since the contribution of the fuel price to the total generation cost is very low, doubling of the fuel price will cause less than 20% increase of production cost in the case of Paks NPP. Fuel stockpiling helps to overcome the price fluctuations on the fuel market. Consequently, the costs are stable and predictable in case of Paks NPP.

Environmental dimension

In comparison with other electrical power plants, Paks NPP is the least environmentally polluting; it has practically no carbon dioxide or other greenhouse gas emissions. Any replacement technology will cause essentially larger life-cycle emission, e.g. the same generation capacity as the NPP burning natural gas will emit more than 5 million tons of CO_2 yearly.

The only environmental load is caused by the heated-up cooling water let-out back to the river Danube. The operational experience shows that the obligatory temperature limits can be ensured by some measures also in case of "low-flow rate high water temperature" conditions in the Danube. The impact of the heat released to the biosphere is monitored and regularly assessed; after more than 20 years of operation no adverse effects have been identified.

Operation of Paks NPP cause negligible environmental effect with respect of radioactive releases, too. Paks NPP in 2008 used 0.25% of the release limits with a share of 0.164 % of liquid releases, while of 0.081% of airborne ones. Concerning the liquid releases, for both the corrosion and fission products, and tritium the data of Paks NPP are lower than the worldwide median. According to the calculations the extra dose relevant to a critical group of the public due to plant releases was 58 nSv in 2008. This dose can be received by humans from the natural background radiation within approximately 10 minutes.

The wastes generated during the operation of the plant, including the radioactive wastes, are collected, classified and contained. There are necessary facilities for the processing and storage of solid and liquid radioactive wastes at the plant. The spent fuel, after five years cooling in the spent fuel pool, is stored minimum 50 years in the intermediate storage facility next to the plant.

Results of the environmental monitoring programme analysed in the environmental impact study for prolonged operation of Paks NPP show no adverse effect on the environment after 20 years of operation.

Security of supply

Nuclear power generation provides the necessary diversity of import of primary energy sources.

Obligatory stockpiling of nuclear fuel for two years is an essential element in ensuring the stability of power generation in case of short-term inconveniences in the import. Generally, uranium mining and the nuclear fuel manufacturing industry are located in geopolitically stable regions of the world. Nuclear fuel for Paks NPP is provided by Russia; however, in case of necessity an alternative fuel supply is manageable and might be ensured.

Future of nuclear power generation in Hungary

Necessity of the development of generating capacities

The policy of the European Union, along with the national aspects and the trends and interests of the industry and of the investors call for the development of power generating industry.

The European Council plan has defined a 20% binding target for reducing greenhouse gas (GHG) emissions (compared with 1990 levels), a goal of 20% share of renewables in the electricity mix, a 20% increase in energy efficiency by the year of 2020[2]. With these targets the EU aspires to become the world's most energy effective region and the EU will retain its position as global leader in renewable energy. There is also a strong commitment of EU to reduce emissions by at least 35% until 2030 and by over 50% up to 2050. At the centre of the new energy package stands the target to reduce CO_2 emissions by 20% until 2020, compared with the levels of 1990, without affecting workplaces or competitiveness.

Considering the differentiated targets for EU member states, Hungary seems to be able to increase the share of renewables up to 13% by 2020 compared with the 4.3% in 2005. Higher target will demand unbalanced social effort and cannot be achieved without essential loss of competitiveness of Hungarian economy. The positive effect of the development of renewable power generating sector on the income sources and on the creation of new jobs seems to be very moderate under Hungarian conditions. Consequently for achieving the GHG reduction targets the energy mix has to be developed under strict control of the GHG emissions.

[2] Official Journal of the European Union 5.6.2009, DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

Behaviour of the power industry in this situation is rather controversial. The industry is oriented to low risk incentives, preparing new project on import gas. Only one ongoing project exists in Hungary utilising domestic lignite. It seems the management of the industry neglects the adverse effects of increasing dependence of imported gas. Development of renewable capacities is strongly correlated by the availability and amount of state subsidies provided in different forms for the investors and producers. An intensive development of renewable capacities is limited by their low technical maturity, economical constrains and grid stability aspects, and also by natural conditions in Hungary.

Assuming that the projects for increasing of energy saving and efficiency of end-use and the new renewable capacities will cover the net increase of demand in Hungary in the forthcoming two decades, assuming further that the growth rate of the economy will be moderate, 3,000–4,000 MW new power generation capacity will be needed between 2015 and 2025 for the replacement of the old plants to be closed down. In case of higher growth rate Hungary will need 6,000–6,500 MW new capacities by 2025. The need in new capacity will be larger by 2,000 MW if Paks NPP is shut down between 2012 and 2017.

Summarizing the above facts and circumstances one can conclude that the energy mix in Hungary has to be developed in line with low-emission, secure supply and stable for long-term pricing which means that the investments into power generating capacities should focus on low-emission technologies and diverse import sources.

Considering the presented situation keeping the share of nuclear power generation in the Hungarian energy mix or even increasing it seems to be a very reasonable option for capacity development. Therefore the Paks NPP has to be operated as long as safe and economically viable and a new plant has to be constructed.

Power up-rate and extension of operational time of Paks NPP

For increasing the competitiveness the capacity of the plant has been extended in two phases: enhancing the thermal efficiency of the secondary circuit, and recently increasing the reactor thermal power (see *Table 1*). By now, Paks NPP has a gross capacity of 1,970 MW. The recently implemented 8% increase of reactor thermal power has been achieved via utilisation of modernised fuel assemblies, improvements in core control and some minor modifications, while the safety margins of the reactor system are ensured. The payback of power up-rate is less than four years. The power up-rate results in emission-less 150 MW capacities producing yearly approximately 1,100 GWh energy.

Licensed term of operation of Paks NPP units is 30 years, which expires between 2012 and 2017. An extension of operational lifetime is feasible due to robustness of design and good condition of the plant. Verification of safety for an additional twenty years of operation is in progress. Solid regulatory system exists for the control and approval of licence renewal. Business assessment shows that the extension of operational lifetime is a reasonable decision.

One of the options for establishing a secure, clean and cheap energy supply is the prolongation of operational lifetime of units at Paks NPP. The design lifetime of units at Paks NPP is 30 years terminating between 2012 and 2017. Starting with a feasibility study in 2000, intensive and systematic engineering work is going on for preparation to prolong the operation lifetime by an additional 20 years. The first step of the licensing procedure was the environmental impact study and environmental licensing of the extended operation of the plant in 2006. The programme for long-term operation was submitted for the regulatory approval in 2008. The programme consists of results of analyses and reviews made for safety verification of 50 years of operation as well as the definition of further measures. The formal licence renewal application for the Unit 1 shall be completed by the end of 2011 and subsequently for the other units.

Prolongation of operation of Paks NPP is feasible both from safety and technical viewpoints; it is reasonable out of business interests and would contribute to an essential reduction in GHG emission of power industry of Hungary. Other conditions as intermediate storage of spent fuel and final repository of radioactive waste are manageable. Renewal of the operational licence of the Paks NPP is a strategic decision, which has also taken into account the social aspects, public and political acceptance. The public acceptance of Paks NPP has been over 70% for many years continuously. In November 2005 Hungary's Parliament passed a resolution with an overwhelming majority to support the lifetime extension of the 1 through 4 blocs of Paks NPP by 20 years.

Preparation of the decision on a new nuclear power plant

Increasing the share of nuclear power generation in the energy mix of Hungary is the way for compensation of volatility of energy import, which was affecting more or less the Hungarian energy policy during the past three decades. The extension of capacity of Paks NPP has practically been on the agenda continuously. (The site at Paks was selected with the intent to build 6,000 MW total capacity.) In the early 1980s significant efforts were made for extension of capacity of Paks NPP by WWER-440/213 type units. During the same decade several other offers were made concerning the construction of a new power plant, e.g. a French proposal for construction of several 1,000 MW units. In

the second half of the eighties preparations were made for the building of two WWER-1000 units. The site north of the existing plant has been prepared for the new units and on-site transportation infrastructure was built. Paks NPP founded a high school for education of future plant employees. Hungarian government cancelled the project in 1988. In 1997 Paks NPP Ltd made an attempt to take part at the MVM tender for new capacities. Feasibility study for constructing two ca 600 MW units has been made considering three technical and business options: a CANDU-6 reactor unit by AECL, an AP-600 unit by Westinghouse (which got its design certificate at that time) and the WWER-640 type of Russian Atomstroyexport which was under development that time. The time consuming preparation of nuclear options did not fit into timeframe of the tender therefore the nuclear proposals failed[3].

In line with international trends, acknowledging the role of Paks NPP in the energy supply of the country and recognising the need of emission-free technologies, the energy policy approved by the Hungarian Parliament in 2008 required preparation of the political or "in principle" decision of the Parliament regarding construction of new nuclear capacities[4]. The "in principle" decision of the Parliament is a mandatory step in preparation of nuclear projects in Hungary required by paragraph 7 (2) of the Act CXVI on Nuclear Energy (1996).

Hungarian Power Companies Ltd[5] (MVM) and Paks NPP Ltd launched a project in preparation for the political decision of the Parliament. Considering the possibility of further development of nuclear power generating capacity in Hungary the following main topics have been studied:

1. Demand-capacity forecast,
2. Analysis of electrical grid,
3. Economical issues and financing,
4. Public acceptance, communication,
5. Technical aspects of feasibility and environment issues,
6. Regulatory framework and licensing.

Engineering companies, research institutes, consultants in financing as well as consultants in public relation and communications have contributed to the project. Preparatory works of the new project required about 300 engineer-year efforts.

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[3] As a matter of fact there were not announced any tender winners in the category of over 200 MW.

[4] The energy policy also emphasises the importance of continuation of the works on solving the radioactive waste and spent fuel depository issues.

[5] Hungarian Power Companies Ltd. (MVM) and companies incorporated constitute Hungary's national power group: MVM Group. Paks Nuclear Power Plant Ltd. is part of the Group. The latter is one of the most important actors on the domestic electricity market.

For backing the proposal for governmental and parliamentary decision the following information sources have been used:

– International Atomic Energy Agency documents regarding preparation of new projects,

– Energy-outlooks of International Energy Agency, OECD Nuclear Energy Agency and U.S. DoE Energy Information Administration,

– European Utility Requirement Document,

– Public information on preparatory works of new projects in different countries, e.g. U.S., Finland, Slovakia, Czech Republic, Romania, Bulgaria and UK.

Arguments of other interest groups within the power industry and also the opinion of non-governmental organisations, including anti-nuclear groups have also been studied.

Three main documents have been compiled on the basis of studies on the topics listed above: a preliminary feasibility study, an environmental impact study and a study on radioactive waste and spent fuel issues.

The need of further power generating capacity development has been justified in the feasibility study. The feasibility of construction of a new nuclear power plant has been demonstrated. Considerations have been made regarding unit capacity with respect to:

– the demand,

– the possibility of integration of the new plant into Hungarian grid system,

– the solutions needed for the integration into Hungarian grid in case of different site options.

Considering the forecast of energy demand and development perspectives of power generation industry in Hungary, and also the targets of the energy policy, building of new nuclear capacity seems to be reasonable and feasible.

Analyses show that a new nuclear power plant with a capacity of two times 1,000 to 1,600 MW might be integrated into Hungarian energy system between 2020 and 2030. However, the system management is more difficult in case of larger unit capacity using the Hungarian system reserves only. Further regional technical and market integration may create better condition for selection of larger capacity units. Also the load-follow capability of the plant is of large importance. Connection to the grid will require significantly less effort and grid development in case of Paks site compared to any other potential sites. (These potential sites are in North-East of Hungary.)

Selection of the Paks site has other advantages too:

– This is already a nuclear site owned by Paks NPP Ltd.

– There is a prepared construction area for the units.

– Well-developed infrastructure and human resources are in place.

– Communities in the region accept and support the new project.

There are several reactor types available at the market with capacities between 1,000 and 1,600 MWe and with acceptable technical and safety features (e.g. AP-1000, EPR, Russian 1,000 MW WWER designs). Obviously the safety should not be an ultimate element of design selection; all possible types of Generation III shall comply with national and international regulations and best international practice. The European Utility Requirement Document (see http://www.europeanutilityrequirements.org) specifies the set of technical and safety requirements. Preference should be given to pressurized water type reactors, since the Hungarian operational experience and knowledge base could be best utilised in this case. However the possibilities for an in-depth analysis of technical options was limited; the Act on Nuclear Energy limits the extent of the activities in pre-parliamentary phase of preparation, e.g. binding communications with potential investors and suppliers shall be avoided prior to the political decision of the Parliament.

Comparing to other options the new nuclear project requires the largest capital investment per unit capacity (EUR/kW) and more than ten years for preparation, licensing and construction, the production cost of nuclear power plant is competitive. The basic options for the financing have been studied and the applicability for Hungarian conditions of different financing concepts of running nuclear projects have been analysed. Final mechanism of financing will be developed in the coming phase of preparation of the project. The project should be implemented with maximum responsibility of suppliers, however a turnkey type implementation of the project is questionable. The involvement of Hungarian subcontractors has an important role.

Licensing of the new plant will be a great challenge for the authorities as well as for the industry. A well-developed legal system exists in Hungary for the licensing of a new nuclear power plant, which is based on the acts for environmental protection, on use of water resources, on nuclear energy and on electrical energy. There is a distributed regulatory system in Hungary, i.e. environmental, nuclear etc. aspects of licensing are the competence of different authorities. Some streamlining of the licensing procedure will be desirable especially in interactions between the authorities. There are scientific and technical institutions to support both the regulators and the industry in licensing processes.

The preliminary environmental impact study has been performed using the conservative bounding parameter values for releases and effluents of the plant and the worst-case probabilities of anomalous events, enveloping the known parameters of the types considered and for the largest possible capacity. The best argument for the acceptability of the new project has been gained from the environmental monitoring data collected during 25 years of operation of the plant and the comprehensive environmental impact study

performed for the renewal of environmental licensing. Although the site is located by the river Danube and the units 1–4 of Paks NPP are freshwater cooled, the new plant should be erected with cooling towers to eliminate the load on the aquatic biota and freshwater resources. The preliminary environmental impact study demonstrated the feasibility and acceptability of the new plant at Paks site. In the energy policy approved by the Hungarian Parliament in 2008 the obligation of the state has been underlined defining the necessary governmental actions for the solution of disposal of radioactive wastes and spent fuel.

In a 30 March 2009 vote, the Hungarian Parliament has given overwhelming preliminary support to a government proposal to begin the detailed preparation for the construction of new nuclear generating capacity at the Paks plant.

Further actions for preparation of the new project

After the in-principle approval of the Parliament the second phase of the project preparation has been started. A new MVM preparatory project was launched in July 2009. In this phase the main tasks are the following:

– Development of the proposal for an ownership and financing structure, which provides the adequate financial resources for the project. Mapping of feasible investment and procurement strategies, analyses of their effect on financing,

– Development of tender document and preparation of the bidding process,

– Solution of technical issues, such as the development of the concept for cooling system of the plant,

– Preparation of the site and environmental licensing, also the licensing for use of water resources, preparation of the licensing process of the construction,

– Implementation of an effective communication programme,

– Development of the nuclear cluster around the new project with its social and economic issues duly taken into account.

Summary

Prolongation of operation of the existing nuclear power plant at Paks and construction of a new plant will improve the security of supply and produce essential share of electricity with practically zero emissions and negligible environmental effects.

The new nuclear plant will really contribute to the sustainable development and reduce the vulnerability of economy due its dependence on import. The new project is to stimulate the development of scientific, engineering and construction capacities in Hungary, and to create thousands of jobs for more than ten years.

The experience of nuclear operators, knowledge of engineering and scientific support organisations, and the legal system should serve for the preparation, construction and licensing of plant. The Paks site is well studied, possesses the necessary infrastructure and provides opportunities to use the synergies offered by the site. Hungarian population supports the prolongation of operation of Paks NPP and the extension of the nuclear capacities.

NOW AVAILABLE!

Hungary in Maps

Edited by
Kocsis, Károly and **Schweitzer, Ferenc**

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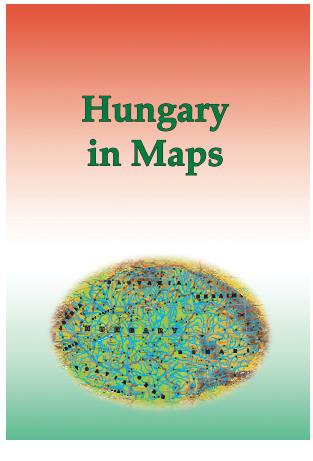
Budapest, 2009

'Hungary in Maps' is the latest volume in a series of atlases published by the Geographical Research Institute of the Hungarian Academy of Sciences. A unique publication, it combines the best features of the books and atlases that have been published in Hungary during the last decades. This work provides a clear, masterly and comprehensive overview of present-day Hungary by a distinguished team of contributors, presenting the results of research in the fields of geography, demography, economics, history, geophysics, geology, hydrology, meteorology, pedology and other earth sciences. The 172 lavish, full-colour maps and diagrams, along with 52 tables are complemented by clear, authoritative explanatory notes, revealing a fresh perspective on the anatomy of modern day Hungary. Although the emphasis is largely placed on contemporary Hungary, important sections are devoted to the historical development of the natural and human environment as well.
In its concentration and focus, this atlas was intended to act as Hungary's 'business card', as the country's résumé, to serve as an information resource for the sophisticated general reader and to inform the international scientific community about the foremost challenges facing Hungary today, both in a European context and on a global scale. Examples of such intriguing topics are: stability and change in the ethnic and state territory, natural hazards, earthquakes, urgent flood control and water management tasks, land degradation, the state of nature conservation, international environmental conflicts, the general population decline, ageing, the increase in unemployment, the Roma population at home and the situation of Hungarian minorities abroad, new trends in urban development, controversial economic and social consequences as a result of the transition to a market economy, privatisation, the massive influx of foreign direct investment, perspectives on the exploitation of mineral resources, problems in the energy supply and electricity generation, increasing spatial concentration focused on Budapest in the field of services (e.g. in banking, retail, transport and telecommunications networks), and finally the shaping of an internationally competitive tourism industry, thus making Hungary more attractive to visit.
This project serves as a preliminary study for the new, 3rd edition of the National Atlas of Hungary, that is to be co-ordinated by the Geographical Research Institute of the Hungarian Academy of Sciences.



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