THE PERSPECTIVES OF NUCLEAR OPTION FOR CROATIA

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ABSTRACT

In order to satisfy the expected level of electricity consumption in Croatia it will be necessary, as a minimum, until the year 2020 to install about 2000 MW in new power plants. Gas and coal fired plants presently are main competitors to nuclear power plants. In near future it my be different doe to expected problems with gas availability and cost increase and also in adverse environmental impact (particularly due to CO_2 emissions) of coal fired plants. Nuclear power plants have advantage not only in economics of produced energy but also in impact to the environment. Preservation of knowledge obtained during construction of NPP Krško is also an important reason to maintain nuclear option. Pre construction and construction period for new plants (particularly for coal fired and nuclear plants) could be long so that timely start of preparatory activities is indispensable to meet the required schedule.

1 INTRODUCTION

Croatia is a country with relatively small electricity grid and with very limited energy resources. Activities to use nuclear energy for electricity generation started in Croatia long time ago, in late 60-ties, when jointly with Slovenia was completed a feasibility study justifying construction of a nuclear power plant with power output of about 600 MW sited near town Krško in Slovenia, close to Croatian border. This project (realized on the basis of equal ownership of both sides) was a success. Because of increased electricity consumption, potential cost increase and availability problems with natural gas (as only competitive conventional energy resource to nuclear energy) revival of use of nuclear power in Croatia is a realistic option.

2 ELECTRICAL ENERGY GENERATION AND CONSUMPTION IN CROATIA

The electricity consumption in Croatia is presently approximately 15 TWh. Installed capacity in hydropower plants is about 1900 MW and in thermal plants about 2040 MW, including 50% of NPP Krško. Possible electricity production in hydro plants in average humid year is about 6 TWh. Thermal plants are oil, coal and gas fired units. The electrical system is interconnected with neighboring countries to allow exchange of power and enhance system stability.

The official forecast for electrical consumption increase in Croatia is very modest. It foresees the consumption in the year 2020 to reach about 21 TWh (average increase rate in period 2000-2020 is only about 1,7 %).

It has to be emphasized that the rate of increase of electrical consumption in any country is correlated with the rate of increase of GDP. The ratio between these two rates (known as elasticity factor) is in most countries larger or equal to one. This fact can be easily observed by Figures 1 and 2 [1]. This means that the officially projected rate of electricity consumption increase in Croatia is not compatible with officially expected rate of GDP increase in the same period of 4-5 %.

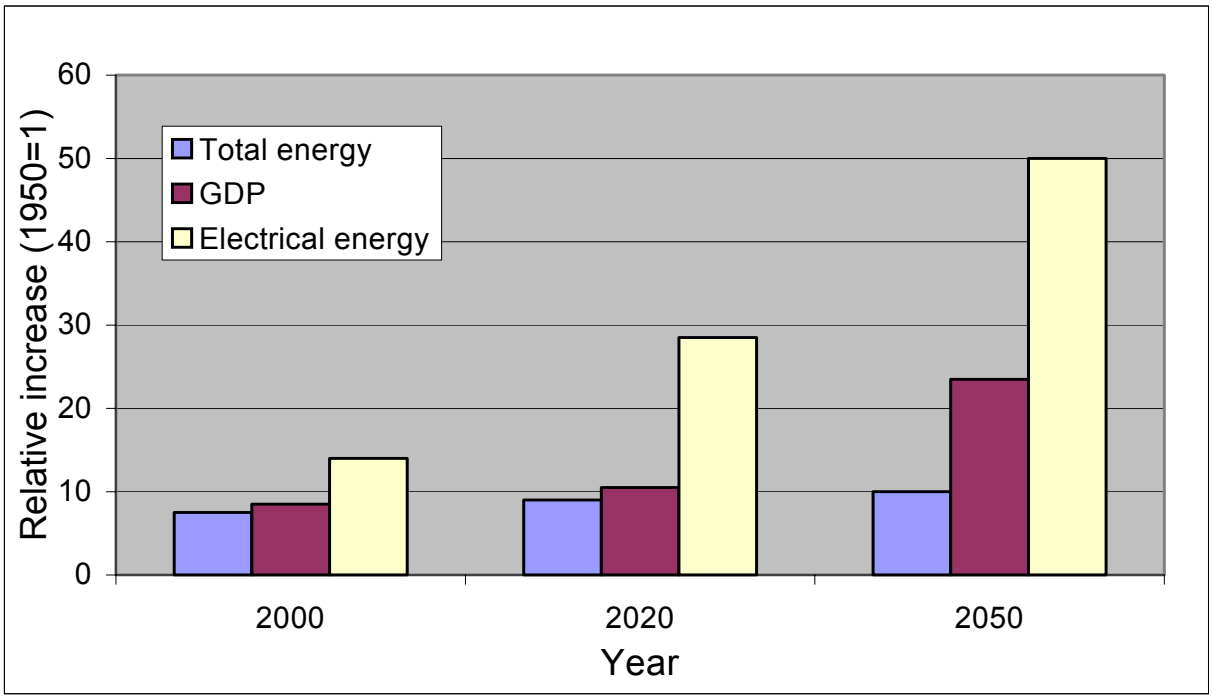

Figure 1 Expected relative increase of GDP, and Consumption of Total Energy and Electrical Energy in the World (1950=1)

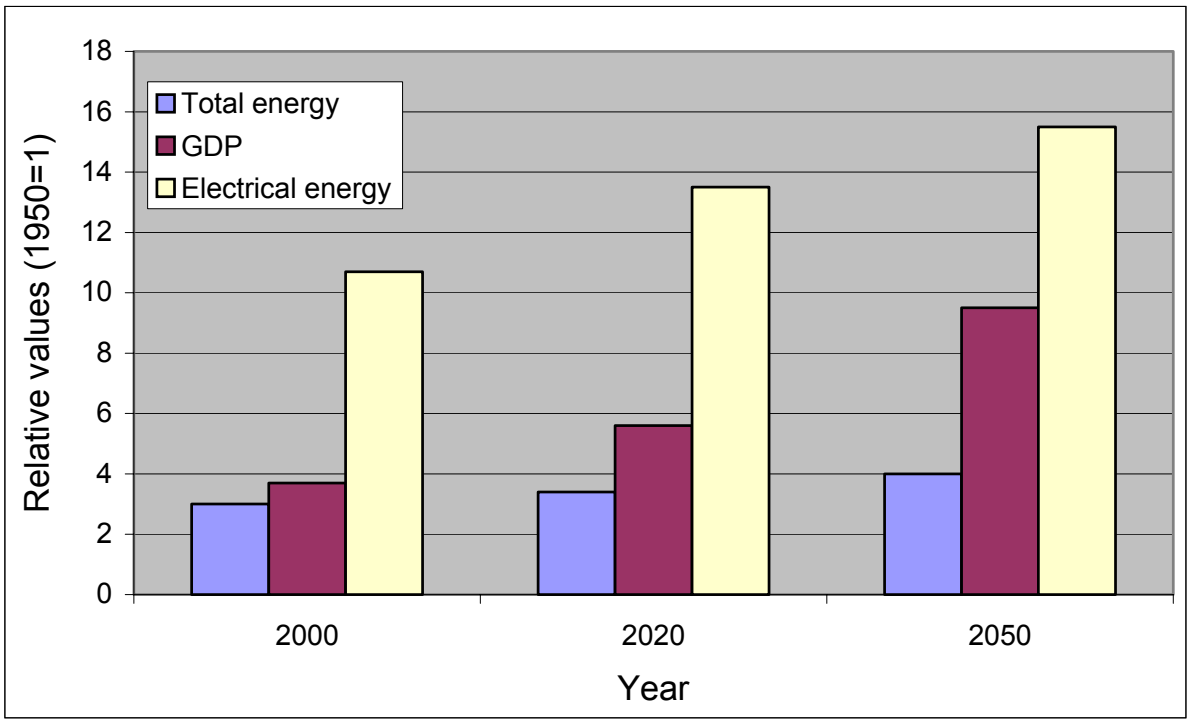

Figure 2 Expected relative increase of GDP and consumption of total energy and electrical energy in US (1950=1)

The figures clearly show that for world in average as well for US that the rate of increase of consumption of electrical energy is larger and the rate increase of consumption of total energy is smaller than the rate of increase of GDP. In industrialized countries elasticity factor (or the ratio of relative values of GDP and electrical energy consumption) is smaller. Elasticity factors for a large number of countries with various status of development for a period of 30 years have been examined [6] and the above given results confirmed. The elasticity factor is larger in the countries in which larger portion of electrical energy consumption is not linked with production of goods and services.

In the period after the year 2010 about totally 1200 MW of outdated oil fired and some older coal fired plants in Croatia will end their life times and will have to be replaced. This results with the necessity, even in the frame of planned very modest rate of increase of electrical energy consumption, to construct by the year 2020 new power plants with total output 2000-2200 MW. This correspond to the power of all presently installed thermal power plants in Croatia (If average increase of electricity consumption in given period is assumed about 4%, to correlate with expected increase of GDP, the necessary installed power would be 1000 MW larger). Lack of possibility to construct additional larger hydroelectric plants imply that total production of electrical energy in thermal power and nuclear plants around the year 2020 would, in year with average humidity, reach 15 TWh. A certain amount of electrical energy production is possible by using new renewable resources of energy. It is expected that this amount would not be essential in solving the increased electrical energy demand.

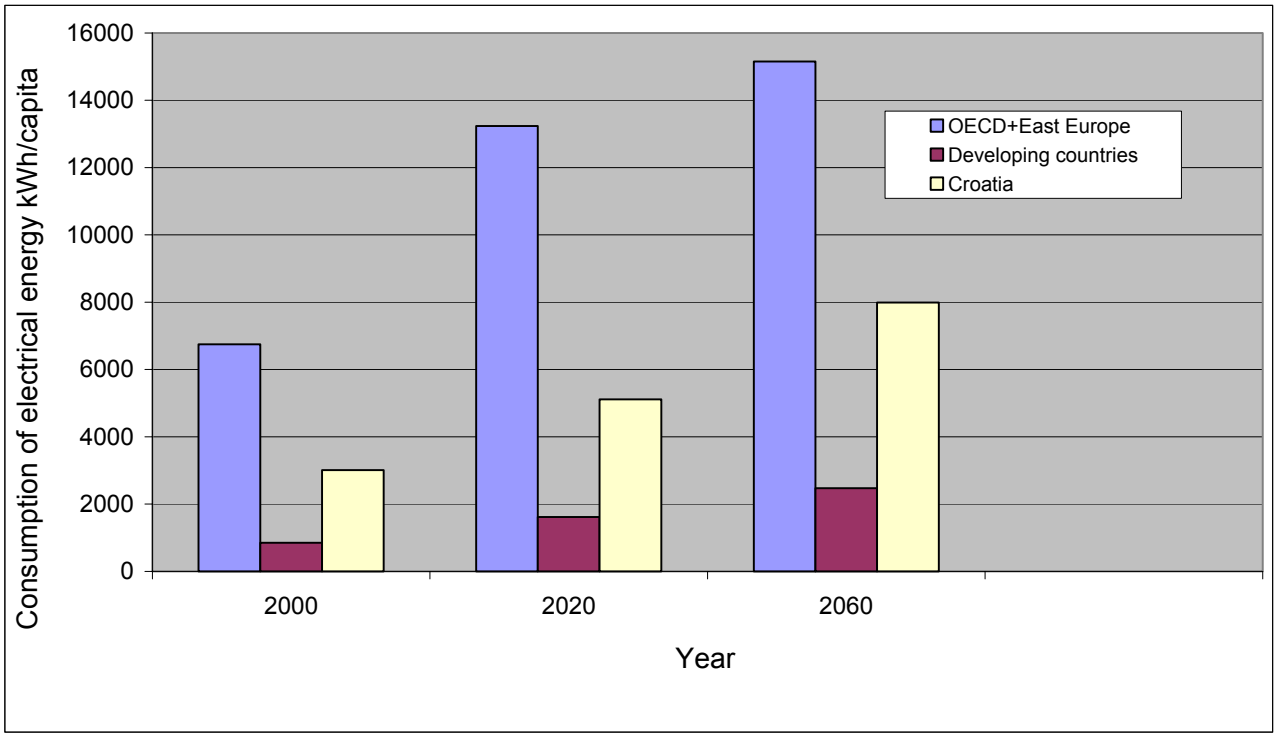

Figure 3. Electrical energy consumption per capita

Electrical energy consumption per capita in Croatia would by given forecast reach in the year 2020 about 5000 kWh/year which is 2-3 times lower than average in industrialized countries. It is larger almost by the same ratio to average consumption in developing countries (where the consumption is very low indeed and includes the fact that presently about 2 billion people have not access to electrical energy)

3 AVAILABILITY OF ENERGY SOURCES FOR ELECTRICITY GENERATION

The potentially available energy resources to meet bulk of expected energy demand in any country are fossil (gas and coal) and nuclear fuel. The corresponding power plants are

-Natural gas fired combined cycle plants

-Classical or advanced coal fired plants

-Nuclear power plants

In order to justify the value of nuclear option for Croatia it could be of interest to comment the value of alternative energy resources for electricity generation. The main areas for energy resources competitiveness are security of energy supply, long term stability in fuel availability and in its price and environmental impact.

4 ADVANTAGES AND DISADVANTAGES OF POWER TECHNOLOGIES COMPETITIVE TO NUCLEAR ENERGY

4.1 Natural gas

Croatia owns some natural gas fields. These fields are in decline so that increased future demand will have to be met with gas import.

Natural gas is presently main competitor to nuclear power. The reasons are in low investment costs of NGCC plants, modest fuel costs, high efficiency, short construction period and relatively favorable public acceptance. This causes low investor risk in short period.

However in longer period (after year 2020) situation may radically change. It has to be noted that the period of interest for economic operation of any plant is the period of about 30 years following its construction. For such period (considering plants completed around the year 2010) according to numerous studies in IEA and other organizations timely gas availability in European market and its price are under question. The cause of concern is in very high difference between gas demand and production in Europe. This difference in the year 2030 is expected to increase to 300-500 billions of m^3/year. Main gas suppliers of gas to Europe are Russia and potentially Middle East countries. These countries have about 70% of world natural gas deposits. Main routes for future and present gas supply to Europe are given in figure 4.

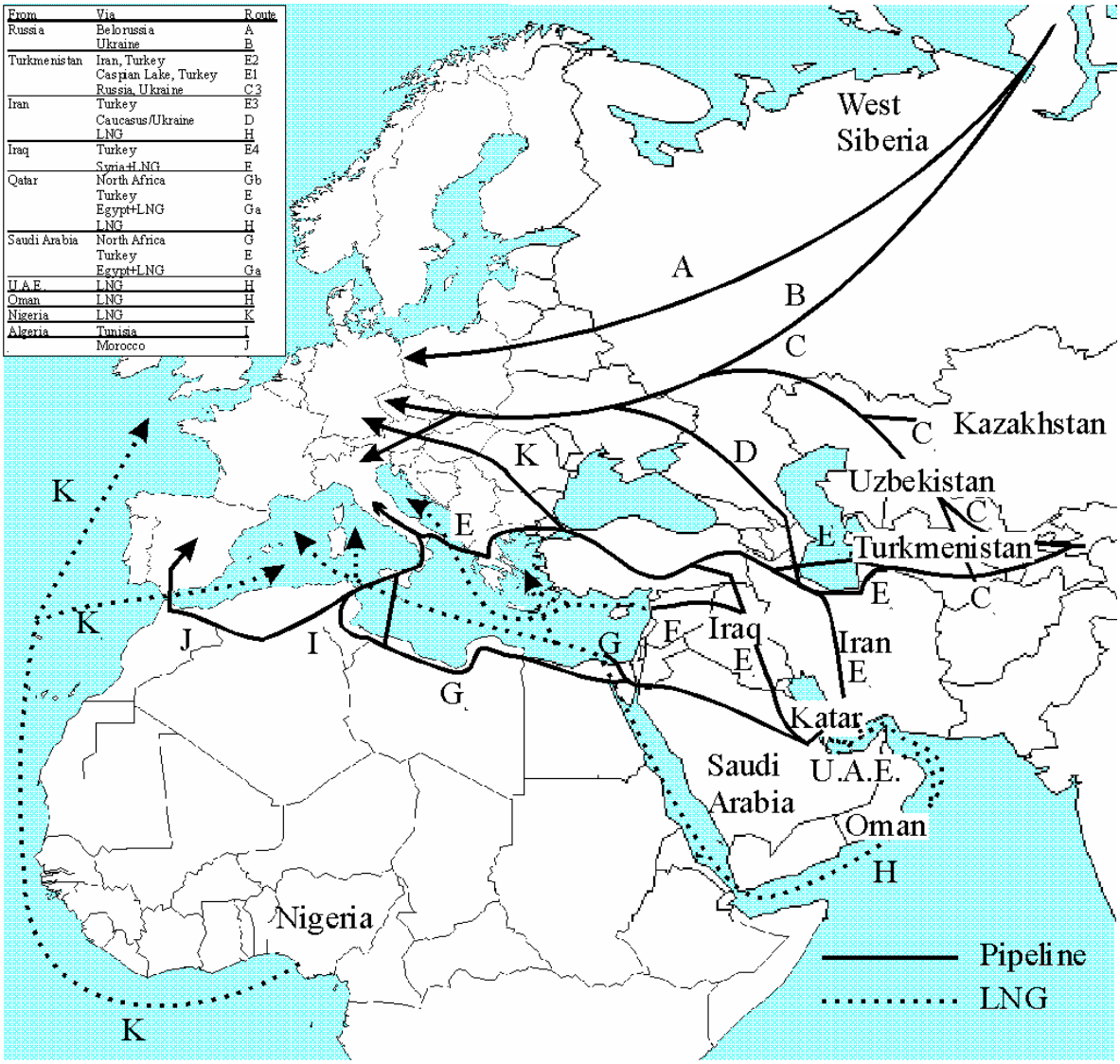

Figure 4. Main routes for natural gas supply to Europe

The problem of energy security is less in availability of gas resources and more in gas transport to the customers through gas lines long 4000-6000 km. According to a recent Exxon forecast [7] it will be indispensable to invest by the year 2020 in gas transport system to Europe 300-350 billion dollars to secure the necessary gas transport capacities. These investments have to be effected timely (due to extended construction period) and with minimum regulation and other interference from the supplier transit and gas importing state authorities.

In addition, investments in gas production fields are also needed. In accordance to a recent OECD analyses about 85% of Gasprom's presently productive fields are in decline and investments of about 2 billions dollars per year are needed to maintain the gas production [4].

It is generally accepted that the above circumstances will cause a substantial increase of gas cost in next decades. This is partially due to basically monopolistic position of future gas suppliers in the market. Present gas cost in 3-4 US$/GJ.

The main routes for gas supply to Croatia are from Russia. Alternative route is the gas line from Algeria through Italy, which also connects North Adriatic gas field owned by Croatian oil company. This route is not very promising because Italy has largest deficit in electrical energy production in Europe and foresees considerably increased gas consumption in future. Additional access to gas supply for Croatia in future could be its import as LNG, but this possibility is still under preliminary consideration.

It could be added that electric utilities are not the only consumers of natural gas. Priority consumers are households and part of industry which cannot switch the fuel.

Situation with gas supply is more difficult in North America than in Europe because of distance of largest gas fields. For this reasons further increase of gas consumption for electricity production in US is not foreseen after the year 2010. This may be the main reason for expected earlier revival of nuclear programs in US than in Europe.

Large European consumers tend to secure gas supply by long term supply contracts leaving small consumers without fixed long term energy programs (such as Croatia) to unstable market conditions.

From the above brief analysis it follows that the natural gas present competitiveness to nuclear power in Croatia and in other countries may diminish or vanish in not distant future.

The above results are confirmed by long term energy consumption forecasts issued by IEA and EPRI in which contribution of gas to world electrical energy generation will diminish after the year 2020 and completely vanish by mid of the century.

4.2 Coal

Use of coal for future electricity generation is regarding question of availability and price far less controversial than use of natural gas. The resources of coal are abundant and evenly distributed in world regions. Its use is restricted practically only to electricity generation. The offer exceeds demand and price is fairly stable (close to 2 $/GJ).The investment in coal fired plants is more than double compared to combined cycle gas fired and its efficiency is lower. Coal price per unit energy is approximately half of gas price. The investor risk relative to coal availability and price is small. In order to reduce local and regional environmental impact of coal fired plants (emissions of SO_2, NO_x and solid particles) new concepts of design for such plants have been developed (Integral gasification with combined cycle -IGCC, Pressurized and atmospheric fluidized bed combustion -FBC).It is probable that in future large part of coal fired plants will be designed according to this concepts.

The main problem related to construction of coal fired plant in Croatia is in public opposition and in violation of commitment to reduce the CO_2 emissions according to Kyoto protocol (CO_2 emissions per produced kilowatt-hour are about 2,5 times larger than in combined cycle gas plants). Besides, external costs for coal fired plants are far larger than for any other power option. Another disadvantage of coal fired plants in Croatia is in the fact that, in order to avoid expensive inland coal transport, they have to be sited in the Adriatic coastal area.

Coal fired plants are not competitive with nuclear plants when economics and environmental impact is considered.

Despite these facts specified need for electrical power in beginning of next decade will have to be met with gas and coal fired plants because of long time needed to prepare construction and construct a nuclear power plant. Additionally, security of electrical energy supply requires diversification of energy sources.

4.3 Renewable energy sources

The presently most used renewable energy source for electricity generation is wind power. Electrical energy generated with wind generators is not competitive or even comparable with base load units because of their intermittent nature of energy production. They can be justified only for saving fuel costs in gas fired plants in a mixed energy system (since this fuel is most expensive).

In a distant future it is possible that application of solar energy (photovoltaic) jointly with suitable energy accumulators (such as production of hydrogen to be further used in fuel cells) would be of interest. However, by present views most economic hydrogen production could be accomplished by nuclear power (using HTGR and thermochemical processes [3]).

5 WORLD ENERGY SUPPLY SCENARIOS

In order to help developing some vision of possible energy supply scenarios for Croatia it could be of interest to consider briefly the characteristics of existing world energy scenarios.

A large variety of future energy scenarios have been produces by many organizations and individual experts. Distant future scenarios are highly hypothetical and reflect viewpoints of individual authors or interest groups. Two of such scenarios [2], [5] are chosen to illustrate the large difference of predictions for future electrical energy supply for the year 2020 (totally expected world consumption around 24000 TWh) and year 2060 (totally expected world consumption around 42000 TWh). The first scenario could be nominated as scenario of intensive usage of renewable energy (conditioned upon substantial governmental subsidies for development of PV cells) and the second a realistic scenario with smaller use of renewable energy (mainly wind energy). This scenario is close to so called business as usual scenario.

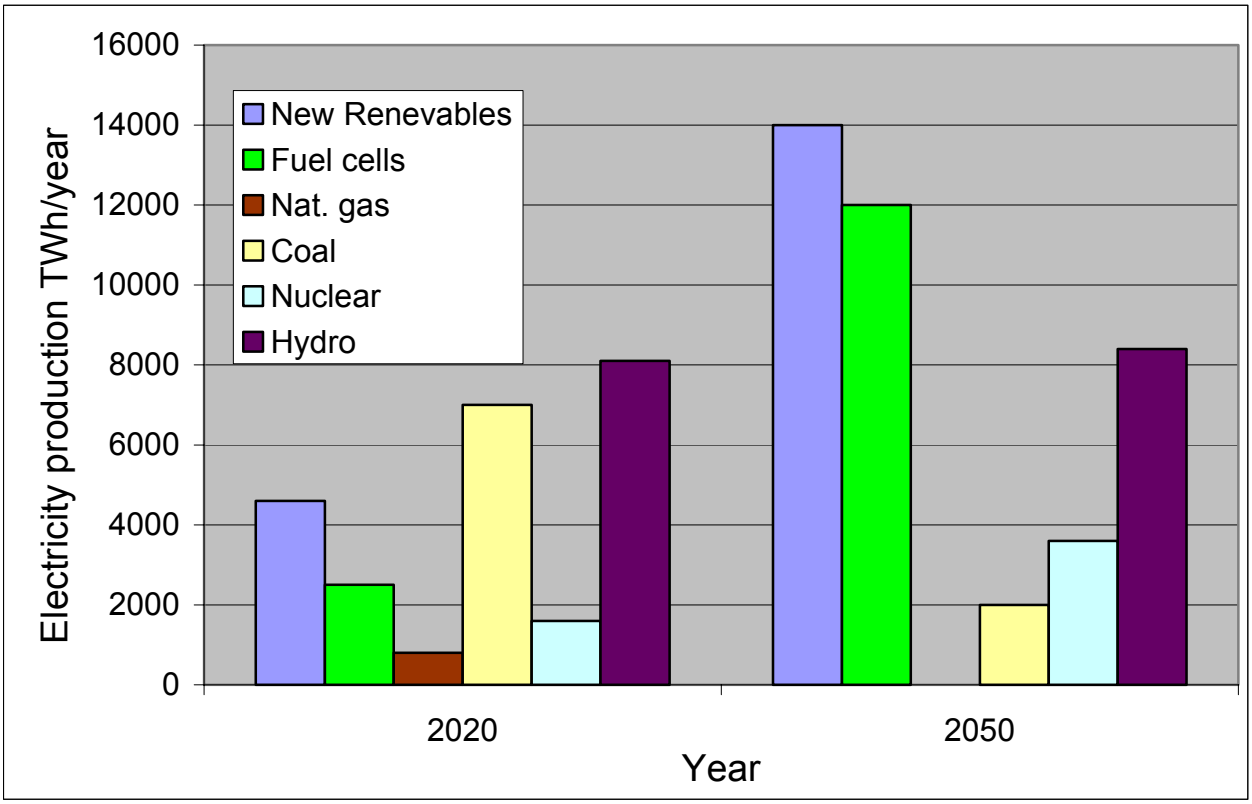

Figure 5. Energy mix used for electricity production in scenario with large share of renewable energy resources

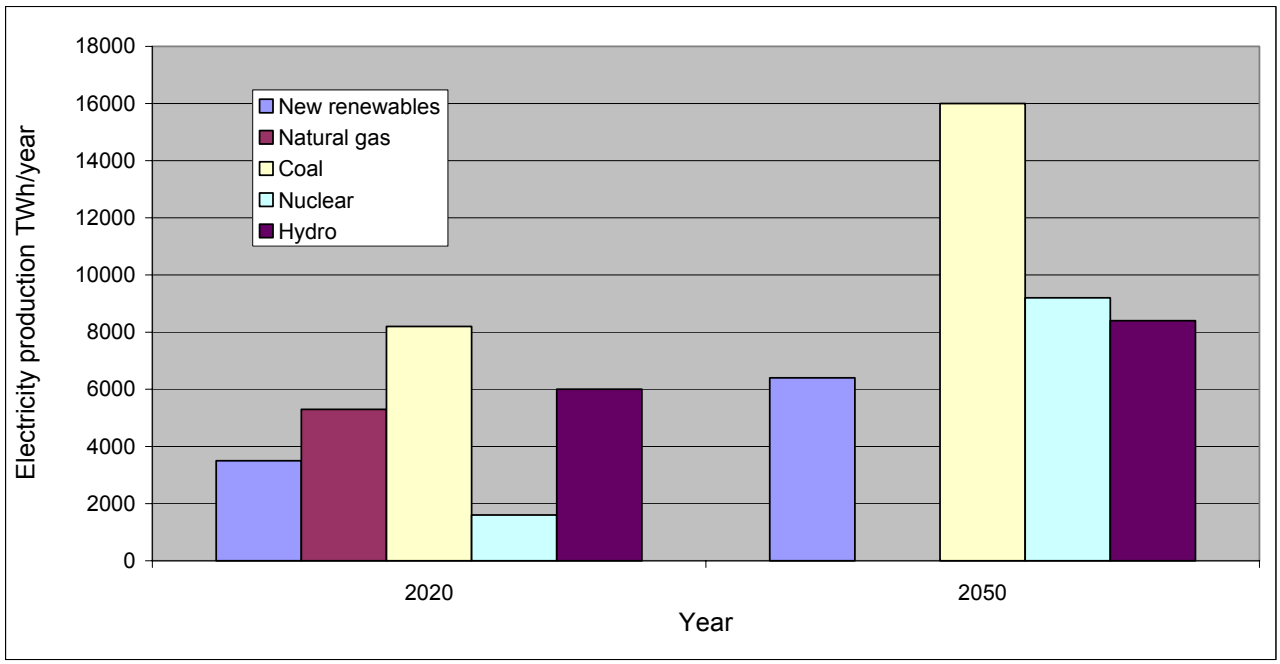

Figure 6. Energy mix for electricity production with moderate share of renewable energy resources

Despite large difference in prediction of the role of renewable resources in future, both scenarios have some common predictions, of which, for present analysis, the most important is that usage of gas for electricity generation disappears by the mid of the century. The decline of its use begins after the year 2020.

The scenarios show that the increase of use of coal in future is probable, but it is to a large extent conditioned upon restrictions of greenhouse gas emissions.

The forecast for nuclear energy use is characterized by a moderate decline by the year 2020 (yearly generated electrical energy changes from present 2300 TWh to about 1600 TWh) due to larger number of NPPs expected to end their life than the number of new plants entering in operation. Following this period it is expected an increase of produced nuclear energy in the world, with the average yearly rate between 2,1% and 4,5%, depending upon scenario.

It has to be noticed that, despite the fact that business as usual scenario is characterized by moderate use of renewable energy, it predicts in mid century generation of about 6000 TWh with wind power. This raises some doubts because with average use of installed power in these plants of 2000 h/year, the installed power of wind generators would reach 3000 GW (which is close to installed power of all power plants in the world in year 2000).

6 FACTS THAT JUSTIFY NUCLEAR OPTION FOR CROATIA

The main reasons for promoting nuclear option in Croatia are:

Reliability of electrical power supply

Reliable electrical power supply is of key importance for national economy. Nuclear power plants are very reliable sources of electricity.

In our case this fact is confirmed by very satisfactory operation of NPP Krško (A two loop PWR of Westinghouse design with original output 636 MW). The plant was build jointly by Croatia and Slovenia and is in commercial operation since 1982. So far has generated more than 100 TWh of electrical energy. Capacity factors achieved in last 5 years vary between 82% and 92% (Figure 7). In total operational period no major abnormal operational events have been experienced and no impact to the environment has been registered.

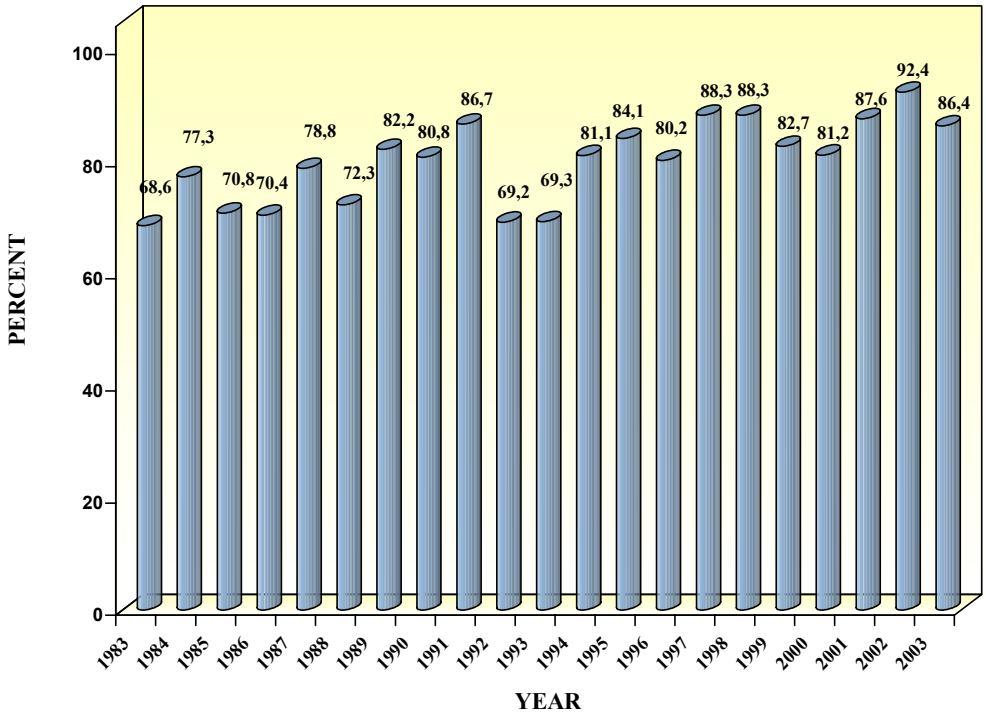

Figure 7 Capacity factors achieved by NPP Krško in the period 1983-2003

The plant has been recently modernized: Steam generators and some other components have been replaced, plant specific training simulator installed and power output increased by 5%.

Increase of capacity factors have been registered in last years in most nuclear power plants in the world.

Economics of power generation

Nuclear power plant Krško generates electrical energy whose cost is presently competitive to cost of electrical energy generated in fossil power plants in Croatian and Slovenian power systems.

In order to predict competitiveness of future nuclear power plants with natural gas combined cycle plants and coal fired plants, a probabilistic analysis has been performed at the Faculty of electrical engineering and computing in Zagreb. Purpose of the analysis was to estimate limiting specific investment costs of NPPs to generate electrical energy with same life time bus-bar levelized costs as competing fossil technologies. The analysis is relating to plants entering in operation in next decade. Ranges of input data (including rate of fuel cost increase) were predicted by using best estimate method. Results of the analysis are shown in figure 8.

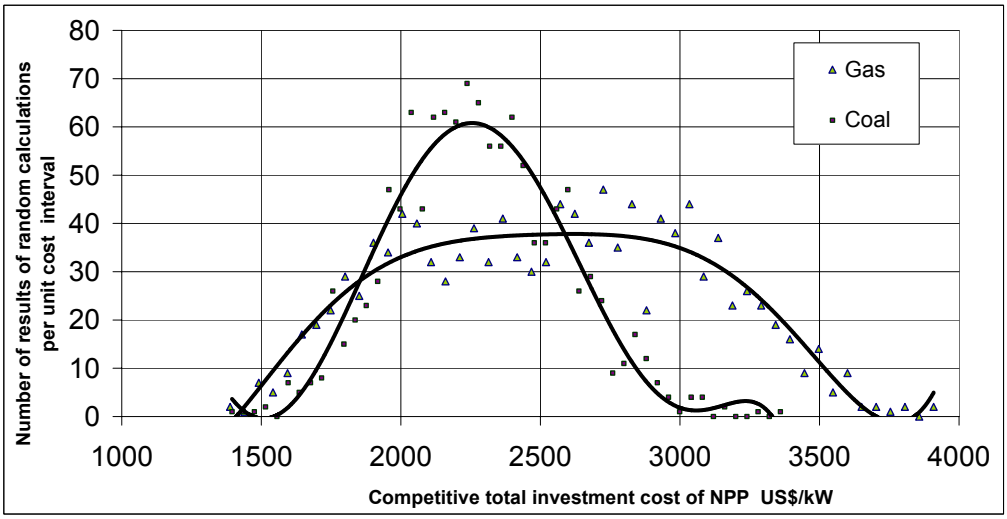

Figure 8. Competitive nuclear power plant specific investment costs

The result of 2000 random calculations show that most probable competitive total investment cost of NPPs (including interest during construction) when compared with coal plant is around 2200 US$/kW and when compared with combined cycle gas plant around 2600 US$/kW. The analysis showed that future nuclear power plants could be competitive even with present investment costs. This would be particularly true if predictions of cost reduction of newly designed NPPs (generation 3+ and generation 4) will be realized. Some predictions for future NPP investment costs are close to 1000 US$/kW. The results showed in figure 8 not include the effect of external cost of plant options. If these costs are included (internalized) competitive investment costs of NPPs become considerably larger.

Maintaining knowledge and experience in nuclear science and technology

During construction of NPP Krško a number of Croatian Industries, Engineering companies, Institutes and Faculties from University of Zagreb have been involved in various activities related to structural analyses, safety analyses, design, civil works, mechanical and electrical construction, and equipment delivery. Courses covering basic knowledge of nuclear science and technology has been introduced in undergraduate and graduate studies at University. A number of new techniques and analytical methods have been acquired including QA/QC programs prescribed for nuclear activities. The upgrade of technical knowledge obtained in nuclear activities was applied to many other areas.

All these achievements would be gradually lost if nuclear option will not be maintained.

Environmental impact

Environmental impact of NPPs is very favorable. External costs of these plants are comparable to plant using renewable energy and are essentially lower than for fossil plants (specially coal fired plants). Obligation taken by Croatia in Kyoto to reduce CO_2 emissions could not be satisfied without use of nuclear power.

Risk of severe accidents (which are main basis for public concern) is very low, considerably lower than other public risks. Contribution of severe accidents to NPPs external costs is only about 10%.

In order to alleviate public concern some designs of future generations of nuclear power plants will include severe accidents into design basis accidents.

7 PROBLEMS WITH IMPLEMENTATIONS OF NUCLEAR OPTION

Public acceptance

Contrary to public acceptance of other power technologies, public acceptance of nuclear power in not proportional to real environmental impact of NPPs (given by external costs). The main reasons for public concern are severe accidents and radioactive waste disposal.

Constant education of public and media in quantification of real environmental risk of NPP is needed to improve public acceptance. In this direction also an observation of actual NPP Krško environmental impact (for instance, as an example, observation of remarkable progress achieved in last years at Čatež Health and Recreation Center which is situated only 7 km downstream of nuclear plant) could help such effort.

It has to be emphasized that public opinion on constructing nuclear power plant in Croatia will probably be significantly influenced by the attitude on this subject in neighboring countries. When the decision was taken to build NPP Krško, constructions of nuclear plants were under way in a number of countries. Most positive influence to this decision had at that time constructions of nuclear power plants in Austria, Italy, Hungary and Germany.

Presently the attitude toward nuclear power within some European countries is not very positive. However, there are signs that use of nuclear power within EU may be considered more favorable in near future due to,

- problems with natural gas security of supply and cost,
- restrictions to build fossil plants (specially coal fired plants) due to limiting of CO_2 emission,
- unfavorable economics and energy supply characteristics of new renewable energy sources,
- decision to build a new nuclear power plant in Finland
- influence of (probably earlier) revival of nuclear power for electricity generation in US

High level radioactive waste

Disposal of spent fuel and/or high level radioactive waste is a real problem for small countries with no nuclear infrastructure. The only solution is multilateral or bilateral cooperation with countries having the necessary facilities to reprocess spent fuel and dispose high level waste. Fair compensation should be provided for such service. The decision to use MOX fuel is linked with economic justification of this option.

Recent efforts to shorter the decay time of high level waste by using separation and transformation (S&T) processes could in future facilitate siting of disposals of this waste.

8 TIME NEEDED FOR IMPLEMENTATION OF NUCLEAR POWER PROGRAM

Preparatory activities for nuclear option are very lengthy and time consuming. Usually the pre constructional period is much longer than the period of plant construction. Specially, time needed to establish a regulatory body, prepare regulatory documents, select the site, perform site investigation, collect and elaborate site data, prepare preliminary environmental impact report, answer questions from public hearings and obtain preliminary site permit may last several years, or even longer than a decade. After this phase of preparatory works starts the process of elaborating bid specifications including specification of plant licensing requirements, bids analysis, definition of domestic supplies, negotiations with potential vendors, solution of financial problems etc.

All nominated activities should be preceded with training of participating staff (including personnel from the utility and regulatory body)

Due to expected need for the nuclear plant in operation in second half of next decade and the long time needed for preparatory work it is obvious that activities for implementation of nuclear option must start in a near future.

In addition, it has to be also noticed that in Croatia is presently in force an official statement (included in Croatian law for territorial planning) [8] that preparatory works to construct coal fired or nuclear plant should not start before the year 2015. This statement was included at the time when it was believed that all electricity supply problems could be resolved by using only gas and renewable energy. Present views are different and this statement should be annulled.

9 REALISTIC SCHEDULE FOR CONSTRUCTION OF FUTURE POWER PLANTS IN CROATIA

Taking into account the duration of pre construction and construction period needed for natural gas combined cycle plant, coal fired plant and nuclear plant it has to be assumed that,

- In short term (by end of this decade) requirement for electrical energy shall be met by combined cycle natural gas plants
- In middle term (first half of next decade) a coal fired plant may enter in operation.
- In longer term (second half or end of next decade) nuclear power plant could be ready for commercial operation.

Due to extended pre-construction and construction period needed for coal fired plant, and particularly for nuclear plant, the preparation of all three options should start almost simultaneously.

When considering the schedule for future power plants construction it should not be forgotten that, in general, circumstances caused by deregulation of electrical energy market do not stimulate investments in this area. This fact has created a reduction of reserve capacities in many countries.

10 CONCLUSIONS

Croatia needs to construct as a minimum 2000 MW of new power plants by the year 2020. In meeting these needs nuclear power should be considered as a dependable and economical source of base load electrical energy. There are some advantages of nuclear power plant over fossil power plants both in security of energy supply, economics and environmental impact. A long pre construction and construction period is needed to complete a nuclear plant project. For this reasons the preparatory activities should start in not distant future.

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