INVESTMENTS IN ELECTRICITY GENERATION IN CROATIAN LIBERALIZED MARKET: ENERGY OPTIONS

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ABSTRACT

System development has to be systematically planned to ensure a long-term reliability of its operation. The Republic of Croatia should have enough capacities built on its own territory to cover the demand. With the prediction of increased consumption of electricity, the security of future electricity supply depends on building of around 2500 MW new power plants, as well as on investment in transmission and distribution facilities.

The market, i.e. a competitive generation, is the driving force in the construction of new power plants. The main stimulus for the construction is the possibility of definite return of invested capital as well as earning of reasonable profit for investors. The construction of generating capacities for tariff customers is subject to the tendering procedure and approval of the Energy Regulatory Council. Croatian electricity market opening is parallel process with establishment of regional electricity market in South East Europe, with a goal of approaching to European Union. Decision on building new power plant for regional electricity market should be in accordance with regional optimization plan of building new facilities of power system.

We must reconsider all energy options in this liberalisation conditions in accordance with Strategy of energy development of Republic of Croatia and with possible requirements of regional market or European Union. Two basic criteria are: electricity price and environmental impact. In mid-term period, because of objective possibilities, new generation facilities will be realized by building of gas-fired power plants or coal power plants and possible nuclear power plant, and in some quantity by building of hydropower plants and power plants on renewable sources. There is a comparision of different energy options in accordance to different criteria like: investment cost, O&M cost, fuel cost, external cost, public impact and investor risk.

This paper is aiming to analyse the possibility of nuclear power plant construction in Croatia as well as in other small and medium electricity grids. Nuclear option will be comprehensively considered in technical, economic, ecological, sociological and other features. It will be discussed about candidates for construction in the period of next ten years which represents investment opportunities for potential investors. But the problem is that in market conditions no one can be imposed the obligation to build new power plants. Technological and financial terms of new power plant is under influence of the law of suplly and demand, so short marginal costs are in the first view – power plant life is at least 30 years – how to deal with this conditions, who will invest in long-term projects with condition of short pay-back period. This paper will try to give some directions for decision of investment in electricity generation under liberalised conditions with evaluation of possible energy options.

1 INTRODUCTION

At present time there are many uncertanties in Croatian energy future, particularly in securing of electricity supply, such as share of energy-generating product in structure of new power plants, new sites for new generating units, commitments in reduction of greenhouse gas emission, fees on greenhouse gas emissions, incentives for renewable sources of energy, incentives for energy efficency (new technologies), impact of regional optimisation plan etc. New developments in energy sector such as restructuring, liberalization,

globalisation and privatisation are introducing market conditions in generation and supply of electricity, and regulation of natural monopoly activities (transmission and distribution). Parallely with this process, the establishment of regional energy market (REM) in South East Europe will have also influence on energy policy in Croatia. This means that optimisation of national interests have impact of regional and European Union policy which presents constraints as well as new business oportunity.

It is very clear that prerequesite of achieving optimal operation of energy system is evaluation of all energy options. Croatia has poor primary energy sources, so we must reconsider all available energy options. In respect of this considarations, diversification of energy supply and fuel usage reduce dependence on some supplier or energy source. Diversification enables risk management and it represents one of energy policy goals.

Although main impulse for investments in new power plants is expecting from market, from recent examples such as outages in Europe and North America, it can be seen the importance of security of energy supply and having enough capacity on national teritory (national interest). So, there is a need for minimal Government intervention for securing energy/electricity supply on satisfactory level.

Key planning documents in Croatia for energy sector are:

1. Energy Sector Development Strategy of the Republic of Croatia [1]
2. Strategy Implementation Programme
3. Long-term and Annual Energy Balance

This documents are defining different dimensions of energy sector such as legislative, institutional, organisational, energy, ecological and educational dimensions. Although some of this documents are not yet defined, it can be concluded that they represent energy sector development frame and within a framework we must find optimal solutions.

Starting point in defining the share of energy sources in electricity generation is analysis of main characteristics such as availability, price and ecology. It can be resumed that main long-term energy sources are natural gas, coal and nuclear fuel (see Figure 1). Development of renewable energy sources depends primarly on public stimulation. Hydroenergy potential in Croatia is almost used up, and expansion of new hydro power plants is not depending on market.

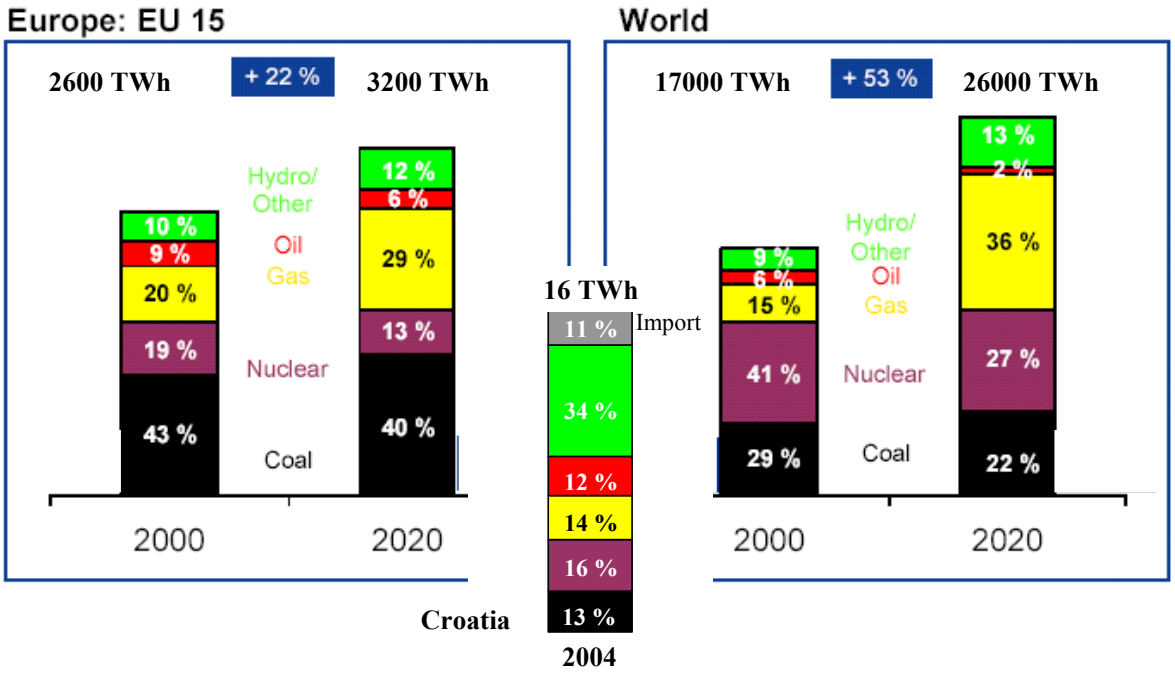


Figure 1. Electricity generation in European Union and World with comparision of Croatia [5][9]

2 ELECTRICITY MARKET OPENING IN CROATIA AND EXPANSION OF NEW POWER PLANTS

Total electricity demand of more than 2,100.00 customers is currently met by electricity generation in hydroelectric plants and thermal power plants located on the territory of the Republic of Croatia and by electricity imports from other systems. Croatian Utility (HEP) owns 30 power plants in the Croatian electric power system (21 hydroelectric plants and 9 thermal power plants), almost 24,000 switching stations and 128,000 km of power lines. In other words, in Croatia is today installed 2063 MW of hydro power plant (HPP) with annual electricity production of 5800 GWh and 1956 MW in thermal power plant (TPP) (Joint Venture: TPP Plomin 2 and NPP Krško – 50 percent of ownership).

According to the reference scenario that envisages an annual increase in electricity consumption from public network of only 3 percent on average and progressive shutdown of the oldest generating plants, electricity shortage is foreseen in the characteristic years as shown in Figure 2. This electricity shortage shows the need for investments in generation facilities for securing reliable electricity supply.

According to the Energy Sector Development Strategy it has been planned investment in new power plants with following strategic objectives:

1. safety of energy supply
2. realistic energy prices
3. environmental protection
4. energy efficiency increase
5. diversification of energy sources energy

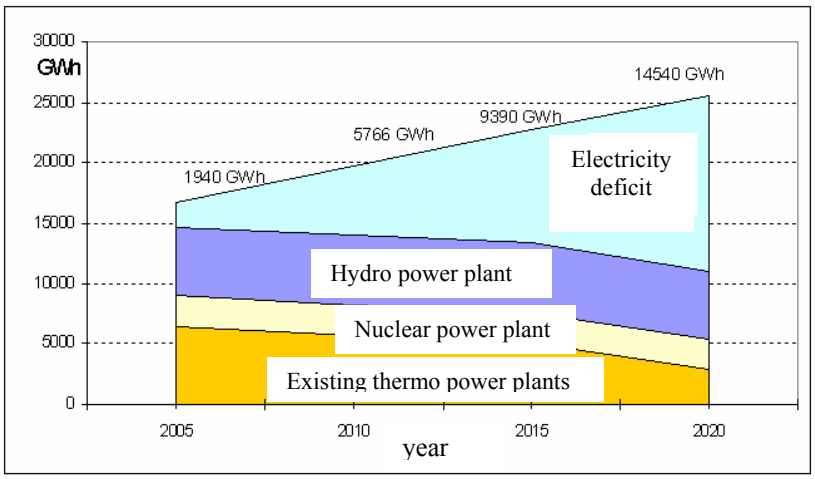


Figure 2. The increase in electricity consumption and electricity shortage in Croatian power system [1]

Because of strategic reasons, with respect to security of electricity supply, we must have energy mix. According to the Strategy of Energy Development, for covering electricity shortage in period from today to 2020, we must invest in:

- 3-5 gas fired TPP (combined-cycle) with 300 MW for each unit
- 2 coal fired TPP with total installed generation capacity of 1000 MW
- 6 HPP with total installed generation capacity of 250 MW
- renewable sources of energy (wind power plants, small hydro, geothermal, etc.)

The construction of generating capacities for tariff customers is subject to the tendering procedure and approval of the Energy Regulatory Council. Each licensed energy undertaking can, by own decision, construct generating capacities for eligible customers. HEP and other energy undertakings that have been granted a license for electricity generation can take part in the construction of new generating capacities. The

interest in the construction of new generating capacities will exist only if the selling price of electricity enables potential investors to realize the expected revenues.

3 ENERGY OPTIONS

3.1 Natural Gas

Natural gas has the most favourable use in combined-cycle thermal power plants, although it is irreplaceable for use in chemical industry (and households). While the compactness, flexibility, low environmental impact (no sumpor, low emission of CO_2), high level of thermal utilisation (up to 60%), low specific investment (600-750 USD/kW), and simple construction are among the gas turbine power plants strong points, the instability of future gas prices appears to be the main shortcoming in this regard, together with the influence of gas networks development plans. At present day minimal price for natural gas is 3 EUR/GJ on the border between European Union and Russia.

European gas market liberalisation opens the way for competition, which is expected to bring bigger gas supply to end users. According to the forecasts, natural gas demand in Croatia will be growing in the future (from present 3 bln m^3/a to 4,7 bln m^3/a in 2020), along with continuing decline in domestic production (today 1,5 bln m^3/a). This means that Croatia as well as European countries will have to ensure additional gas quantities for meeting their own market demand (some of them, like Germany, have already concluded new arrangements for bigger supply from Russia). The biggest natural gas stocks (for Europe) are in Russia and Middle East, as well as in North See and North Africa. Croatian import from Russia is 1,1 bln m^3/a.

It can be expected with high certainty that gas prices will grow faster than coal prices. Namely, in Europe today most of new power plants are gas-fired. Gas demand will rise quickly and it can lead to problems of securing transport gas capacities for Croatia. As a matter of fact the risks of gas market disruptions is a threat all gas importing countries could face (in some periods interrupted gas supply is already present in Croatia) – this is expected to be a case after 2020. In such circumstances it is necessary to ensure sufficient gas quantities and develop several supply routes, if we want to have higher share of gas in electricity generation.

The first candidate plant for construction is gas-fired power plant. According to current estimates there is a need to start with operation in 2007. If the Gas Energy Adriatic (GEA) gas pipeline project is realised (the present assessment shows that it could happen in 2005 at earliest – 1.5 bln m^3/a) the best location for this power plant would be Sisak or Zagreb. In view of power system management, the favourable location would be Osijek. This means that there shold be a new pipeline to Osijek, connected to the gas pipeline in Hungary (max 0,5 m^3 bln/a) or Serbia (max 1.5 bln m^3/a). There is also a potential Liquid Natural Gas (LNG) project in Ploče.

Potential new gas pipeline projects, important for Croatia as well as for European Union and South East Europe are (natural gas from Middle Asia):

- Turkey-Greece-Macedony-Serbia-BiH-Croatia-Slovenia (doubtful)
- Turkey-Greece-Italy
- Turkey-Bulgaria-Romania-Hungary-Austria

Capacity of natural gas storage in Croatia is 0,5 bln m^3/a – that is not enough in case of extreme climatological conditions (higher consumption – lower pressure in pipelines).

3.2 Coal

Croatia does not have its own sources of good quality coal, so we must import it (~40 USD/t or 2 USD/GJ). Coal has the largest proven global reserves which are equaly distributed (in comparision with oil and gas). On this prerequesite the best locations for new coal-fired power plant in Croatia are on seaside (there is no need for expensive transportation of coal by land). Investments in coal-fired thermal power plant are higher than in gas-fired power plant, but the price of coal on international market is very stable (for long-term). Thermal utilisation in new coal-fired power plants is about 43 percent.

Actual shortcomings of coal are growing environmental concerns, primarily related to CO_2 emissions, and storage difficulties. But, the imported coal prices, diversification of export suppliers and relative price stability are important elements. The future of coal in Europe depends on its global supply security and development of clean and efficient technologies.

The coal-fired thermal power plant, which use imported coal, is one of the most prospective energy option (for long-term) when it comes to Croatia's strategic decisions concerning electricity generation sector (from present point of view). According to current estimates there is a need to start with operation in 2011. Charges on CO_2, SO_2 and NO_x emissions, according to the Law on environmental protection and energy efficiency Fund, will have additional influnce on final electricity generation price, but coal-fired power plants will have continued and stable growth in securing electricity supply. In the long term, coal is likely to remain of interest as new technologies come on stream which reduce extraction costs, reduce emissions and dramatically increase its efficiency.

Cleaner coal technologies will help Europe in investments of needed 550 GW by 2020 (Green Paper - European strategy for the security of energy supply) as well as other advanced technologies. For the increase of net efficiency exists several possibilities which are concentrated on increase of steam parameters on the basis of technological improvement of materials. In european program Comet 650 are used materials for temperatures till 650°C. Power of generating units are 400-1000 MW.The next step is increasing of steam parameters on 350 bar/700°C with net efficiency >50 percent. For this temperature, material improvements are crucial for this development – problem is solving by EU-THERMIE project (Clean Coal Technologies) under the organization of: E.ON Energie, EdF, Electrabel, Elsam, EnBW, Enel Produzione, RWE, Vattenfal, VGB which gather more than 500 GW of power plants. In the same time CO_2 emission reduction will be 25% in comparision with existing coal-fired power plant.

The example od modern coal-fired thermal power plant is TPP Nordyllandsvaerket (Gross power output 450 MWe; steam parameters 290 bar/582°C; reheat 580/580°C ; net efficiency 47 percent; >7000 h/a on nominal power; usuful waste is transported to cement industry.

3.3 Renewable Sources of Energy

Renewable energy has a prospect but at the same time technical and economical problems for significant use in electricity production, especially for base-load consumption. If the fundamental opportunity of renewables is their abundance and relatively widespread occurrence, the fundamental problem, especially for electricity supply, is their variable and diffuse nature. Sun, wind, tides and waves cannot directly be applied as economic substitutes for coal, gas or nuclear power, however important they may become in particular areas. Construction cost is high because of using large quantities of material per unit of installed power. But they have political and public backing. It has been calculated that to achieve the capacity of a large power plant - say a 1000 MWe nuclear or coal plant - by using solar cells, an area of more than $20km^2$ would have to be covered by such cells. If you rely on windmills, you would need wind farms covering more than $50km^2$.

The hydroelectric potential in Croatia will not be entirely utilised due to environmental and other constraints. The Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market as well as green certificates (Renewable Energy Certificate system) have remarkable impact on investors decision for constructing wind power plants or other renewable energy sources (example: Germany, Spain, Denmark). In this direction, in Croatia is considering of investment in renewables, but legislative in that area is not yet entered into force as well as fees for producing electicity from renewable sources of energy.

3.4 Nuclear power

Nuclear power plants can insure electricity production for relatively low price and with small impact on health and environment, as well as protection from interruption of fuel supply and rise of prices. On future of nuclear power plants in medium and long term impacts many factors. Technologies of reactors and other nuclear facilities, as well as fuel reserves, are ready for widely use in whole world. Nuclear development obstacles are institutional and organizational and not technological character.

Bringing about major expansion of nuclear power over this century would require winning public confidence that nuclear power is safe, that radioactive wastes can be successfully managed, and that the civilian nuclear

fuel cycle will not become a source of materials for nuclear weapons to be used by rough states or subnational, criminal, or terrorist groups. The financial markets would also have to be convinced of the economic viability of the nuclear option in competitive energy markets.

Main arguments for the decision of constructing nuclear power plant in principle are as follows:

- New nuclear power plant unit will supply a significant part of the growth of electricity demand and replace old thermal power plants
- Together with renewable energy sources nuclear power will reduce carbon dioxide emissions and thereby a new unit makes an important contribution in achieving the Kyoto commitments
- Nuclear power secures a predictable and reasonable electricity price level for households and industries
- New nuclear power plant unit reduces the dependence on electricity import and thereby reinforces the security of energy supply

A recent study by the Lappeenranta University of Technology indicates that in baseload power production in Finland the generating costs of a nuclear power plant are the lowest in comparison with base load generation using coal, natural gas or peat. The cost comparison is shown in Figure 3 and it reflects the specific situation in Finland. The low variable cost of nuclear generation is especially beneficial in the deregulated electricity market conditions. Only plants having variable cost less than the prevailing market price are in operation. The situation in Finland during the last years has been such that, due to the volatile market price, coal fired condensing plants have been in operation less than half of the time and gas condensing plants only occasionally.

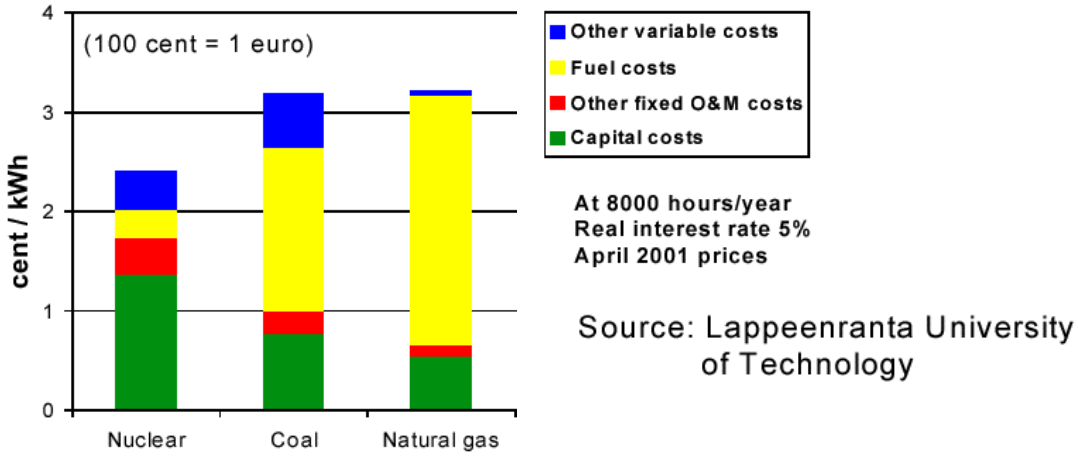


Figure 3 Generating costs of different base-load production alternatives in Finland [17]

Sustainability and environmental considerations have markedly increased worldwide awareness of the need for an enhanced contribution by nuclear power. The next generation reactors must represent an improvement over current designs in terms of economy, safety, public acceptance and environmental impact. They will incorporate technology that is well proven and anchored on the successful performance and experience gained over the last 40 years.

Nuclear stations emit negligible quantities of the acid rain gases, sulphur dioxide (SO_2) and nitrogen oxides (NOx), and the greenhouse gas carbon dioxide (CO_2), a major contributor to global warming. The major burdens of the nuclear fuel cycle are the radioactive emissions from the mining and milling activities, the risk of accidents, and the air pollutant emissions from energy used for other stages, such as enrichment and reprocessing. The external costs for nuclear energy were less than 1% of internal costs, even after factoring in hypothetical nuclear catastrophes. This is because all waste costs in the nuclear fuel cycle are internalised which reduces the competitiveness of nuclear power when internal costs are considered (Table 1). So, if you include these costs (for example, decomission costs), external costs of nuclear power are around 10%.

Table 1 Quantifiable external costs of energy systems (in Euro-cent/kWh) [16]

Impact	Coal	Lignite	Gas CC	Nuclear	Solar (PV)	Wind	Hydro
Health effects	0.8	1.0	0.3	0.2	0.4	0.05	0.04
Crop losses	-0.03	-0.03	-0.01	0.0008	-0.003	0.0005	0.0004
Material damage	0.02	0.02	0.007	0.002	0.01	0.001	0.0007
Noise nuisance						0.006	
Acidification/Eutrophication	0.2	0.8	0.04	0	0.04	0	0
Global Warming	1.6	2	0.8	0.03	0.3	0.03	0.03
Sub-total	2.6	3.8	1.1	0.2	0.8	0.09	0.07

3.4.1 IRIS Project

IRIS (International Reactor Innovative and Secure) is a small to medium advanced light water cooled modular reactor being developed by an international consortium (and Croatia – Faculty of Electrical Engineering and Computing) led by Westinghouse/BNFL. This reactor design is specifically aimed at utilities looking to install new (or replacement) nuclear capacity to match market demands, or at developing countries for their distributed power needs. IRIS is designed to satisfy four key requirements: enhanced safety, improved economics, proliferation resistance and waste minimization. Its main features are: medium power (up to 335 MWe/module); a simplified compact design where the primary vessel houses steam generators, pressurizer and pumps; a novel, extremely effective safety approach; and, optimized maintenance with intervals of at least four years. Integral vessel configuration eliminates loop piping and external components, thus enabling compact containment and plant size.

The resultant analysis reveals an optimum power rating for a single module of 335 MWe, with a construction period of 3 years or less and a minimum plant life of 60 years. Individual modules can be installed in a staggered fashion (3 equivalent to 1005 MWe) or built in pairs (2 sets of twin units' equivalent to 1340 MWe). Uncertainty in Market Clearing Price for electricity, Annual Operating Costs and Construction Costs primarily influence lifetime Net Present Values (NPV) and hence IRR % for Utilities. Generation Costs in addition are also influenced by Fuel Costs, Plant Output, Plant Availability and Plant Capacity Factor. Therefore for a site based on 3 single modules Generations Costs of approximately 30.0 $/MWh are required to achieve an IRR of 20% (30 year finance period), a level which enables IRIS to compete with all other forms of electricity production. This is well within the range of market clearing prices forecasted to remain at or above 40 $/MWh.

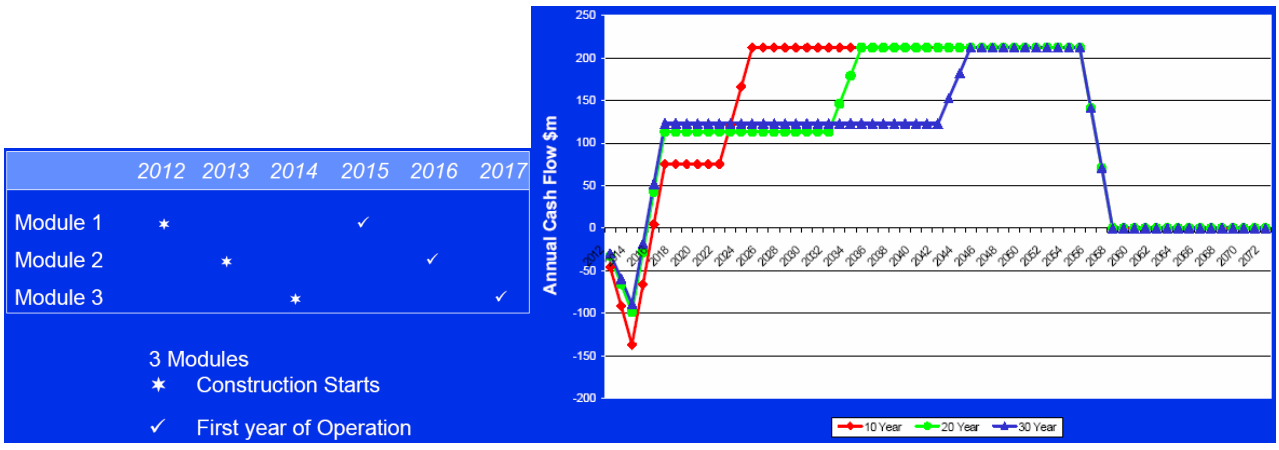


Figure 4 Example Build Schedule & Cash Flow Profile [15]

Plant size is critical to commercial success. Sustained (lifetime) high factors for Plant Output, Availability and Capacity Factor are required to achieve a competitive advantage. Modularity offers Utilities the option to match their investments with market conditions, adding additional capacity as and when the circumstances are right. It also offers the functionality to address other market requirements, such as co-generation (electricity / desalination). Finally the construction schedule needs to be controlled. There is a clear trade-off between reducing financing charges and optimizing revenue streams.

The staggered installation approach also enables Utilities to match their investment programs with rises in demand for electricity, minimizing their financial exposure. It also avoids disruption of local market conditions, which could occur when connecting say, a single large plant of over 1000 MWe capacity. Financing charges can also be stretched and effectively managed, minimizing exposure to fluctuating economic conditions.

Having established the optimum configuration, sustained (lifetime) high factors for Plant Output, Capacity Factor, and Plant Availability are required in order to attract further investment, achieve a competitive advantage and deliver lifetime value. Therefore, the current plan is to submit an IRIS design certification application in 2005, with the objective of obtaining design certification in 2008/2009. Following certification, with a parallel firsttime-engineering effort, a construction period of three years for the first IRIS module is expected, thus IRIS deployment could be as early as 2012, and more realistically around 2015.

4 CONCLUSIONS

Energy supply considerations are coloured by environmental, economic and political developments. Currently, some aspects of policy tend to favour certain forms of energy, e.g. climate change policies might give preference to gas, renewables or nuclear compared to coal and oil; market liberalisation has made gas more popular for reasons of cost; technological developments could tilt the energy balance in favour of renewable energy sources, advanced nuclear energy technologies, fuel cells or “clean” coal.

Besides economic competitiveness, radioactive waste disposal, accident and other risks raise major concerns and may be an obstacle for considering nuclear power within a sustainable energy mix in some countries. On the other side, natural resource management and atmospheric pollution control objectives, which are part of sustainable development goals, provide some incentive to keep the nuclear power option open (Figure 5). In the long term, a combination of nuclear power and renewable energy sources is likely to be needed in order to support economic growth and sustainable development world-wide.

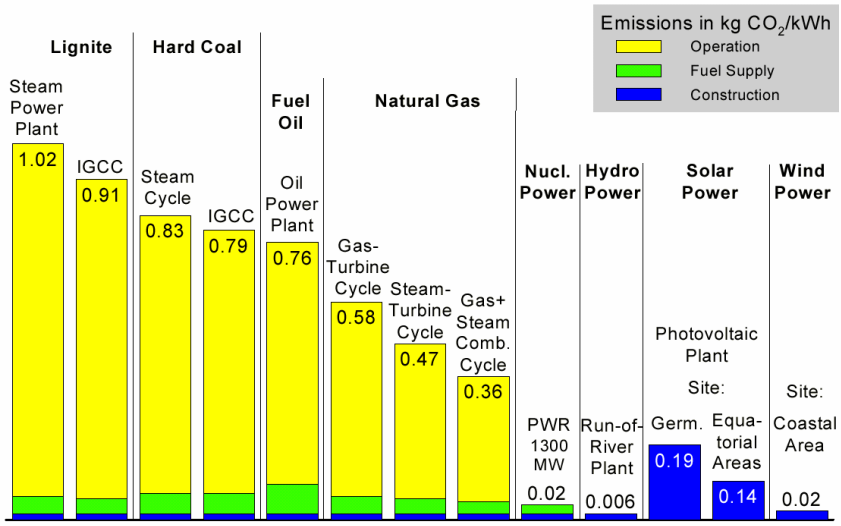


Figure 5 Greenhouse Gas Emissions from Electricity Production per kWh (Source: Siemens/Voss/VDI-GET)

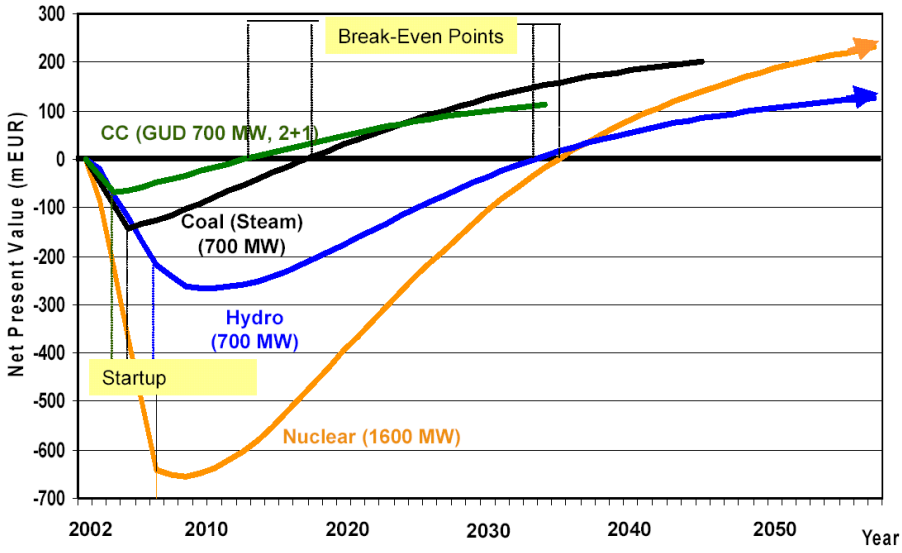
Investment in new power plants will largely depend upon investment costs, construction time and projected profitability. Prospects for building new nuclear power plants in a competitive environment are not yet promising, mainly because nuclear power is generally perceived as not being economically attractive as compared with gas-fired power plants, but with some new projects (IRIS) nuclear is atractive energy option.

If we come back on present rules of investments in new power plants, it can be seen that today are still applicable some of primitive methods of economy valorization of energy options. One of this method is net present value (*NPV*) – the higher *NPV* value it's higher profit:

$$NPV = -FC_0 + (TR - VC) \cdot \frac{(1+r)^T - 1}{r \cdot (1+r)^T}$$

Where FC_0 is fixed cost, TR is future revenue, VC is variable cost, r is relevant cost of capital, and T represents valorization period. One of results of these economy valorization is on Figure 6 which partly explaines why the investors in the last years have most confidence in gas fired thermal power plants (combined cycle). With a development of advanced power plant technologies, other energy options come also into competitive relationship (new generation of nuclear and coal fired power plants).

The nuclear industry must develop appropriate, long term technological solutions which allow full use of uranium reserves with economic sensitivity (IRIS project). The disposal of long lived radioactive wastes is the single most important environmental hurdle facing nuclear power (geologic disposal). Development of a carbon value, or a value on reducing emissions of carbon dioxide, would increase the cost of fossil fuel options relative to nuclear and renewable energies. In the long term this could be the main advantage of nuclear power compared to fossil fuels.



Net Present Value for Fossil-, Nuclear- und Hydro- Power Plants

Source: Siemens PG

Figure 6 Investment pay-back period from present view (Source: Siemens PG)

Providin all specified aspects of energy options, it is necessary to conclude that because of increasing demand for electricity, needs for replacement of old power plants, requirements for energy diversification and with respect on environmental protection, we must use all given energy options. Simultaneously, it is necessary to start with investments in electricity generation facilities on locations suitable for this energy options. Technologies which have long-term perspective for satisfying electricity demand are advanced nuclear and coal power plants, while renewables will play continuous energy option with development of technology and regulations. However, gas option is, after present significant expansion and development, going to handover primacy to other energy options and technologies.

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