POLITECNICO DI MILANO
Facoltà di Ingegneria dei Sistemi

POLO REGIONALE DI COMO

Master of Science in
Management, Economics and Industrial Engineering

Investments analysis for construction of Nuclear Power Plant in Ukraine: The influence of the size

Supervisor: Prof. Mauro Mancini

Master Graduation Thesis by: Oleg Mikerin

Student Id. Number 722531

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ABSTRACT

This thesis provides a feasibility study and analysis of Nuclear Power Plant construction in Ukraine and the influence of the size on the investments.

Energy sector is considered one of the most prospective fields for investments. Development of nuclear energy facilitates ensuring of energy safety of the country, decreases or totally eliminates dependence from electricity import and provides a profit to the investor. At the present time, the energy sector stands in the stage of reforming, which is determining by market reforms in power – energy complex. In the base of reforming process, there is a creation of real working and competitive market of electricity and electric generation facilities. All these facts make a question about investing in NPP to be an actual today. During a study and analysis for NPP construction it is important to define which type of reactor to choose: Large or Small reactors.

Today in Ukraine operates four nuclear power plants with 15 nuclear units in total. These units have been in operation, on the average, about half of their design service life. From 15 nuclear power units operating in Ukraine 13 of them are LR's with VVER – 1000 type and 2 reactors with VVER – 440 type. Ukraine has experience in exploitation of both LR and SMR's, but the majority belongs to LR.

An object of analysis is Nuclear Power Plant with Large and Small reactors.

Thesis consists of 4 chapters:

- Introduction to Energy System of Ukraine
- The Ukrainian Scenario
- Financial/ Economic Results
- External Factors Analysis

First chapter "Introduction to Energy System of Ukraine" describes a situation and prospective of power-energy complex of the country, generating capacities

structure, nuclear power energy industry. Electrical Energy Market structure, its mechanisms of work, regulation policy and new coming market reforms are represented in a first chapter.   Introduction to Energy System of Ukraine shows problems and prospects of integration in the energy grid of European Union, which can increase exporting of electricity by nuclear power plants to foreign markets.

“The Ukrainian Scenario” part analyses information used for studying possibility of investing into new Nuclear Power Plants on the territory of Ukraine. Second chapter reviews generation costs of nuclear power plant capacities, operation and maintenance, financing and revenue. Necessity of enterprise in nuclear fuel, its costs and its utilization are described in the “Ukrainian Scenario” chapter.

Financial results about NPP construction in Ukraine and comparison of results when the size of reactor changes is analyzed in the third chapter “Financial/ Economic Results”. During financial analysis of investing into new nuclear power plant in Ukraine the Internal Rate of Return, Net Present Value and Payback Time shows better result in a case of choosing Large Reactor choice. A Financial analysis promotes a Large Reactor choice.

Last fourth chapter “External Factors Analysis” shows that size influences on the external factors and studies the choice of the better nuclear power plant size as a multidimensional problem. Some external factors promoted Large Reactors, some factors were the same in both cases, but the total result of external factors analysis promotes Small Reactors choice.

Conclusion of the feasibility study for NPP construction results, that for Ukrainian scenario it is more profitable for investor to choose Large Reactor. Even if external factors analysis promotes small reactors choice, financial/economic analysis promotes Large Reactor choice. In this case for investor it is more profitable to invest into Large Reactors. All in one, the goal was to make analysis of NPP construction in Ukraine and study a difference between investing to construction of

NPP with Large and Small reactors. Ukrainian scenario promotes to invest into nuclear power plants with Large Reactors.

Contents

CHAPTER 1 INTRODUCTION TO ENERGY SYSTEM OF UKRAINE

Fuel and energy complex is one of the major structural components of the economy of Ukraine, a key factor in the viability of the state.

Fuel and energy complex is composed of companies that specialize in extraction, enrichment, processing and consumption of solid, liquid and gaseous fuels, the production, transfer and use of electricity and heat.

Unbroken chain of production → conversion → transmission → distribution → consumption → storage of used resources (e.g. in a case of spent nuclear fuel for NPP) → the use of energy resources determines technological unity (integrity) of fuel and energy complex. (Usenko, 2008)

Functional complex is divided into sectors, systems and energy sector companies: mining, processing, transmitting and distributing.

Branches of the complex are closely connected with all branches of the economy.

Fuel and energy complex creates prerequisites for the development of energy intensive industries and is the basis for the formation of industrial complexes, including not only electric power, petrochemical, coal-chemical, Gas, and metallurgical, chemical, wood, etc.

Fuel is used not only in energy, but also as raw material for obtaining a variety of valuable products. For example, oil is needed for the development of chemical industry. Because oil required not only for creating fuel, but also for various oils and lubricants, plastics, detergents, synthetic fibers and fabrics, fertilizers. Because natural gas produces synthetic alcohols and protein drugs revoke sulfur. Coal is a valuable technological raw material in the steel industry, a source for plastics, gasoline and other products of production.

The peculiarity of the fuel and energy balance of Ukraine (FEB - the ratio of production and consumption of fuel and energy resources) is a high proportion of coal and nuclear energy and small hydropower and oil.

Electricity is a basic area of economic complex, and the use of electricity - the driving force of scientific and technological progress. Industry influences on the territorial organization of the productive forces. A sufficient quantity of electricity has complex forming value and attracts business and production, in which the particle energy costs in the cost of finished goods is much higher compared to the traditional areas of industry. In some areas of Ukraine (Donetsk Basin, Dnieper), it defines production specialization is the basis for the formation of clusters.

Placing of a power depends on two factors: the availability of energy resources and consumers.

All types of energy generation in Ukraine energy can be divided into 4 groups: thermal power stations (for solid, liquid and gaseous fuels), hydro power plant (using water resources), nuclear power plants and power plants that use non-conventional energy sources (wind, sun).

The leading role in the electricity industry by the number of produced electricity (about 50%) belongs to Nuclear power plants. Nuclear power in Ukraine is represented by such powerful operating nuclear power plants, as Zaporozhye, South-Ukrainian, Rivne, Khmelnitsky, and a failed Chernobyl. Ukrainian Nuclear Power Plants produce about 50% of all electricity in the country. (Energoatom, 2010)

A little more than 40% of generated electricity belongs to the thermal power stations - power plant and power station. The advantage of TPS is relatively free accommodation, double lower cost of investment compared with the HPS. The greatest number of large thermal power plant is located in the Donbas.

Growing importance combined heat and power. They are built near the consumer, because the radius of the transportation of heat a small (10-12 km), however, the efficiency of the heat is almost 70%, whereas TPP - only 30-35%.

Hydroelectric power plants in Ukraine - Kiev, Kanev, Kremenchug, Dneprodzerzhinskaya, Dneproges, Kakhovskaja, Dnistrovska, Tereblya-Rizk has an (especially the Dnieper cascade) outdated equipment and plain character of the valley, that them to have a little efficiency. Hydroelectric power plants give up to 4,5% of electricity in Ukraine. Moreover, their construction has resulted in the inundation of large tracts of fertile lands and has created a host of environmental and social problems. The most effective hydroelectric power plants are those which situate on mountains rivers.

At this time, electric power, like the rest of Fuel-energy Complex (FEC) of Ukraine, is in deep crisis. However, this applies not only to FEC – it applies to a lot of industries in the country.

The main problem of fuel and energy complex, at the present stage of economic development, is the aggravation of non-payment for fuel and energy. Not enough money for the reproduction of fixed assets in the industry, as well as to develop the most advanced and highly efficient technologies, such as technologically complete production of fuel for nuclear power plants.

Status and technical level of existing capacity Fuel-energy Complex at this time becomes critical. An important task of further development of the petroleum and energy industries during the formation and development of market relations is the implementation of environmental measures and environmental management. Environmental Policy in the complex should be directed at preserving the environment. Today it accounts for about 45% of harmful emissions into the atmosphere, more than 30% of waste water and the same amount of solid waste from all pollutants.

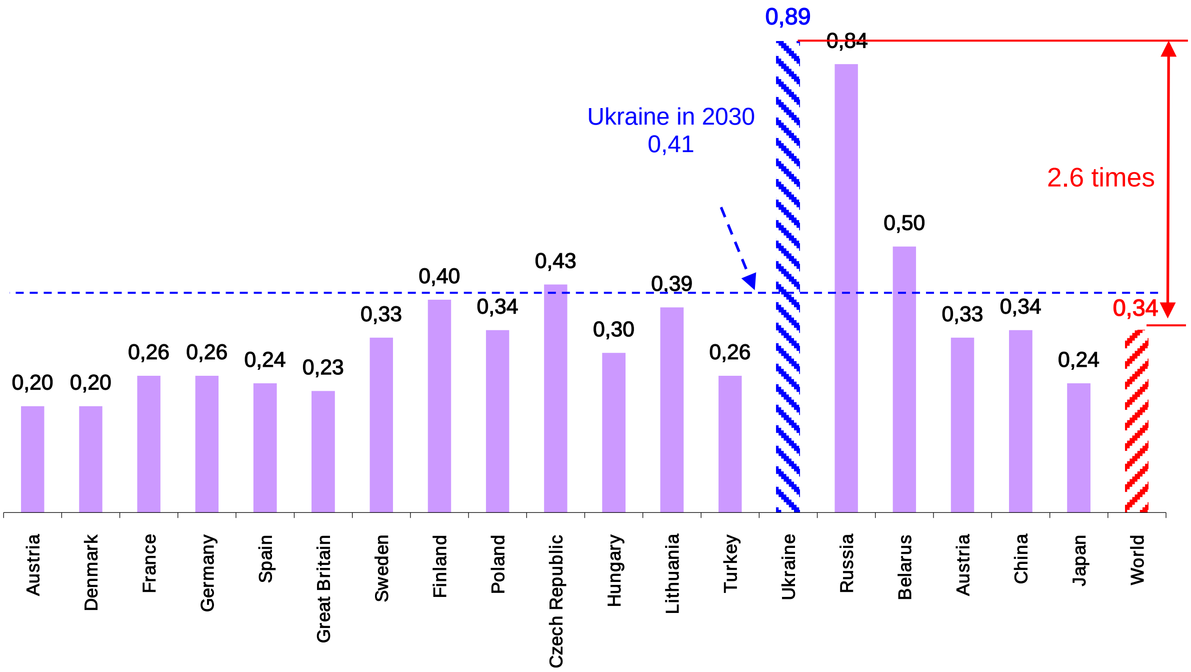
The important task is to reform the fuel and energy market through pricing and taxation policies, by creating a competitive environment and attracting investments.

Regional government strategy in the energy industry should be directed to the development of market relations and the maximum energy savings in each region.

Summary measure of efficiency for fuel and energy resources of the country is unit costs of primary energy resource per unit of gross domestic product (GDP energy intensity).

The energy intensity of Ukraine's GDP in 2.6 times exceeds the average energy intensity of GDP of the world. More over this indicator is higher than any industrialized or at least some developed countries. This deeply pessimistic situation clearly demonstrates the following diagram.

Table. The energy intensity of GDP of the world, kg of unitary fuel / USD (Key World Energy Statistics, 2006)



High energy intensity of GDP in Ukraine is a result of significant technological lag in most sectors of the economy and housing sector, poor branch structure of the national economy and, in particular, import-export operations and the impact of the "shadow" economy.

The main directions of development and improvement of fuel and energy for the future should be:

1. Forming a coherent and effective system of governance and regulation in the energy sector, development of competitive relations in the energy markets.

2. Creation of preconditions for radical reduction of energy consumption in domestic production due to the introduction of new technologies, advanced standards of modern control systems, and accounting management at all stages of production, transportation and consumption of energy products, the development of market mechanisms to encourage energy efficiency in all areas of the economy.

3. The development of export potential of energy, mainly due to electricity by upgrading and renovation of power generating facilities, transmission lines, including the interstate.

4. The development of domestic energy engineering, instrumentation and power building complex as a prerequisite for the competitiveness of Ukrainian enterprises in energy projects, including abroad.

5. Optimization of production of own energy resources, taking into account their suggestions in foreign markets, pricing and the geopolitical situation, increased energy and energy products derived from alternative and renewable sources of energy.

6. Diversification of external sources of supply of energy products, as well as the diversification of routes of their transportation.

7. Creating a unified state system of statistics, strategic planning, monitoring production and consumption of energy products, the formation of the balance of supply and demand.

8. Balancing the pricing policy for energy products, which should provide cover the cost of their production and creating appropriate conditions for safe operation and continued development of energy sector companies.

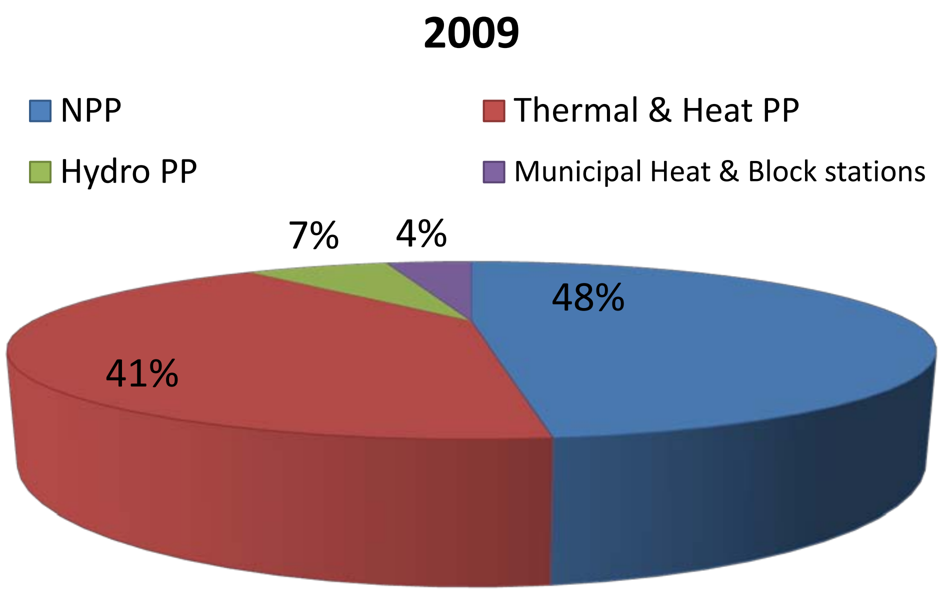
9. Normative legal support for the objectives of energy policy in the light of existing international obligations under the Energy Charter Treaty, the Kyoto Protocol, numerous bilateral treaties, as well as the requirements of the European energy legislation (Power energy strategy of Ukraine till 2030, 2006).

1.1 Characteristics of the current state of electricity generation capacity.

1.1.1 Nuclear energy

In 2008, the four operating nuclear power plants operated 15 units, who have spent, on average, about half of the envisaged project service life. In recent years achieved a significant improvement in techno-economic performance of nuclear power plants. In 2009, the NPP has generated 83 billion kWth or 48% of total electricity generation in the country. (Statistics, 2010)

Table. Share of electricity generation of Ukraine by NPP and other producers in 2008 – 2009. Electric energy in Ukraine. 2010



The strategy of development of nuclear power plants till 2030 plans to have a proportion of electricity generation at the level of 2005. (about a half of the total annual electricity production in Ukraine).

This decision is justified, primarily, because of the availability of own raw uranium resources, because of a stable work of NPPs, the potential of the country for the establishment of nuclear power capacity, available technical, financial and environmental problems of thermal energy.

Image Zaporizhzhya NPP. Energoatom. 2010

The world experience of nuclear power reactor systems and operation of water-cooled type of reactor in Ukraine can make a choice for new construction in favor of power reactor facilities with pressurized water, i.e. type of PWR /VVER. Estimated level of unit capacity of new nuclear units should be from 1000 to 1500 MW. The principal decision on the choice of power and types of new units will be based on:

- further assessment of conditions of power system of Ukraine;
- comparison of technical and economic indicators;
- assessment of the development and deployment of exploitation of units in other countries.

During selecting the type of power unit, to the specific site, the same type power units should be provided. A principle of homogeneity should be followed within the time period of 3-5 years.

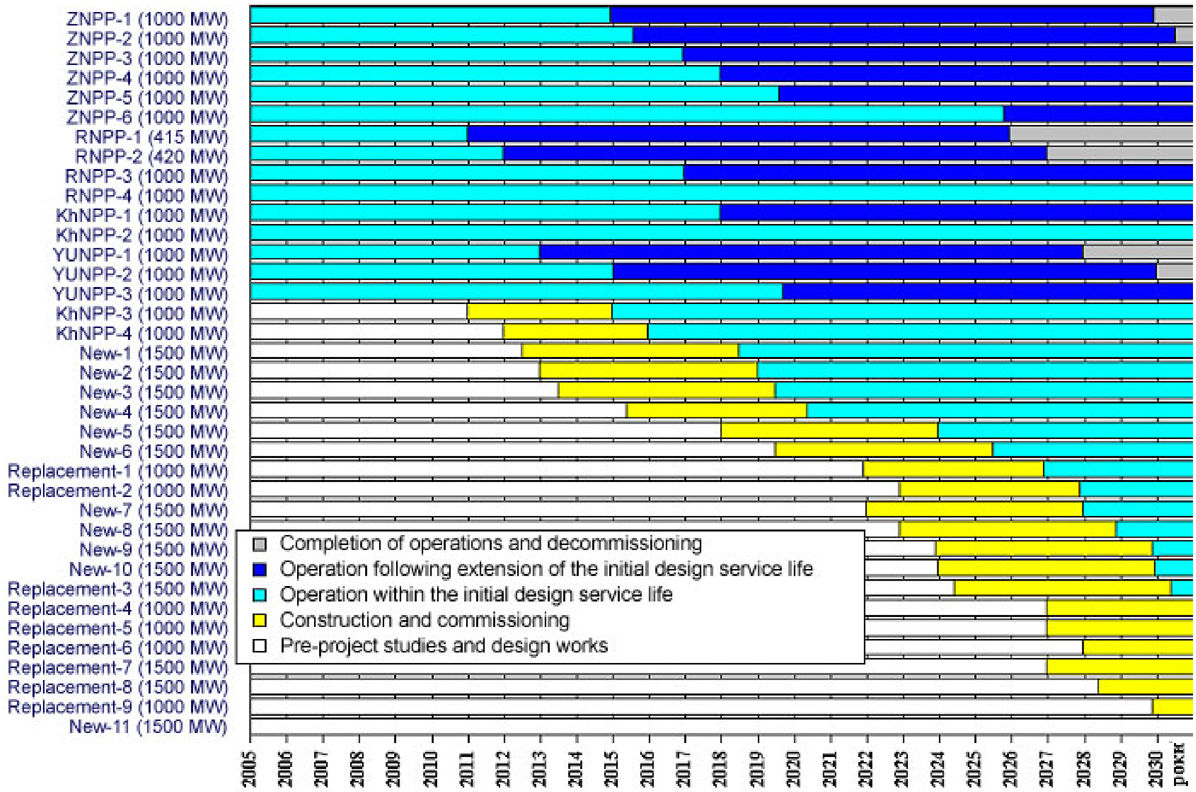


Figure. Construction and Commissioning of nuclear power units. Strategy of development of power and energy complex of Ukraine. 2006

Till the end of 2016 it is planned to put in exploitation power units number 3 and number 4 of Khmelnitsky NPP.

In building construction schedule and the introduction of generating capacities of power generating facilities accounted cycle - roughly 12 years, a period covering the implementation of all phases, from design feasibility study (design, construction, commissioning) as well as implementation of the relevant permit procedures at each stage. Moreover, for power units, which will be constructed before 2021, the duration of this cycle is to reduce for 2-3 years.

There is a necessity for improvement of fuel efficiency by completing the transition to the 4-year and the next transition to a 5-year fuel cycle, reduce the duration of preventive maintenance by optimizing the frequency of their conduct and to improve the quality of work. It is important to implement measures for the modernization and reconstruction of basic equipment and systems plant, to fully implement measures to extend the period of operation, above all, the elements which change is impossible or extremely costly. Necessary to ensure effective decommissioning of nuclear units at the stage of completing their life cycle and the timely construction of new facilities to supplement and replace those that are removed from service required (energy, 2006)

- Ensure, started from 2006, work on the rationale and the choice of 3-4 new sites for construction of nuclear power;

- To finalize the feasibility study for the construction of new sites in the years 2013-2021 units with total capacity of 6 GW;

- To justify and decide on the extension of power unit № 1 of Rivne NPP beyond the designed limit.

In the period 2011-2030 should:

- Put into operation before the end of 2016 2 GW of new capacity at the site Khmelnitsky nuclear power plant units number 3 and number 4;

- To be commissioned in 2019-2021 of new sites 6 GW nuclear power plant;

- To continue the service life of power unit № 1, № 2, № 3 South-Ukrainian NPP, № 1, № 2, № 3, № 4, № 5 and № 6 Zaporozhye NPP, № 2, № 3 Rivne nuclear power plant and number 1 Khmelnitsky NPP in over the project period;

- Put into operation in the period 2024-2030 replacement and additional power plants with total capacity 12.5 GW;

- To begin works on the decommissioning of 6 nuclear units after completion of their prolonged service life;

Moreover, in the period 2027 – 2030 years to begin construction of 6.5 GW of new nuclear power plant (energy, 2006).

Releases to the environment of pollutants from nuclear power plants are insignificant. The individual dose of the population of plant operation does not exceed a norm. Actual quantities of emissions of radioactive substances NPP amounts to less than 10% of this quota. At this time, the collective dose received by the population of Ukraine from the production of electricity at thermal power stations, significantly greater than that from electricity production at nuclear power plants.

Further ensuring environmental safety of NPPs will be implemented through improved systems of local, regional and global monitoring and forecasting of radiation, a periodic reassessment of the effects of nuclear power plants on the environment, more stringent requirements of radiation security.

Progress at Ukrainian NPPs safety level corresponds to the level of safety of nuclear power plants of the same generation in other countries. Nevertheless, the potential to improve the safety of domestic nuclear power is not exhausted.

Priorities for improving nuclear and radiation safety for the next 3-5 years should be aimed at ensuring secure management functions of nuclear reactions, heat release from a reactor, and the retention of radioactive materials and radioactivity in the allowed limits.

Nuclear Fuel for NPP

Nuclear fuel for Ukrainian nuclear power plants is supplied by Russia. In order to diversify sources of supply of nuclear fuel in August 2005 on the power unit № 3 South-Ukrainian NPP plant started operation research 6 heat-radiating assembly of American production (made by Westinghouse). After the research operation of the heat-radiating assembly, there is a possibility of purchase of heat-radiating assembly for Ukrainian nuclear power plants on the basis of tenders from the two suppliers that will produce fuel, licensed for use in the Ukrainian nuclear power plants.

To reduce dependence from import of energy resources, government took a decision for production of own nuclear fuel for nuclear power plants. The program approved by Cabinet of Ministers of 12.04.1995 № 267 and from 06.06.2001 № 634-8.

According to a program of development it is planned:

- To increase a production of uranium concentrate to 100% of the demand for uranium plant in Ukraine;

- Development of zirconium production in the volume needs of Atomic Energy of Ukraine and Russia;

- Organization of Ukrainian production of zirconium metal and components TIS in the volume needs of Ukrainian NPPs.

Actual funding of the nuclear fuel cycle is only 20% of the planned volume, so to solve certain problems the program fails.

In world practice there are three main ways of ensuring nuclear fuel:

- The purchase nuclear fuel on the world market;

- Production of nuclear fuel on its own;

- Production of nuclear fuel in cooperation with other countries.

The acquisition of technologies for the production of all components of nuclear fuel has not only the engineering and economic aspects, but also political. (Ukraine is interested in modern technologies for uranium processing, 2007)

According to the strategy of Ukraine a sphere of nuclear fuel production is aimed at:

- Development of uranium production for the needs of Ukrainian NPPs in the concentrate of natural uranium;

- Development of production of zirconium, zirconium alloys and components for heat-radiating assembly;

- Construction plant heat-radiating assembly.

At present, Ukraine's nuclear energy needs are met through domestic uranium only by 30%. Therefore, one of the most important tasks of the uranium industry in Ukraine is an increase in concentrate production of natural uranium at least for full satisfaction of the needs of domestic nuclear power plants (Ukraine is interested in modern technologies for uranium processing, 2007)

Image . Location of the Nuclear Fuel Cycle Facilities in Ukraine. Ministry of Fuel and Energy. 2006

On the territory of Ukraine locates one of the largest in the world uranium – mining provinces. There are a number of features that ensure the competitiveness of the produced uranium concentrate:

- Large amounts of uranium deposits, which apply high-performance systems of production;

- High strength bearing rocks, which allows to pass mine workings without fixing and cleaning power to pass large volumes;

- Small water inflows to the mine workings;

- Relatively simple measures of radiation protection due to low content of uranium in ores.

Proved reserves of natural uranium in Ukraine allows to meet the needs of existing nuclear power plants by more than one hundred years, and in case of a transition to the use of reactor systems for fast neutron potential of domestic uranium reserves will increase by 60-70 times.

Insufficient funding in 1995 - 2005 led to a critical point of the uranium industry and backlog for the introduction of new mines. For existing mines derailed commissioning dates for new horizons, there is a critical deterioration of production equipment.

Conditions which have the prospect of Ukraine, as a major world producer of natural uranium, are a stabilization of the existing production capacity with a phased increase in production capacity for uranium

Further growth in output is expected due to development of new deposits.

The main producers of zirconium products in the world are the United States, Russia, France, Britain, Germany, Canada. Ukraine also has the opportunity to develop the production of zirconium as a raw material base (DP "Volnogorsky

Mining and Metallurgical Plant, Dnepropetrovsk reg.) Research and production of nuclear grade zirconium alloys in DNVP" Zirconium ". Financing Development Program YAPTS in the period 1995-2005 allowed only to preserve the assets DNVP "Zirconium", launched in 2003 the production of zirconium tetra fluoride. DNVP design capacity "Zirconium" – zirconium tetra fluoride 250 tons per year, representing 100% of the demand for the production of Great Plain for nuclear power plants in Ukraine, attained in 2006. (Power energy strategy of Ukraine till 2030, 2006)

Further development of the zirconium production associates with the choice of production technology of rolled zirconium and tube blank. Start a nuclear fuel production is associated with the development of zirconium production facilities, availability of technology to produce nuclear fuel and the economic justification for the term beginning this production.

In Ukraine, developed and implemented the program to ensure continuous development of the region extraction and primary processing of raw uranium for the year 2006-2030 and approved by Cabinet of Ministers of Ukraine dated 16.12.2004 № 1691, which also includes the implementation of measures to improve the environment. (nuclear energy, 2009)

For development of promising technologies of new reactors facilities and nuclear fuel cycles for nuclear energy, Ukraine takes part in the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) under IAEA auspices. It is advisable to provide Ukraine's participation in the project of the International thermonuclear experimental reactor (ITER).

Spent Nuclear Fuel Management

Spent nuclear fuel management (SNFM), as well as the RW management process, is a subject that is always in the focus of public attention. For SNF of the Ukraine’s NPPs, it envisaged to implement the so-called “deferred” option that implies long-term (up to 50 years or even longer) storage of SNF until a final decision on its processing and/or disposal is made and approved.

In addition, it is important to provide the following: safe operation of the storage site for “dry” spent nuclear fuel (DSNF) at Zaporizhska NPP; establishment of a central DSNF storage facility designed for the SPF produced by VVER-440- and VVER-1000-type reactors of the existing NPP and for the SNF of new nuclear power units, with an objective to have the central DSNF storage facility commissioned in the close period; development of a strategy and techniques for safe SNF management after their long-term storage is over. (Spent nuclear fuel in NPP, 2009)

Radioactive Waste Management

Serious problem for the Ukrainian nuclear power plants is to prepare for decommissioning and the management of spent nuclear fuel and radioactive waste.

No progress has been made in Ukraine so far to develop and implement a national Radioactive Waste Management Strategy. This is a primary reason why the current RW management activity is limited to the existing NPP sites. As of today, the problem of RW handover for disposal remains unsolved. Analyses of existing opportunities for RW disposal in temporary storage facilities at sites of each operating NPP and studies of the existing and developed RW management systems suggest that the year of 2020 should be a deadline for disposal of the operational RW. In case of the Zaporishska NPP, special additional decisions need to be made to establish a safe interim storage for solidified radioactive wastes.

It necessary in close time period to develop the basic technical solutions of the treatment and long-term storage of radioactive materials and implement priority activities to ensure the reception and handling of radioactive waste from reprocessing spent fuel that is returned from Russia. (Radioactive wastes: zone of risk and way out)

1.1.2 Thermal power

At this time, 92,1% thermal power plant units have worked out their current resources (100 thousand hours), and 63,8% of thermal power units according to the global energy practice, crossed the boundary of a limit of the resource life 170 – 200 thousand hours and need a modernization or replacement.

Annually at 70 – 80 thermal power units with total capacity of around 19 million kW are under repairing work, it is needed to ensure uninterruptible operation of TPP power unit equipment. However, the funds allocated for this purpose are insufficient, which results in lowering the level of TPP equipment operation, over-consumption of fuel and downturn of economic performance.

Thermal power stations will remain the basis of the power system of Ukraine at least until 2030. It is expected gradual decline in excess capacity to bringing them to the best value in the years 2015-2017.

In the development of thermal power is planned in 2011-2020 acquire investments in the amount EUR 11.8 billion, and in 2021-2030 – EUR 14 billion.

According to the program of development of thermal power energy it is planned (Usenko, 2008):

- Within the period of 2011-2020:
  - to rehabilitate TPPs units with 4.0 thousand MW capacity;
  - to decommission units of 2.0 thousand MW total capacity;
  - to renew and put into operation TPPs units with the capacity of 10.0 thousand MW by means of replacement of main equipment of operating power units and construction of new ones;
  - to put into operation new generating units of CHPP with the capacity of 2.0 thousand MW.

Required volume of capital investments for 2011-2020 is EUR 11.8 billion.

- Within the period of 2021-2030:
  - to rehabilitate TPPs units of 5.4 thousand MW capacity;
  - to decommission units of 1.0 thousand MW total capacity;
  - to renew and put into operation TPPs units with the capacity of 10.0 thousand MW by means of replacement of primary equipment of operating power units and construction of new ones, including instead of decommissioned units;
  - to put into operation new generating units of CHPP with the capacity of 2.0 thousand MW.

It is expected to increase utilization of the working capacity of thermal power plants to 55,4%, bringing the unit cost of fuel for electricity production to the European average.

Complete reconstruction of the coal-fired power plants in Ukraine will be implemented through the introduction of modern economic coal-fired steam-turbine power units are equipped with systems to reduce emissions of NO_x (nitrogen oxides), SO_2 (sulfur dioxide) and dust and gas CHP with coal gasification, high pressure boiler and others to focus on the maximum use of domestic coal, including technology and equipment for the combustion of brown coal.

For generation of electric and heat energy by Thermal (TPP), Heat electric power station (CHPP) was used 37.0 million tons of standard fuel. From this volume coal – 51.8%, gas – 47.4%, fuel oil – 0.8% were consumed in 2005 for generation of power and heat by TPPs, CHPPs and local generating plants (taking account of local sources).

When considering supply of fuel to the electric power sector it is necessary to take into account gradual rise in prices for fossil fuels, which is caused by the following forces:

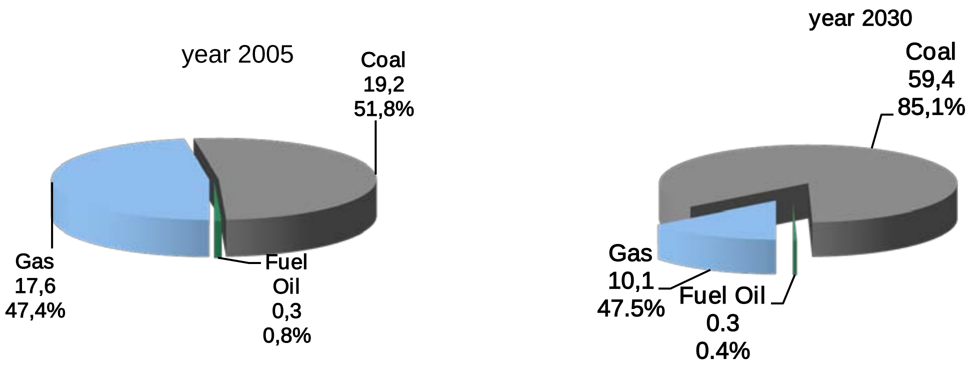
- increase a price for natural gas, due to increase in respective demand, as the most environmentally acceptable and efficient type of fossil fuel, increase in main exporter-countries (first of all Russia) costs of production and transportation of natural gas to Ukraine, as well as transition to the market oriented pricing principles;
- increase price for coal is based on increase in the investment component of the cost of domestically produced coal due to replacement of fixed assets in the sector, as well as due to the wage rise component. Gradual increase in world prices for coal is forecasted as a result of rise in price for natural gas. At the same time the rate of rising in coal price are supposed to be considerably lower than the rate of rising in natural gas price.

The rate in rising fuel oil price is forecasted to be pretty close to that of natural gas price.

Until 2030 the absolute consumption of fossil fuel by TPPs, CHPPs and local generating plants (taking account of local sources) will be increased in 1.9 times, from 37 million tons of standard fuel in 2005 to 69.8 million tons of standard fuel in 2030. At the same time coal consumed for the power and heat generation will increase to 85.1% while the natural gas consumption will correspondingly decrease to 14.5%.

The dynamics of changes in the structure of fuel thermal power resources following diagram illustrates.

Table. Forecasted Fuel Balance for TPPs, CHPPs and Local Generating Plants (taking account of local sources) until 2030 (million tons of standard fuel).



In the field of ecology major challenges will be: reduction of pollutant emissions (particulates, sulfur dioxide, nitrogen oxides) and greenhouse gases into the atmosphere, preventing (minimizing) pollution of surface and underground waters, including the heat on the surface water, reduce pollution of land, land, which were allocated for energy facilities, reclamation of land occupied by objects that have exhausted their resources for their further use.

In 2011 –2020 and later the main factors in reducing emissions of particulate matter will be further improved efficiency of ash collection to 99,8 – 99,9% during the reconstruction of existing thermal power plants, introducing the latest technology of solid fuel combustion and dust cleaning.

Emissions of sulfur dioxide in the near future will be governed by the content of sulfur in fuel used and in the future, in the years 2011 – 2020. Reducing these emissions will be achieved by the introduction of mainly low-cost (to the level of efficiency 50 – 70%) of sulfur sequestration technologies during the reconstruction of existing thermal power plants and advanced coal technologies based on boilers with circulating boiling layer. In the longer term - reduction of specific emissions of sulfur dioxide in flue gases of thermal power plants will provide the latest technology of solid fuel combustion and gas cleaning.

Reducing emissions of nitrogen oxides in the period between 2010 and 2020 will occur through the introduction of classification regime of technological measures for thermal power plants and boilers, and later the main directions to reduce the specific emissions of nitrogen oxides will also have the latest technology of solid fuel combustion and gas cleaning. (Power energy strategy of Ukraine till 2030, 2006)

1.1.3 Hydro Power Plants

The installed capacity of hydropower plants in the power system of Ukraine is 4 736 MW, including Kiev and the Dnieper hydro power plant – 3 887 MW, Dniester HPP – 743 MW and small hydropower stations – 95 MW.

In the balance of power hydroelectric power system of Ukraine does not exceed 9,1%, against 15% of optimal, which determines the deficit as shunting, and regulatory capacities.

World Bank granted a loan, and the Government of Switzerland – a grant to upgrade equipment Dnieper hydro cascade for the total amount of $ 53 million. The program is designed for Reconstruction until 2012. After its realization the Dnieper hydroelectric station will be able to work safely and reliably even during the 40 – 50 years, with an additional annual production of electrical energy of about 300 million kWh.

To increase the extremely scarce for the country's energy regulatory and shunting facilities, creating favorable conditions for the integration of IPS of Ukraine to the European energy system and increase the export of electricity taken such lines of development of hydropower:

– Completion of construction of power plant the total capacity of 4074 MW;

– Continuation of the reconstruction of the Dnieper hydro cascade and Dniester HPP with a view to lengthening their life extension of 30-40 years;

– Construction of hydroelectric stations on the rivers Tisza and the Dniester and its tributaries;

– Reconstruction of existing, restore broken and construction after 2010 of new small hydroelectric power stations on small rivers and drains with bringing electricity to them prior to 3338 million kilowatt hours by 2030 against 325 million kWh in 2004.

For realization of listed about actions, for the period until 2030 industry needs EUR 2.5 billion of investment, of which Euro 100 million is a financing of "Energoatom" for completion of Tashlitskaya Hydro accumulating power station.

To perform the tasks outlined from hydropower development to implement the following measures:

- Create conditions for investment attractiveness hydro energy objects;

- Develop and legislate a system of state support of small hydropower;

- To create a competitive domestic equipment for small hydropower.

In the case of completion of certain tasks of strategy 2030, total capacity of hydro power plants will increase to 10 500 MW. The total production of electricity at these facilities (including hydro accumulating power plant - 4,5 billion kWh, about 15%) will reach 18.6 billion kWh (Aanalytical review of power-energy complex of Ukraine, 2005)

1.1.4 Non-conventional and renewable sources of electricity

The development of alternative and renewable sources of energy (ARES) should be regarded as an important factor in enhancing energy security and reducing anthropogenic impact energy on the environment. Large-scale use of renewable energy capacity in Ukraine is not only internal, but also considerable international importance as a major factor impeding the global climate change the planet, improve the overall energy security of Europe. Therefore, the path and direction of strategic development of renewable energy in the country should promote joint efforts of the European Community on energy and meet the basic principles of the Green Paper "The European strategy of constant, Competitive and Secure Energy"

Technically achievable annual energy potential of renewable energy in Ukraine in conventional fuel represents about 79 million tons unitary fuel (u.f.). Economically feasible potential of these sources is 57,7 million tons unitary fuel, including natural sources of renewable energy - 35,5 million tons of standard fuel, off-balance sheet (nontraditional) - 22,2 million tons u.f.

At this time, the potential is not enough. A particle of renewable energy in the energy balance of the country is 7,2% (6,4% - off-balance sheet sources of energy; 0,8% - renewable sources of energy). (energy, 2006)

Table. Indicators of the use of renewable energy for the main directions of development, million t u.f. / year. Fuel and energy complex of Ukraine. 2006

Areas of development of renewable energy	The level of development of renewable energy for years			
	2005	2010	2020	2030
Off-balance sheet sources of energy, everything.	**13.85**	**15.96**	**18.5**	**22.2**
including coal mine methane	0.05	0.96	2.8	5.8
Renewable sources of energy, total, including	**1.661**	**3.842**	**12.054**	**35.53**
Bioenergetics	1.3	2.7	6.3	9.2
Solar Energy	0.003	0.032	0.284	1.1
Small Hydropower	0.12	0.52	0.85	1.13
Geothermal Energy	0.02	0.08	0.19	0.7
Windenergy	0.018	0.21	0.53	0.7
Total	**15.51**	**19.83**	**30.55**	**57.73**

Prospective development of renewable energy in the country, founded under the principles of the Green Book, should be based on economic competition with other energy sources with the simultaneous introduction of measures of state support of promising renewable energy technologies, which represent the public interest for enhancing energy security, environmental hygiene and combat global climate change.

Promising directions for the development of renewable energy in Ukraine are: bioenergetics, production and utilization of coal mine methane, the use of secondary energy resources, off-balance sheet deposits of hydrocarbons, wind and solar energy, thermal energy of the environment, development of economically viable hydro potential of small rivers of Ukraine. On the basis of renewable sources weighty development are technologies for both thermal and electrical energy.

The use of methane for heating and electricity generation provides the replacement of 5,8 million ton of unitary fuel at the period by 2030 ,however, will improve ecological conditions.

Alongside this, it is anticipated a further increase in natural gas use of small fields, gas condensate fields and associated gas for electricity and heat production, electricity production from blast overpressure and natural gas to 1.3 billion kWh in 2030. Using the heat of the environment through heat pumps and thermo transformers are one of the most efficient and clean lines of low-temperature heating systems, which is widespread in the global energy sector.

In recent years there is a prospective for world trend in increasing of generation of solar energy. In 2005, world production of silicon solar energy converters has reached 1.8 GW, but in 2030 Europe plans to master the production of 200 GW of solar modules with a significant decrease in the cost of electricity. Ukraine has tried and tested technologies production of solar modules, which carry out the transformation of solar energy into electricity using photovoltaic devices based on polycrystalline silicon, and exports them to Europe. Ukrainian companies with adequate funding for 1-2 years can learn the serial production of large quantities of solar photo module, significantly reduce the unit costs of silicon and the cost of electricity.

Alternative and renewable sources of energy potentially are cost-effective, but the country lacks sufficient for industrial applications experience in large-scale industrial operation.

As state support, especially in the provision of concessional investment needs in the development of renewable energy such as wind power, solar electricity, recycling of livestock and poultry, raw sewage in obtaining the energy effect, small hydropower, biofuel production and the like.

The development of renewable energy needs in the legislative creation of an enabling environment for investment and appropriate government support the development and introduction of competitive technologies and equipment samples, put them into production and on the basis of further increasing the use of alternative and renewable energy sources, ensuring free access to electricity power producers to renewable energy.

In general, the projected level of development not traditional renewable energy generation (NREG) sites will provide a significant effect of reducing the use of traditional sources of energy, and emissions of harmful greenhouse gases. He is in the best performance in the world practice, the principles of the Green Paper on the prospective level of use development not traditional renewable energy generation in the countries - members of the European Union.

1.2 Electrical Energy Market of Ukraine. Structure of the electricity owned enterprises

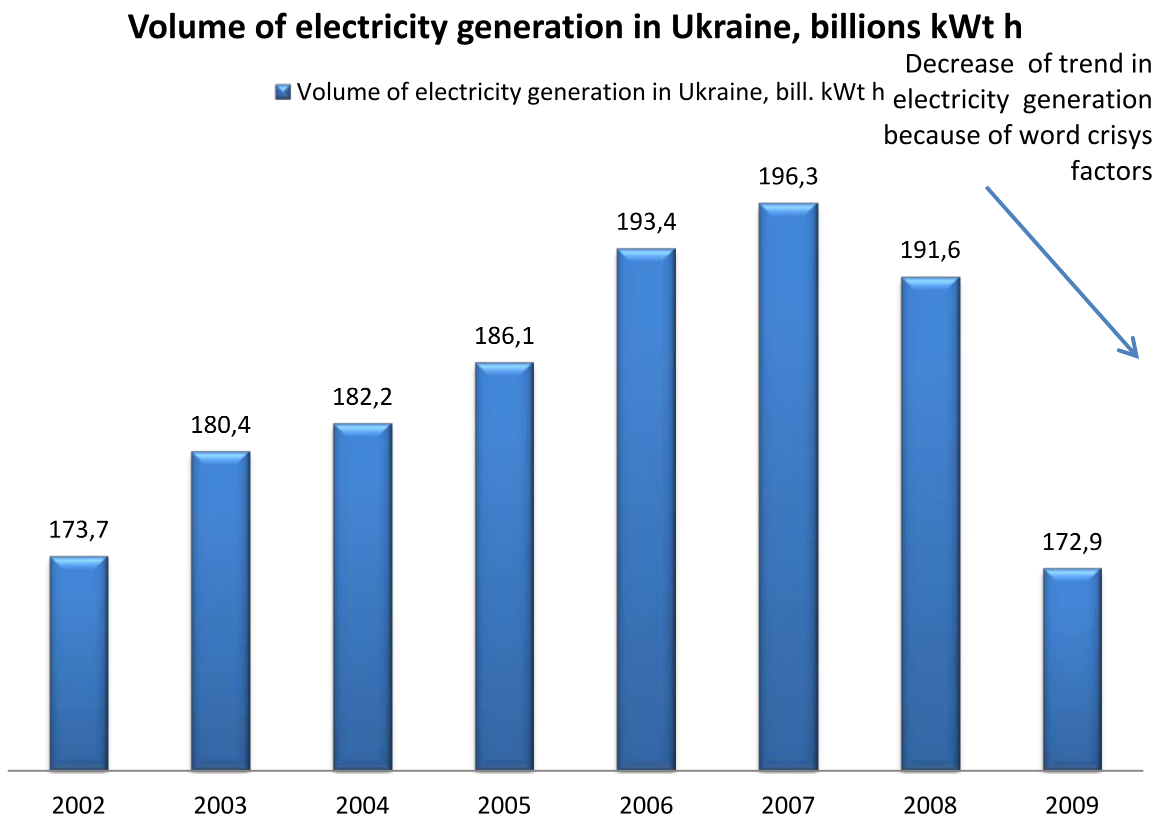
Ukrainian market of electricity in 2009 was 173 000 mln. kWt.h and share of electricity generation by NPP was almost 50% of all generated electricity in the country (47,5%). The main producers of electricity are 14 powerful thermal, 8 hydraulic and 4 nuclear power plants. In the first chapter about “Structure of electricity owned enterprise” is possible to get more detailed information about this.

11 thermal power plants enters into four joint-stock power generating companies with state share over 70% of the shares that are subject to national joint-stock company "Energy Company of Ukraine", and three power plants owned by a private company.

Eight hydraulic power plants belong to united state joint-stock company of hydro generation “Ukrhydroenergo”, four nuclear power plants – National Nuclear Energy Generating Company "Energoatom".

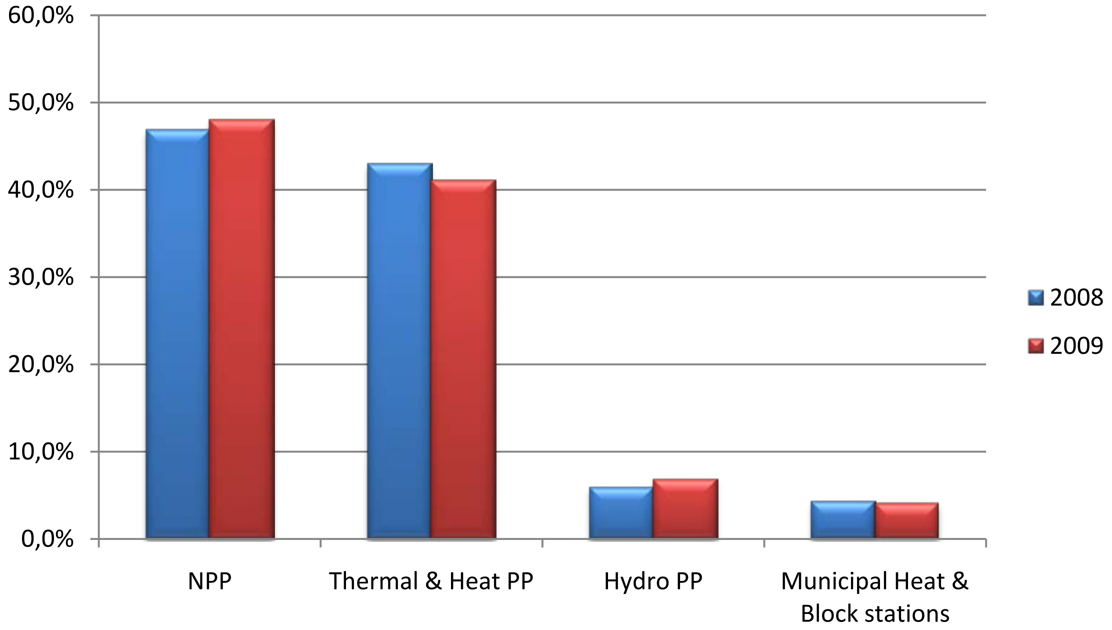
The transportation of electricity from power generating companies in the power supply to the power consumers, as well as supervisory control functions of the United Energy System of Ukraine (national energy company), provides “Ukrenergo”, which consists of eight regional electric power systems.

Table. Volume of electricity generation in Ukraine. Ministry of statistics. 2010



In 2009 Ukrainian power plants generated 172 900 mln.kWt.h and consumed 169 009 mln kWth, which is 10% less than in 2008. It was because of decrease of consumption in 9%, which is associated with world economic crisis. But from 2010 situation changes and in the period January – April 2010 a total consumption of electricity increased on 10,3% or 6017 mln kWth (in April 14,6%), consumption by industrial enterprises increased by 18,7% or 3786 mln.kWth. comparing with 2009. (Electric energy in Ukraine, 2010)

Table. Share of electricity generation of Ukraine by NPP and other producers in 2008 – 2009. Electric energy in Ukraine. 2010



According to the official data of Power and Energy complex of Ukraine, share of NPP, in structure of electricity generation, in 2009 was 48% (in 2008 – 46,9%), Thermal power plants and Heat stations – 41,1% (in 2008 – 43%), Hydro power plants 6,8% (in 2008 – 5,9%), municipal Heat stations and Block-stations – 4,1% (in 2008 – 4,3%). Analyzing data of 2009 and 2008 is possible to see a trend of increasing generation electricity capacity by NPP and decreasing of generation by other power plants. (Electric energy in Ukraine, 2010)

Table. Historical value of the price of EE paid to NPP in recent years

Name	Unit	2007	2008	2009	F 2010
Tariff on electricity for NPP of "Energoatom" (average annual)	EUR./kWt.h	0.013	0.017	0.0125	0.015
Tariff on electricity for NPP of "Energoatom" (average annual)	GRN./kWt.h	0,0942	0,1222	0,1384	0,1583

Trend of a price for 1 kWt.h shows annual increase. Only because of difference in exchange in Euro currency a forecasted price of 2010 seems to be lower than in

2009. Moreover, a government announced about policy of increasing a price for final electricity consumers. Thus way for example person, which consumes less than 150 kWt.h will pay normal tariff – 0.23 EUR/kWt.h. and for those people (physical persons), who will consume over a norm of 150 kWt.h. will pay 0.07 – 0.08 EUR/kWt.h. Till today information about increase in electricity tariffs was announced only for population consumers (families).

A necessity of upgrading of electricity price is accepted also by Ukrainian Parliament responsible for power – energy complex. They tell that a price for electricity for population increased on 88%, when a price for gas increased on 418%. (Ukraine intends double increase prices for electricity, 2010)

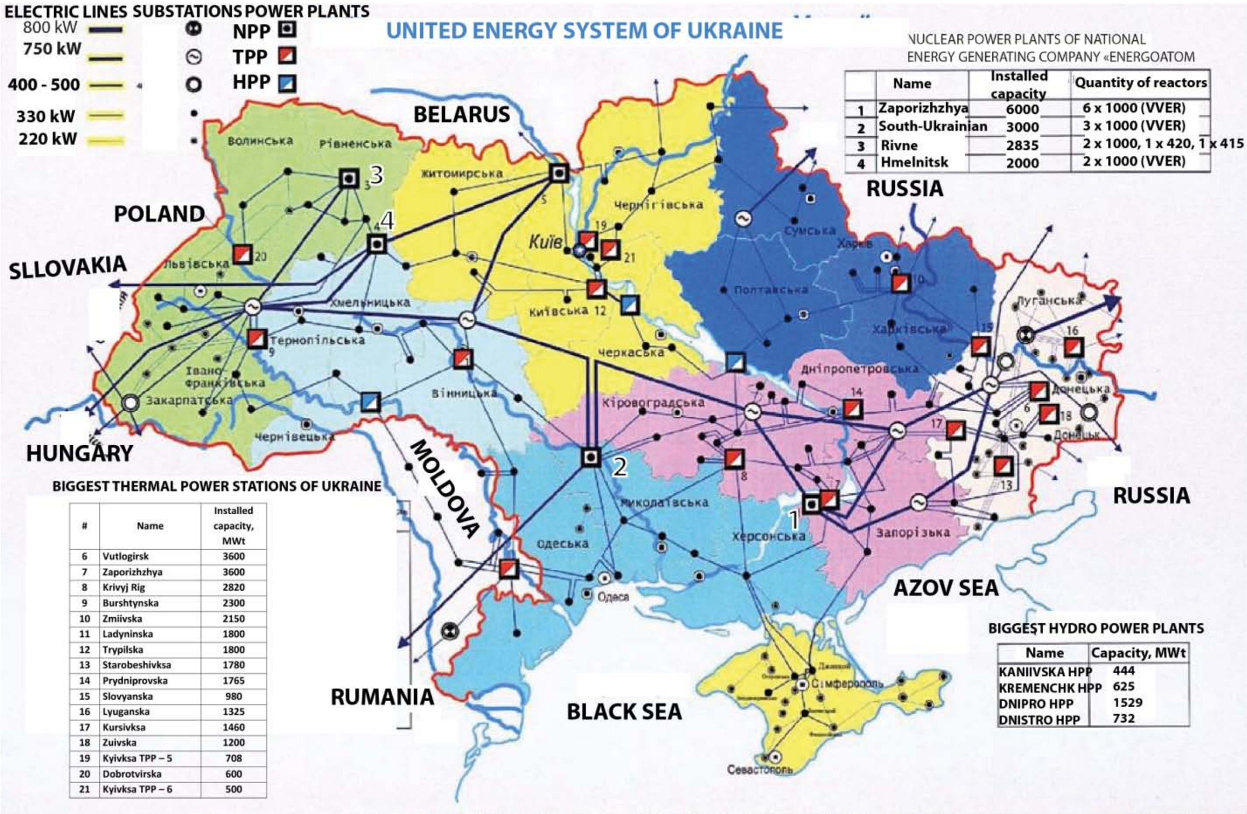
Transmission of electric energy distribution networks carry 43 vendors on the regulated tariff, of which 15 are Joint Stock Company with state particle shares over 50%, corporate governance, what has the National Joint Stock Company "Energy Company of Ukraine" within the stakes, which remained in state ownership.

In industry, the nuclear fuel cycle in Ukraine has four major state-owned enterprises of uranium and zirconium production, scientific and design institute “Ukrniipromtehnologiya”.

1.2.1 Generation structure

The electric power industry is a basic sector which meets domestic needs in electric power and is able to generate considerable volume of power for export. Total capacity of generating power plants in 2005 amounted to 52.0 million kW, of which 57.8% fell to thermal power plants (TPP) and combined heat and power plants (CHPP), 26.6% - nuclear power plants (NPP), 9.1% - hydro power plants (HPP) and hydro pumped storage power plants (HPSP), 6.5% - local generating plants and other facilities.

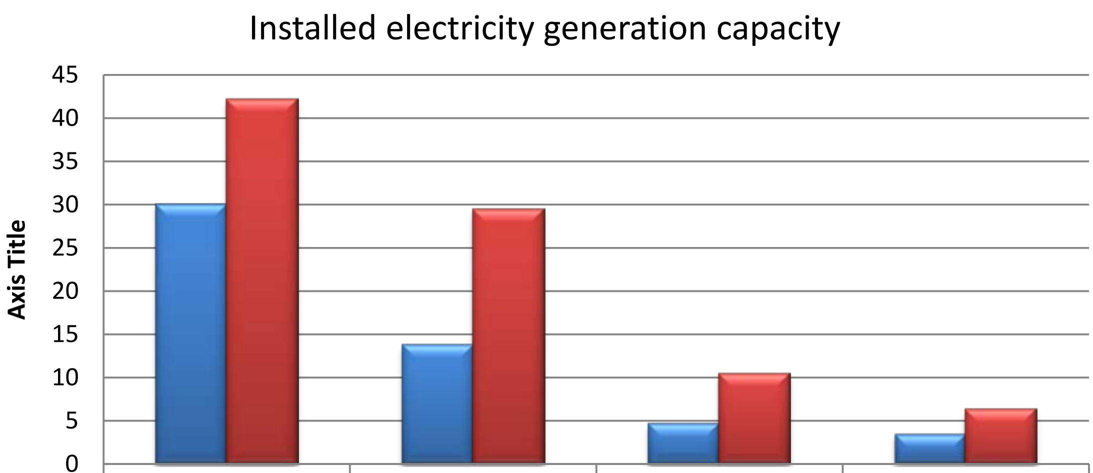
Image. United energy system of Ukraine. Fuel and energy complex



Capacity of generating power plants shall be increased to 88.5 million kW in order to meet power consumption and export demand envisaged by the base-case scenario of the national economy development until 2030. According to the worst-case scenario of the economy development this index may reach 74.9 million kW, according to the best-case scenario – 98.6 million kW.

Electrical energy generation capacities and its prospective capacities according to the Strategy of development till 2030 are shown bellow. (Power energy strategy of Ukraine till 2030, 2006)

Table. Structure of Generating Capacity of Ukrainian Power Plants (base-case scenario), GW

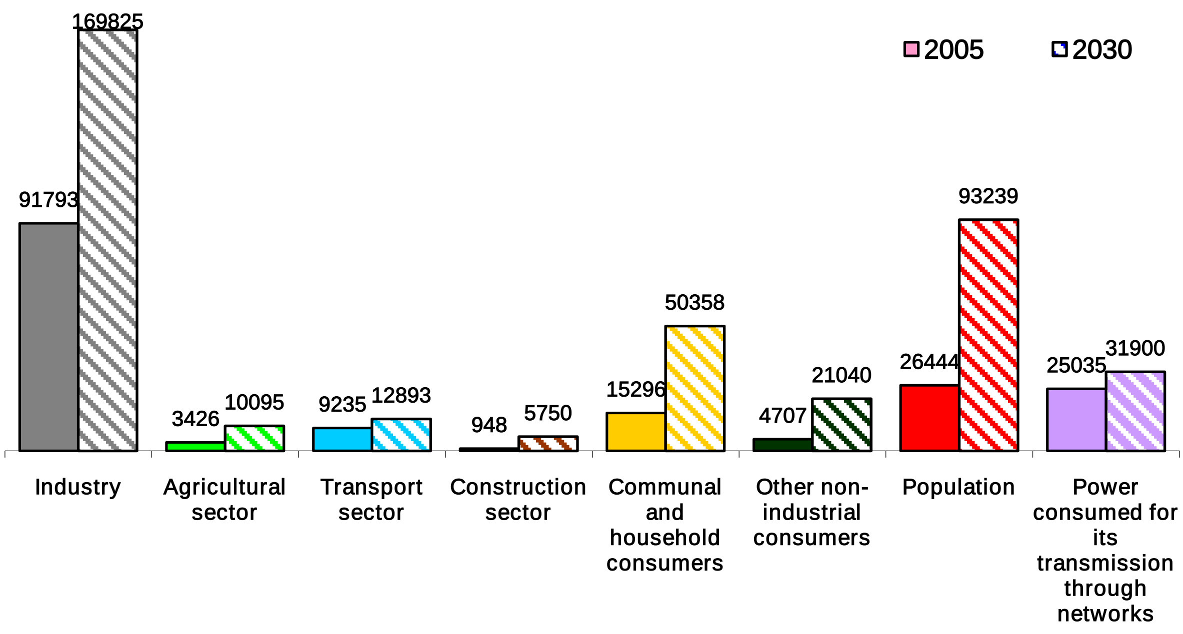


	TPP and CHPP	NPP	HPP	Local plants and other facilities
2005	30,1	13,8	4,7	3,4
2030	42,2	29,5	10,5	6,3

1.2.2 Structure of Electrical Energy Consumption

According to the base-case scenario the electric power consumption in 2030 is forecasted to reach 395.1 billion kWh. Compared to 2005 (176.9 billion kWh) the power consumption will increase by 218.2 billion kWh (123%). Industry will remain the largest consumer among Ukrainian economy sectors - its power consumption in 2030 is estimated to be 169.8 billion kWh (average annual increase will come to 2.4%). For the same period power consumption in the agricultural sector will rise almost three times (from 3.4 to 10.1 billion kWh). For the period from 2005 until 2030 power consumption in the construction sector will grow from 1.0 to 5.8 billion kWh, in the transport sector - from 9.2 to 12.9 billion kWh, in the housing and communal services as well as for residential purposes (including power heating) - from 41.7 billion kWh to 143.6 billion kWh.

Table. Forecast of Electric Power Consumption by Consumer Groups (million kW/hour)

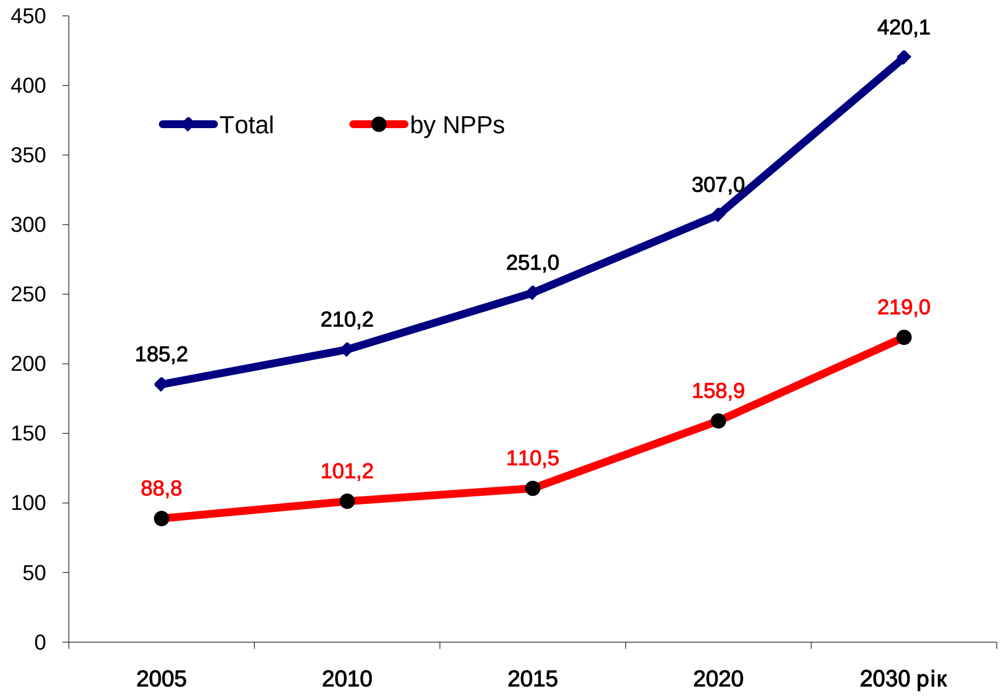


1.2.3 Electricity generation by NPP: nowadays and prospective

The Strategy assumes that the NPP share in the total national power generation reached in 2005 will be maintained on the same level during the period of 2006 to 2030 (that is about a half of the total annual electric power generation in Ukraine).

Decision on the above assumption was made primarily on the following grounds: availability of domestic uranium deposits; stable operations of the existing NPPs; and good potential opportunities for expansion of the power generation capacities at the NPPs, with due consideration for the present operational, financial and environmental problems faced by the thermal power engineering.

Table. Annual Electric Power Generation in Ukraine for the period of 2005 to 2030, billion kWh.



The forecasted NPPs generation of 219.0 billion kWh by the year of 2030 will require 29.5 GW of installed capacity operating with ICF of 85%.

Construction of new generation facilities at the NPPs in the period up to 2030 will depend on the number of existing nuclear units that may be kept in operation during this period, with consideration for the upgrade options intended to extend service lives of the units by 15 years. By the year of 2030, nine of the existing nuclear power units will still stay in operation, including 7 nuclear units with extended (over designed) service life (namely: Units #3, 4, 5 and 6 of Zaporizhska

NPP, Unit #3 of Rivnenska NPP, Unit #1 of Khmelnitska NPP and Unit #3 of Yuzhno-Ukrainska NPP) and 2 power units that were newly commissioned in 2004 (namely: Unit #2 of the Khmelnitska NPP and Unit #4 of the Rivnenska NPP). Therefore, to achieve objectives of Strategy about planned generating volume of electricity, in Ukraine till 2030 should be built 20 – 21 GW of new and substitutional capacities of NPP. (Development of new nuuclear power generation capacities, 2008)

Within the period of 2011 - 2030, the following works need to be completed:

- to commission, by the end of 2016, new power generation units with total capacity of 2 GW at Khmelnitska NPP (Power Units #3 and #4);
- to commission, within the period of 2019 - 2021, nuclear power generation facilities with total capacity of 6 GW on the new construction sites;
- to implement upgrade projects to extend the design service lives of Units #1, #2 and #3 of the Yushno-Ukrainska NPP; Units #1, #2, #3, #4, #5 and #6 of the Zaporizhska NPP; Units #2 and #3 of the Rivnenska NPP; and Unit #1 of the Khmelnitska NPP;
- to commission, within the period of 2024 - 2030, replacing and additional nuclear units with total capacity 12.5 GW;
- to start decommissioning of 6 nuclear power generation units when their extended service lives is over.

Table. Construction and commissioning of nuclear power generating capacities in Ukraine between 2010 - 2030. National strategy of development till 2030

	New capacities, MW	Replacement, MW	Decommissioning, MW
2010 – 2015	1000		
2011 – 2016	1000		
2012 - 2018	1500		
2013 – 2019	3000 (2 x 1500)		
2015 – 2020	1500		
2018 – 2023	1500		
2019 – 2025	1500		
2022 – 2026		1000	
2022 – 2027	1500		
2023 – 2027		1000	
2023 – 2028	1500		
2024 – 2029	3000 (2 x 1500)		
2024 – after 2030		1000	
2026 – after 2030			415 (Rivne NPP)
2027 – after 2030		2500 (1000 + 1500)	420 (Rivne NPP)
2028 – after 2030		2500 (1000 + 1500)	1000
2030 – after 2030	1500		3000 (3 x 1000)

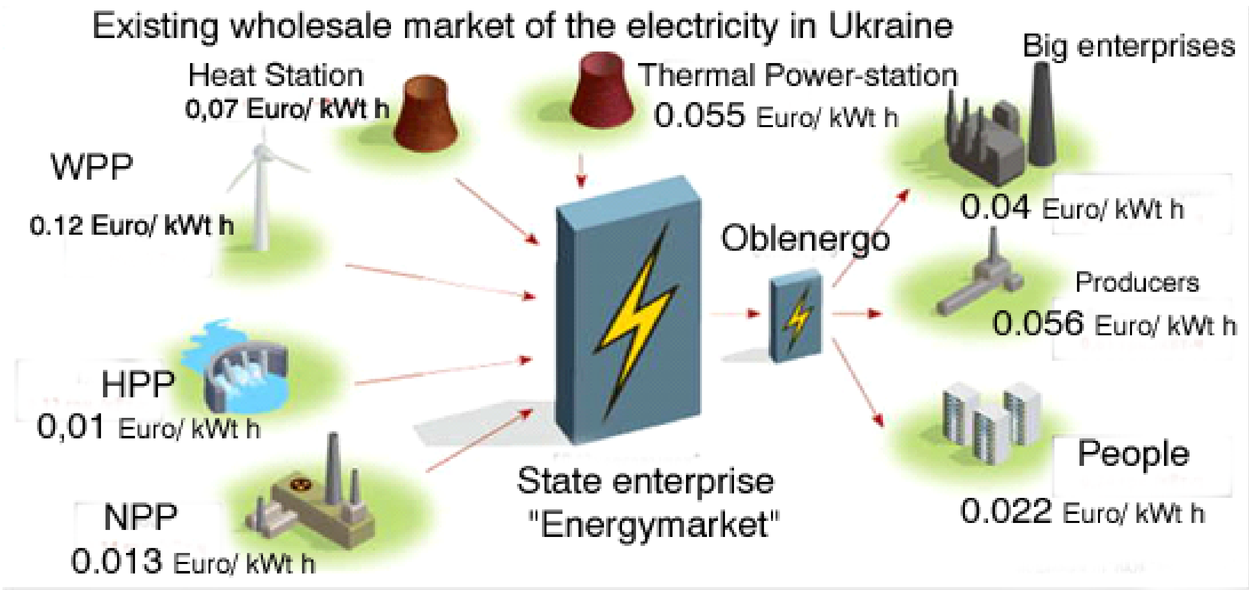
From analyzed data is possible to see, that in Ukraine between 2010 and 2020 is planned to build new 8GW of generating capacities and from 2021 and till 2030 – 9 GW of new power generation capacities and make a replacement by commissioning 2000 MW. Decommissioning of NPP will be started since 2026. In addition, special efforts need to be taken within the period of 2027 - 2030 to launch construction of new 6.5 GW nuclear power generation facilities, to have them put into operation after 2030. (Power energy strategy of Ukraine till 2030, 2006)

1.2.4 How a market of electricity works in Ukraine

All nuclear electric energy belongs to state enterprise “Energoatom”, hydro power plants – specialized enterprise “Ukrhydroenergo”. Thermal power plants belongs to 4 companies “West-energo”, “East-energo”, “Center-energo” and “Crimea-Energo”, shares of “Center-Energo” and 50% of “West-Energo” are in the private belongs to private property. Management of government electric grids (including international) belongs to jurisdiction of special created system operator “Ukrenergo”. (UkrBusinessCapital, 2010)

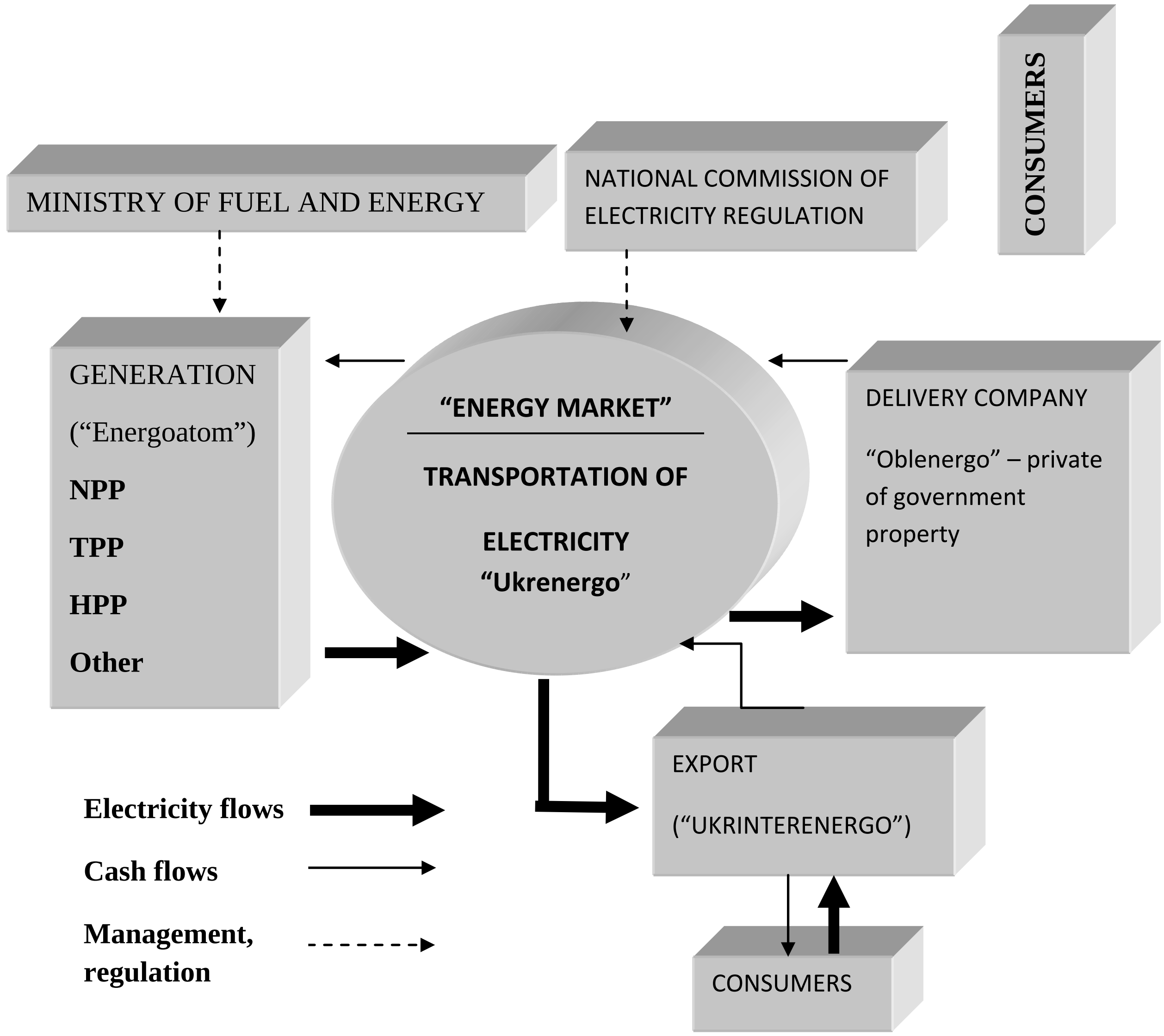
Today purchasing and selling of electric energy, generated in Ukraine, is made through one intermediary – “Wholesale electricity market of Ukraine”. Existing market, created in 1996, bases on the model of Pool of electricity of England and Wales, and time ago permitted to create fundament for implementing a competitive environment in the industry.

Image. Selling price of electricity generation companies in Ukraine in 2009. Committee of statistics. 2010



Bellow, there is a scheme, that describes a work of nowadays market of electricity, but soon there will be changes, because now there is a process of reforming of the market of electricity from existing model to new one, which will have bilateral contracts and other instruments that will make Ukraine a country with a market economy.

Table. Scheme of work of Wholesale electricity market of Ukraine



In years 90s, during a period of economical crisis, new created "Wholesale electricity market" faced with serious problems. First of all there were nonpayment, barter payment and critical high level of liabilities for electrical energy. Only a little part of electric energy was paid with money. With the aim of overcoming these problems in 2000 – 2001 by the government there was implemented a number of actions for providing a full payment for electrical energy. (Derzki, 2007)

However, from own and international experience it was understood, that a model, which is working has its disadvantages. Problems about pricing, decrease of administrative power for management of cash flows of wholesale electricity market, creating of reliable investments climate and effective market competiveness could be solved only because of radical changes in structure and principles of electric energy market.

1.2.5 Reforming of wholesale electricity market of Ukraine

In 2002 Ukrainian specialists with a help of international experts analyzed situation in the industry and created possible steps for further development. There was developed a “Concept of functioning and developing of a wholesale electricity market of Ukraine” (CMU, 2002), which supposed provision of activity by two directions:

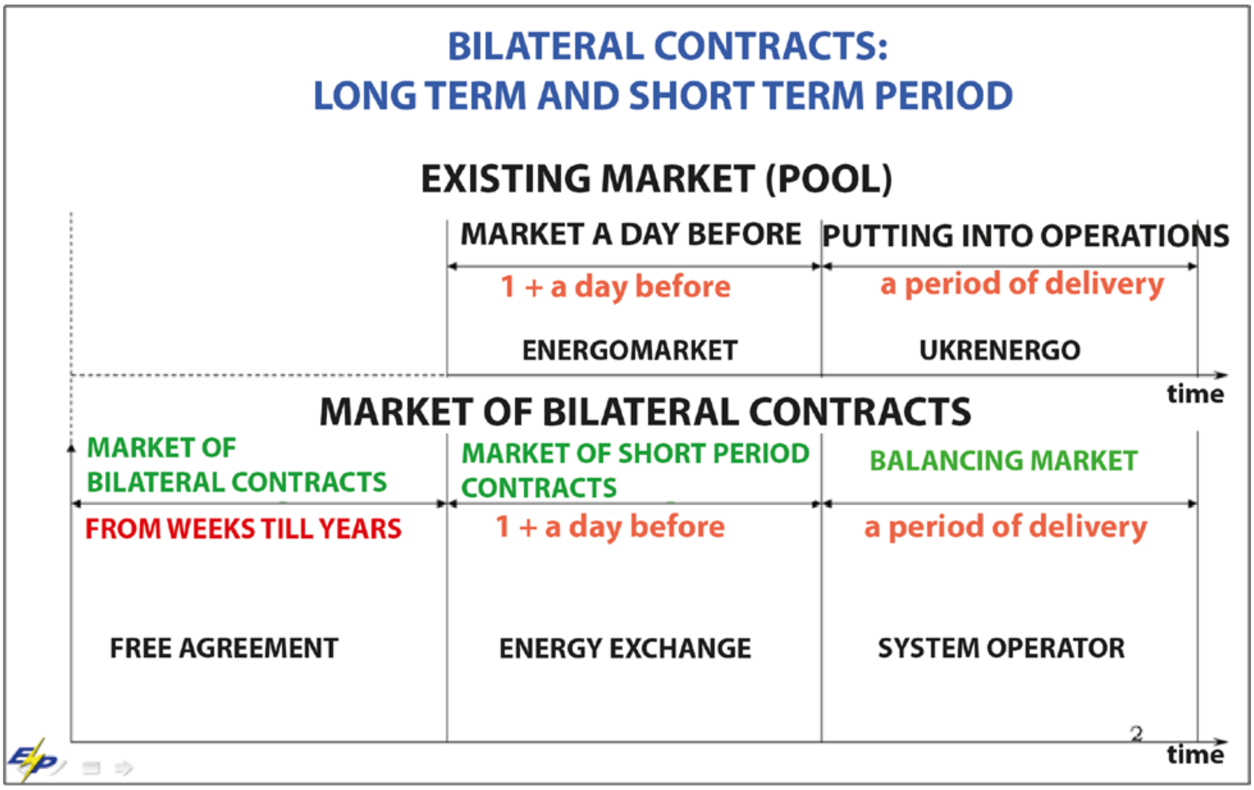
- realization of potential of existing market model, by solving current problems
- a step – by – step passage from existing model of “single buyer” in the electricity market to full scale competitive market of bilateral contracts with balancing market, which could satisfy balancing of demand and proposition in real time.

1.2.5.1 Segments of new coming competitive market

New model of work of wholesale electricity market, in comparison with existing one, will be based on bilateral contracts and will take at the same time several segments of the electricity market:

- Market of long-term contracts, where buyers will create contracts of sale of electricity, generally for a year, quarter of a year, week in advance.
- Market of short-term contracts or Energy Exchange, where buyers and sellers will make contracts for supplying of electricity for next 24 hours
- Balanced market, that is created for making propositions for electricity in real time or during 24 hours

Table. System of bilateral contracts. Ukrenergo. 2010



In a table above is shown illustration of work of wholesale market of electric energy for existing model comparing with work of the market with bilateral contracts and balanced market in a time period.

As a rule, buyer will try to use long – term contracts market, to fulfill its forecasted demand and volumes of purchase. Such process could be one – time or continuing, till entering to the market short – term contracts.

Market of short – term contracts will give a possibility to correct forecasted demand and contract supply on terms of more precise demand for the next 24 hours.

Balanced market provides parity between demand and proposition in a period of real time. (Vrublevski, 2008)

1.2.5.2 Participants of competitive market

Suppliers of electricity on the market could be:

- Energy generating companies (state and private)

- Commercial companies, which purchasing electric energy with purpose for its future reselling

Buyers on the competitive market could be organizations, which correspond to minimal consumption capacity, defined by the entering to the market (UkrBusinessConsulting, 2010):

- Final consumers of electricity
- Independent commercial enterprises (resellers), which purchase electricity for further reselling
- Distributing companies (particularly municipal), which own distributing networks and get electricity for further distribution to consumers connected to their network

1.2.5.3 Phases for reforming a market of electricity in Ukraine

There are 4 stages of process of reforming of the electrical power market

- Phase 1 – Initial studies

Creation of conditions for first bilateral contracts between electricity generation companies and some qualified users. All generating companies continue to work according to Pool model. During this phase is supposed to learn how to make bilateral contracts and determining a price of contracts according to expected market prices.

- Phase 2 – Implementation of balancing mechanism

An implementation of a balancing mechanism in a real time, that at the beginning can be used for Pool applications for 24 hours ahead, later can be based on applications and propositions, which at the end of the second stage will be coming from generating companies. At the end of this phase, all participants of the market should understand necessity of precise planning and demand forecasting, and also evaluate risks, related to disbalance.

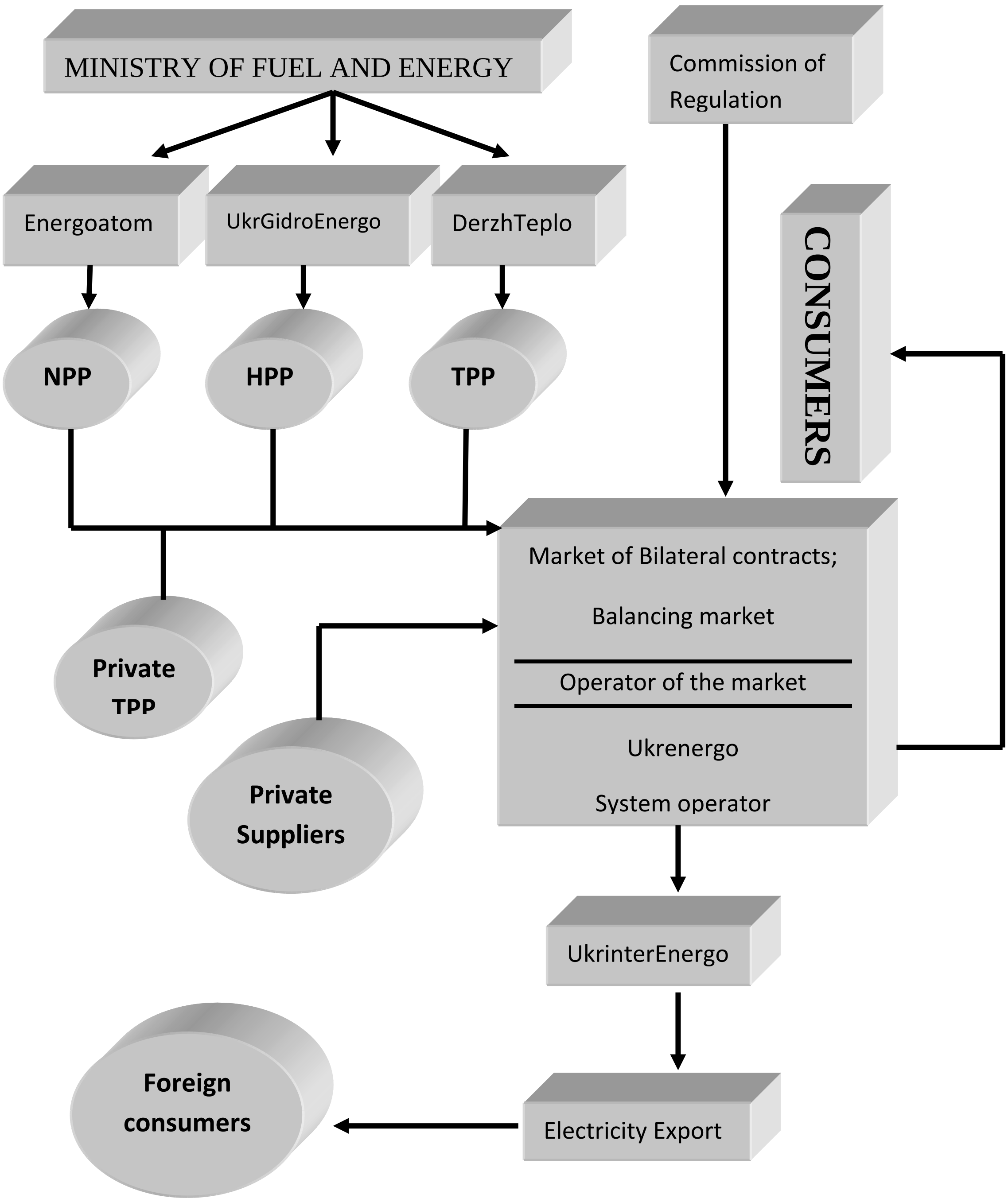
- Phase 3 – Implementation of independent graphic of capacity

This phase is the most important of all reforming process, during which a market moves from centralized creation of capacity graphic through Pool system to independent composition of individual graphics, where all participants take responsibility for creation graphics for 24 hours ahead of their own power generation plants and execution of their own contracts. At the same time, an operator of the market should begin management of Electric Energy Exchange. At this phase an Exchange will be obligatory for a market regulation of bilateral contracts. A price in Exchange can be used like basic price during making bilateral contracts. In addition an operator of Pool will be transformed to operator of modern Electric Energy Exchange, and its activity after time can be enlarged to forward contracts or other products.

- Phase 4 – Principles of work of obligatory market

This stage is a final stage of reforming process, when a market riches its final goal. A market will be totally based on bilateral contracts, but will continue to use services of Electric Energy Exchange, which will be voluntary at that period of time. All producers and delivers of energy will be totally responsible for their risks of imbalance. At the result of this stage a Wholesale electricity market of Ukraine will be totally competitive according to the model, which is popular in continental Europe. (Ukraine - Implementation of concept of Wholesale market of electricity, 2009)

Table. New concept of energy market of Ukraine. Ukrenergo. 2010



In 2008 began a realization of second stage. According to results of the first semester, there was prepared propositions about functioning about future electricity market of Ukraine, defined a structure of new model of the market. (Transformation to a new model electricity market in Ukraine, 2010).

National commission of electric energy regulation of Ukraine and Ministry of Fuel – energy complex should not later than 2011 create an Exchange for selling electricity and within 2014 finish implementation of concept of bilateral contracts. (New model of electricity market will be implemented not later 2015, 2008) Bellow is shown a scheme of work of new model of the electricity market of Ukraine.

1.2.6 NNEGC «Energoatom»

The State Enterprise «National Nuclear Energy Generating Company «Energoatom» was founded in October, 1996. The company is the operator of all running nuclear power plants in Ukraine. The company's primary objective is to increase electricity production at nuclear power plants under condition of continued operation safety improvement.

Four nuclear power plants: Zaporizhzhya NPP, Rivne NPP, South Ukraine NPP, Khmelnitsky NPP, and «AtomRemont- Service», «Scientific and Technical Center», «Emergency and Technical Center», «AtomEnergoMash», «AtomKomplekt», «Warehouse Inventory», «Administrative Department» are separate entities of NNEGC «Energoatom». They have their own settlement accounts and pay taxes to local budgets according to applicable legislation.

Today, 15 power units are in operation at the Ukrainian NPPs, 13 of them have VVER-1000 reactor installations and 2 have VVER-440 (new generation) reactor installations. Ukraine is the 8th in the world and the 5th in Europe by NPPs' installed capacity.

The share of electricity production by NPPs remains stably high. It was 43.8% in 1996, 45.3%, 53.2%, 47.5% in 2000, 2004 and 2007, respectively. In 2009 this indicator was at the level of 47.9% (Energoatom, 2010)

Table. Sales of electricity by Ukrainian NPP during 2006 - 2009. Energoatom. 2010

	2009	2008	2007	2006
Revenue from selling electricity, mln. Euro	1202,8	1624,42	1438,44	1347,8
Revenue from selling electricity, mln. UAH	13 062,2	12508,6	9 939,6	8 531,6

In 2009 company decreased electricity generation on 7,7 % till 6,9 billion of kW/hour if to compare with 2008 and its revenue in 2009 was Euro 1202,8 millions. EBIT was fixed at the level of Euro 65 millions.

During last year an accounts payable (debt) of the corporation increased on the Euro 50 million because of the keeping the same tariffs on the electricity for consumers due to the strategy of the government in the period of financial crisis. “Energoatom” last year attracted as a loan about Euro 110 millions. And total liability of the company doesn’t exceed 20% of the annual turnover.

According to the Law of Ukraine «On Nuclear Energy Utilization and Radiation Safety» «Energoatom» is entrusted with the functions of the operating body responsible for safety of all Ukrainian NPPs in operation. Besides, the primary tasks of «Energoatom» today include construction of new power units and lifetime extension of those in operation; purchase of the fresh nuclear fuel and removal of spent fuel; establishing the national infrastructure of spent fuel management; physical protection of nuclear facilities; retraining, qualification upgrading, resolution of social problems of the company’s employees.

Priority tasks of «Energoatom» include expanding preparatory works at the industrial site of units 3 and 4 of Khmelnitsky NPP, construction of central spent fuel dry storage facility for Rivne, South-Ukraine and Khmelnitsky NPP, commercial operation of dry storage facility of spent fuel at Zaporizhzhya NPP.

The company’s specialists work on operating lifetime extension of Ukrainian power units, power increasing, selection of a new reactor type, creation of open-end nuclear fuel cycle, searching for alternative nuclear fuel options.

Strategic Objectives of “Energoatom”

According to the adopted Energy Strategy of Ukraine till 2030 and for the long-term outlook, NNEGC «Energoatom» have to do the following (Energoatom, 2010):

- select 3-4 new sites for construction of NPPs;
- develop a feasibility study for construction of power units to the total capacity of 6 GW on new sites during 2019-2021;
- substantiate and make a decision on service life extension of the pilot unit, Rivne Unit 1, followed by the rest of the fleet depending upon the design service life termination period;
- commission, by the end of 2016, new Khmelnitsky Unit 2 and Unit 3 to a total capacity of 2 GW.

In the long-term, the Company shall:

- put into operation replacement and additional power units to the total capacity of 12,5 GW from 2024 through 2030;
- launch decommissioning activities for six power units once their extended service life terminates;
- Initiate a construction of new capacities totally rated at 6,5 GW in 2027-2030 to allow their commissioning after 2030.

The key contributing factor that permits the expected evolution of nuclear power industry to eventually constitute the principal share in the energy balance is full compliance with increasing safety requirements. Therefore, it is among priority objectives of the state policy in the nuclear energy sector as defined in the Energy Strategy of Ukraine to enhance operational safety of NPPs in operation, which is also in line with Ukraine’s international commitments and IAEA recommendations.

Results of IAEA expert missions’ show the safety status of Ukraine NPPs to be compliant with the international standards against all criteria. At the same time, the safety level of Ukraine NPPs still has a potential for growth.

Another critical task of the Company is public acceptance related activities for the purposes of dissemination of reliable information on nuclear power industry, its status in Ukraine and in the world. Creation of a positive image of a peaceful atom relies upon scientific and technical progress. Because, all specified strategic targets for the nuclear sector development in Ukraine are directly dependent upon the public attitude towards the nuclear power industry.

1.2.7 NPPs of Ukraine

According to a statistical data in 2009 NPP of Ukraine has produced about 83,155 billion kWt-hours of electricity, which makes 101,1% from planned.

Image. Electricity generation by Ukrainian NPP. Ministry of statistics of Ukraine

NPP	Planned, mln. kWt.h.	Produced, mln. kWt.h.	Execution of planned, %
Zaporizhzhya NPP	40 675,0	41 271,2	101,5
Rivne NPP	12 204,0	12 214,0	100,1
South-Ukraine NPP	16 749,9	16 888,1	100,8
Khmelnitsky NPP	12 656,0	12 780,9	101,0
Total	82 284	83 153,9	101,1

In 2009 Ukrainian NPP generated 47,9% of all electricity produced in Ukraine

Table. Installed generation capacities in Ukrainian NPP. Energoatom

NPP	Unit №	Type of reactor	Installed electric capacity (MW)	Beginning of construction	Startup of the unit
Zaporizhzhya NPP	1	PWR/ VVER – 1000/320	1000	04.1980	10.12.1984
	2	PWR/ VVER – 1000/320	1000	04.1981	22.07.1985
	3	PWR/ VVER – 1000/320	1000	04.1982	10.12.1986
	4	PWR/ VVER – 1000/320	1000	01.1984	18.12.1987
	5	PWR/ VVER – 1000/320	1000	07.1985	14.08.1989
	6	PWR/ VVER – 1000/320	1000	06.1986	19.10.1995
South-Ukraine NPP	1	PWR/ VVER – 1000/302	1000	03.1977	31.12.1982
	2	PWR/ VVER – 1000/338	1000	10.1979	06.01.1985
	3	PWR/ VVER – 1000/320	1000	02.1985	20.09.1989
Rivne NPP	1	PWR/ VVER – 440/213	420	08.1976	22.12.1980
	2	PWR/ VVER – 440/213	415	08.1976	22.12.1981
	3	PWR/ VVER – 1000/320	1000	02.1981	21.12.1986
	4	PWR/ VVER – 1000/320	1000	08.1984	16.10.2004
Khmelnitsky NPP	1	PWR/ VVER – 1000/320	1000	11.1981	22.12.1987
	2	PWR/ VVER – 1000/320	1000	1983	08.08.2004

Zaporizhzhya NPP
Beginning of construction — 1979
Start up of Unit 1 — 1984
Number of power units — 6
Type of reactor — VVER-1000
Total capacity — 6000 MW
NPP Satellite town — Energodar,
Zaporizhzhya region

Zaporizhzhya NPP (ZNPP) is the largest nuclear power plant not only in Ukraine, but also in Europe. It is situated in the steppe zone of Ukraine, on the bank of the Kakhovka water reservoir. In the period from 1984 to 1987 the four power units had been put into operation. Unit 5 was started up in 1989 and unit 6 — in 1995. Zaporizhzhya NPP is a state-of-the-art high-tech enterprise, a powerful electricity generator in Ukraine. The plant generates 40–42 billion kWh that accounts for one fifth of the average annual electricity production in Ukraine and for almost 47% of electricity generated at Ukrainian NPPs. In 1992 the Training Center comprising full scope simulators, which are full analogs of control rooms of units 1, 3, 5, was established at ZNPP to maintain high level of occupational training.

Image. Zaporizhzhya NPP. Energoatom

ZNPP is the first among Ukrainian nuclear power plants with VVER type reactors that constructed on-site spent fuel dry storage facility (SFDSF). Commercial operation of this facility started on August 10, 2004.The designed capacity of SFDSF at Zaporizhzhya NPP is 380 casks that will provide for storage of all spent fuel assemblies, which are removed from the reactors during the overall plant service-life. As at April, 2008, 64 casks have already been installed on the site.

SFDSF of Zaporizhzhya NPP is the first nuclear facility, whose design passed all stages of the review and approval envisaged by the new nuclear legislation of Ukraine. For the first time in the CIS, Information and Measuring System «Koltso» («Ring»), intended for regular radiation monitoring on the industrial site of the nuclear power plant, at sanitary protection and 30-kilometers radiation control zones, was put into operation at Zaporizhzhya NPP.

The high level of Zaporizhzhya NPP performance and its personnel adherence to the safety principles were proved by the positive conclusions of international expert missions: in 2004 ZNPP hosted IAEA’s OSART (Operational Safety Review Team) mission and in 2006 — the OSART follow-up mission, in 2007 — WANO peer review.

South Ukraine NPP
Beginning of construction — 1975
Start up of unit 1 — 1982
Number of power units — 3
Type of reactor — VVER-1000
Total capacity — 3000 MW
Satellite town — Yuzhnoukrainsk
Mykolayiv region

South Ukrainian NPP (SUNPP) is the basis of the power complex. It comprises three VVER-1000 power units built in two industrial stages. Its history dates back to December 1982 when its first unit was commissioned. In May, 2007 SUNPP celebrated its 25th anniversary. Units 2 and 3, 1000 MW each, were commissioned in 1985 and 1989, respectively. Annual contribution of the South Ukraine Nuclear Power Plant to the total electricity production in the country exceeds 10%.

Image. South Ukrainian NPP. Energoatom

SUNPP can be considered a pioneer among the Ukrainian nuclear power plants in terms of implementation of the program on diversification of nuclear fuel supply sources. For the first time, together with the Russian fuel assemblies the US manufactured («Westinghouse») fuel assemblies were loaded in the Ukrainian nuclear reactor core (SU NPP-3).

SUNPP is a lead subdivision of NNEGC «Energoatom» in the area of quality management system certification. In March 2006 the plant became the first one among Ukrainian NPPs to confirm compliance of its quality management system with international standards. In October 2006 a team of the IAEA’s OSART mission experts worked at SUNPP. Leading nuclear power experts acknowledged that safety level of SUNPP complies with international requirements.

Rivne NPP
Beginning of construction — 1973
Start up of Unit 1 — 1980
Number of power units — 4
Type of reactor — VVER
Total capacity — 2835 MW
NPP satellite town — Kuznetsovsk
Rivne region

Designing of West-Ukraine NPP started in 1971. Later, the plant was given a new name — Rivne NPP. Rivne NPP is the first nuclear power plant with the VVER-440-type reactors (pressurized water reactor type) in Ukraine. First two VVER-440 power units were put into operation in 1980 and 1981, and Unit 3 with VVER-1000 reactor was put into operation in 1986.

Image. Rivne NPP. Energoatom

In 1990 construction of power units on the site was stopped according to resolution of the Head Council of Ukraine «On Moratorium for Construction of New NPPs».

The construction was resumed in 1993, and Unit 4 was put into operation in October, 2004. In April, 2006 the state acceptance commission admitted Unit 4 of RNPP to commercial operation. When unit 4 of RNPP was started up, annual electricity production exceeded 16 billion kWh. IAEA’s commission highly assessed the NPP’s safety level.

The European Union has selected Rivne NPP as a lead plant for implementation of a number of international projects. In 2007 Rivne NPP was given a «TUV NORD» certificate of compliance with the international standards ISO 9001:2000 of «Quality Management System» and ISO 14001:2004 «Environmental Management». Rivne NPP employs automated radiation monitoring system ASKRO. Supervision is carried out in automated mode on a continuous basis that allows obtaining on-line information for systematic analysis and projections. ASKRO complex, in terms of quantities, frequency and accuracy of collected parameters and characteristics is unique not only for Ukraine — it is one of the best complexes of the kind in the world. The design lifetime of the first two power units of Rivne NPP will expire in 2010–2011. Due to this, Rivne NPP was selected a pilot plant for implementation of activities on preparation of the reactors for operation beyond the design lifetime.

Khmelnitsky NPP
Beginning of construction — 1981
Start up of Unit 1 — 1987
Number of power units — 2
Type of reactor — VVER-1000
Total capacity — 2000 MW
Satellite town — Netishin,
Khmelnitsky region

Khmelnitsky Nuclear Power Plant (KNPP) is located in the central part of the Western Ukraine, on the border of three regions, namely: Khmelnitsky, Rivne and Ternopil. Khmelnitsky NPP has been designed as the four-power unit plant. Construction started in 1981. In late 1987 Unit 1 was put into commercial operation. Construction of unit 2 started in 1983. Its commissioning was planned for the end of 1991. At the time of declaration of moratorium for construction of new nuclear power units in 1990 main process components had been erected and personnel had been trained for operation of Unit 2. Construction of Khmelnitsky Unit 2 was resumed in 1993.

Image. Khmelnitsky NPP. ENergoatom

On August 8, 2004 Unit 2 (with VVER-1000 reactor type) was connected to the grid. In September 2005, state acceptance commission admitted Khmelnitsky unit 2 to commercial operation. When unit 2 of KNPP was started up, annual electricity production exceeded 15 billion kWh. Due to implementation of safety and modernization measures, safety conditions at Khmelnitsky Unit 2 were acknowledged the best among the VVER-1000 units in operation in Ukraine. A number of expert missions and peer reviews conducted by international state and independent experts of the IAEA, Riskaudit, Technical Aid to the Commonwealth of Independent States (TACIS), and WANO confirmed that its environmental, nuclear and radiation safety meets the international requirements. In the framework of commissioning Khmelnitsky Unit 2 the automated radiation monitoring system ASKRO was introduced in addition to the existing radioecological monitoring system. In addition, taking into account importance of the environmental issues, monitoring of non-radiation source of contamination of the air, surface and underground waters is carried out.

One of the main Energoatom’s tasks after commissioning of Unit 2 is to complete Units 3 and 4 of Khmelnitsky NPP. Khmelnitsky NPP is the most future-oriented site for expansion of Ukrainian nuclear power facilities. It is planned to complete preparation of the feasibility study for construction of Khmelnitsky Unit 3 and Unit 4 and to determine the reactor design for these power units.

1.2.8 Governance and regulation in the electricity

Existing control system in the Fuel-and-Energy Complex was built up spontaneously and was acting primarily in the interests of some influential groups and thus is considered as that far from being perfect. As a result the state has lost energy assets control, faced qualified personnel outflow and the level of scientific and technical support to the Fuel-and-Energy Complex (FEC) decreased considerably.

State control and regulation of the FEC should comply with organizational structure and operational requirements of the industry. Power sector development and reforming provided for by the Strategy requires clear definition and sharing of tasks, and also shall avoid influence of natural monopolies affecting decision-making process of respective public authorities.

The Cabinet of Ministers of Ukraine, key ministries and departments: Ministry of Fuel and Energy of Ukraine and Ministry of Coal Industry, State Nuclear Regulation Committee of Ukraine, National Agency of Ukraine for Effective Energy Use are the key players of State control in the Fuel-and-Energy Complex (FEC).

As a supreme governing body, the Cabinet of Ministers of Ukraine was delegated with powers to implement the laws of Ukraine referring to FEC, approve energy policy and terms of public energy assets management, develop FEC management system. Powers of Ministries embrace inter alia direct state regulation of industries according to fundamentals established by the Cabinet of Ministers.

Relevant self-government bodies may be empowered with certain managerial responsibilities in the power sector related to location of energy facilities and establishing socially significant tariffs.

National Energy Regulation Committee (NERC) and Ministry of Construction, Architecture, and Housing and Communal Services (in the field of heat supply) exercise state regulation of activity of natural monopolies and relative markets in power sector, gas and oil industries. Primary task of the Committee is to regulate relations between participants of energy markets being guided by nondiscrimination principles and efficiency of their operations.

State management of business activities is carried our through:

- formulation and ensuring implementation of a single public policy for development and functioning of relevant markets;
- formation of price and tariff policies in markets having natural monopoly status, and control over competitive pricing in the industries;
- ensuring that customers have equal access to relevant markets;
- preventing monopolization and encouraging competition in the markets adjacent to those having natural monopoly status;
- balancing interests of energy markets entities and consumers of goods and services of such markets;
- protection of rights of consumers of goods and services rendered by natural monopoly entities and adjacent markets to ensure adequate quality of goods and services at economically justified prices;
- licensing activity of relevant markets participants and control over observance of license conditions by business entities.

In the established procedure, NERC reviews conditions of licensing business activities and formulates qualification requirements to business executives, sets up systems of licensed activities monitoring, establishes mechanisms of license termination.

Main tasks of the National Agency of Ukraine for Effective Energy Use are the following: to ensure single state policy in the field of energy resources utilization and energy saving; to ensure growth of the share of alternative and renewable fuels in supply-demand balance of energy resources; to set up the state system of monitoring production, consumption, export and import of energy resources, to develop systems of accounting and control over consumption of energy resources; to ensure functioning of the uniform system of regulating specific consumption of energy resources in social production.

Control over technical conditions of facilities, energy consumption modes, compliance with the safety standards is exercised by the relevant governmental inspections and committees responsible for technogenic and environmental safety and emergency situations. Functions and powers of such bodies should be strictly regulated by laws and other regulations and legal acts so as to ensure the balance of interests of citizens, state and owners of energy companies.

Mainstreams of strategic development in the field of energy supply to the country regions, to be addressed by local authorities are the following:

- to use economically attainable regional (local) deposits of fossil fuel, secondary energy resources, alternative and renewable energy resources, to take energy saving opportunities and to ensure the development of domestic decentralized sources of electricity and heat generation with further approximation to the required level of energy and environmental safety;
- to overcome the deficit of fuel oil for municipal and residential sector;
- to prevent from emerging monopolies and to ensure fair competition in the field of supply of energy resources to regional consumers, etc.

For the purpose of fulfillment of the above development measures the local (regional) authorities shall draft corresponding programs and approve them in the established procedure.

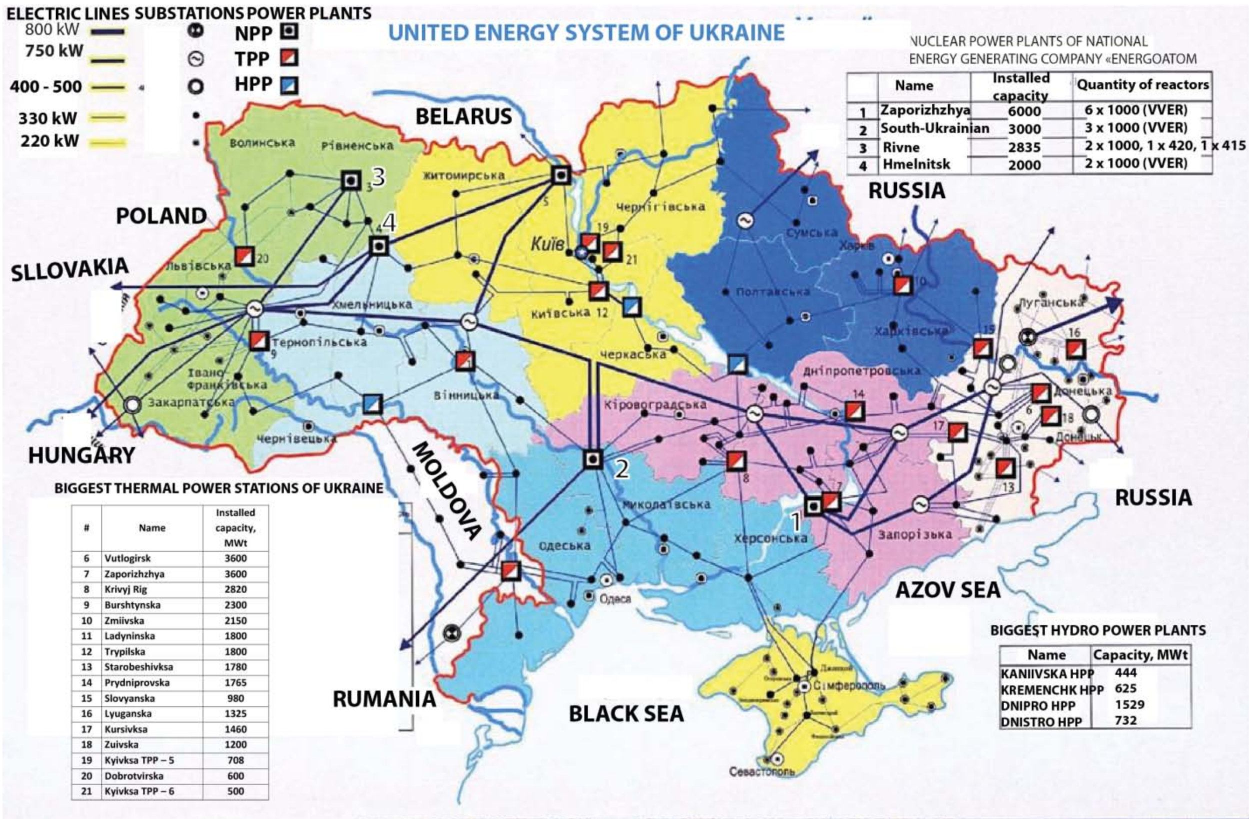
Legislative regulation of powers and responsibilities of central and regional power bodies, self-government bodies with regard to economic, technological and economic management of regional energy supply systems is provided for proper organization of the State management in the field of regional energy supply. (State control and regulation of the Fuel end Energy complex, 2006)

1.2.9 Status and prospects of distribution and transmission networks

1.2.9.1 Power distribution networks

Power distribution networks consist of about 1 million km of overhead and cable power transmission lines of 0.4 – 150 kV, about 200 000 switch-yards of 6 – 110 kV.

Image. Power distribution and transmission electricity networks of Ukraine. Fuel and energy complex



Poor condition of power distribution networks entails emergency situations in different regions of the country. Lack of funds make unfeasible from reconstruction, upgrading and rehabilitation of existing power networks of all the voltage grades, as well as construction of new power transmission lines. Number of facilities, which worked out their useful operating life, increased dramatically. 19% of switch-yards and 17% or about 140,000 km of 0.4 – 150 kV power distribution networks are subject to rehabilitation and replacement.

Unsatisfactory state of power networks, their inconformity with existing norms and power consumption regimes, as well as outdated metering devices result in substantial increase in process losses during power transmission.

To meet consumers' demand in quality and reliable power supply it is necessary:

- within 2011 – 2020: to put into operation annually at least15 000 km of such lines of new and rehabilitated power transmission lines of 0.4-150 kV
- within next years to construct annually new transmission lines according to needs of developing power load of consumers and to reconstruct operating transmission lines in scope established by the norms of depreciation charges. At the same time construction of new transmission lines and switch-yards, and rehabilitation of operating ones shall be carried out with taking into account switching rural householders from gas to power.

Construction and upgrading of 35-150 kV switch-yards shall directly depend on the level of further equipment of industrial, agricultural and municipal and household consumers, and shall be carried out in advance compared to increase of power load.

Development and rehabilitation of power networks in rural areas shall be carried out with attraction of funds from local and state budgets and business entities.

Technical re-equipment and rehabilitation of power networks, as well as their development shall comply with national regulations and take account of recommendations of the International Electro-technical Commission and regional specificity concerning reliability and environmental safety conditions, as well as actual land value and maximum use of basic domestically produced materials and equipment, strengthening material base and manpower potential of construction and mounting organizations (mechanical crews etc.).

About EUR 4.5 billion is planned to be allocated for the development of distribution networks until 2030, including EUR 2 billion - within 2011 – 2020;

EUR 2.4 billion – within 2021 - 2030. (Power energy strategy of Ukraine till 2030, 2006)

Total amount of funds that should be invested until 2030 for the development of backbone, interstate and distribution power networks, including organization of parallel operation of Ukrainian UPS and UCTE, as well as for modernization, upgrading and construction of switch-yards, will come to EUR 13 billion.

1.2.9.2 Transmission networks

Transmission networks is one of the main components of UPS of Ukraine, which includes 22 700 km, of them 4 900 km are of 400 – 750 kV, 13 200 km - 330 kV, 4 600 km - 220-110 kV and 132 power substations (PS) of 220 – 750 kV.

Year by year the state of transmission networks is deteriorating: 34% of 220-230 kV overhead transmission lines (OTL) have been operated for more than 40 years, of them 1700 km of 330 kV OTL (13% of total length) and 1600 km of 220 kV OTL (52%) require rehabilitation, 76% of switch-yards main equipment worn up its designed useful operating life.

Insufficient allocation of funds for upgrading and rehabilitation of operating power networks and substations, and for construction of new ones results in lowering reliability of the United Power System operation.

Serious problems arise due to insufficient line capacity for realization of NPP potential (Rivne, Khmelnitsk, Zaporizhzhya); insufficient reliability of power supply to the Crimea, South of Odessa oblast, Eastern Donbass; impossibility to transmit excess power from Western region to the center and East of the country; uncompensated power network of Ukrainian UPS as regards reactive power and maintaining necessary voltage (Western, Central and Southern power systems).

For the period until 2030 the UPS of Ukraine will adhere to the strategy of main power networks development, according to which system-forming functions of realization of power plants potential and securing parallel operation with power systems of other countries will be kept for 330 and 750 kV power networks with subsequent attributing greater importance to 750 kV networks.

330 – 750 kV networks shall be developed by means of constructing lines for:

- creating new and strengthening existing system-forming connections both within individual power regions and between regions and power systems of other countries;
- transmitting power from operating power plants and those being constructed and expended;
- ensuring reliable power supply to power-intensive regions.

Essential increase in power export to European countries may come true within the specified period only subject to fulfillment of commercial projects for construction of direct current links (DCL). The existing 750 kV OTL West Ukraine – Albertirsha (Hungary), Khmelnitska HPP – Zheshuv (Poland) and South Ukraine – Isakcha (Romania) will be included in this process. The capacity of specified 750 kV OTL is sufficient to implement up to three 600 MW DCL modules at each line.

In addition, to ensure possible parallel operation of Ukrainian UPS with European power network, to improve operational standards of Ukrainian UPS and bring them gradually in correspondence with UCTE requirements it is necessary to fulfill considerable scope of organizational and technical activities, aimed at upgrading and development of all the power system, and to develop emergency automatics systems.

In future, in order to ensure stable operation of UPS of Ukraine, to use efficiently Ukrainian power plants capacity, to observe standard conditions of power transmission from Khmelnitsky, Rivnenska and Zaporizka nuclear power plants and regulating facilities of HPSPs, in particular, Dniestrovska HPSP, it is necessary to complete construction of two 750 kV transit backbone transmission lines: Southern (Khmelnitsky NPP – Dniestrovska HPSP – Prymorska – Kakhovska – Zaporizka NPP, with total length up to 1 500 km and 4 000 MW of transformer capacity of Prymorska and Kakhovska switch-yards) and Northern (Rivnenska NPP – Kyiv – North Ukrainian – Kharkiv – Donbass, with total length 1 200 km and 4 000 MW of transformer capacity of Kyivska and Kharkivska switch-yards).

Commissioning of these backbone transmission lines will provide necessary basis for parallel operation of Ukrainian UPS with the UCTE power system and for considerable increase in power export, which is in line with the long-term foreign policy task related to the integration of Ukraine into the European Union.

After 2010, when switched to parallel operation with the European power systems, transmission capacity of existing international Ukraine – EU 220-750 kW OTL will be about 6 000 MW.

Under present conditions parallel operation with the UCTE power system (joining of Balkan countries, Romania and Bulgaria to the UCTE) requires engineering development of new principles of emergency control of power system.

Stage-by-stage implementation of the program of backbone power networks development requires construction and implementation of (UkrEnergo, Development of Power Networks, 2006):

- within 2011-2020 –3000 km of 330-750 kV OTL (including 1 900 km – 750 kV) and 6 750 MW transformer facilities (including 6 000 MW at 750 kV switch-yards) – total costs will make up EUR 5 billion;
- within 2021-2030 –700 km of 330-750 kV OTL (including 500 - 750 kV) and
  2 200 MW transformer facilities (including 2 000 MW at 750 kV switch-yards), which requires EUR 1,7 billion.

Depending on selection of sites for NPPs location and taking into consideration the program for development of resistance heating in localities, the total length of 330 kV OTL may extend within the period of 2010 – 2030 by 1 200 – 1 500 km with adding 1 500 – 2 000 MW of transformer capacities, the total cost of which will amount to EUR 700 – 800 million. (UkrEnergo, Development of Power Networks, 2006)

75% of the worn-out 220-750 kV switch-yard equipment and 58% of 220-750 kV OTL require full or partial replacement; 112 switch-yards of 220-750 kV, which service life exceeded 30 years (according to corresponding development periods), require rehabilitation with replacement of more than 200 units of high-power transformer and reactor equipment of 220-750 kV and other high-voltage equipment. At the same time 67 switch-yards are subject to rehabilitation within the period until 2015, 30 switch-yards - within 2016-2020, and 15 switch-yards - within 2021-2030.

It was also envisaged to upgrade relay protection and emergency automatics, replacing them with up-to-date, microprocessor based devices.

The development and rehabilitation of backbone power networks are planned to be carried out together with telecommunication systems based on fiber-optic networks. This will provide opportunities to introduce state-of-the-art functional automatic process control, automated dispatch control and computer-aided manufacturing systems to ensure reliable transmission of power according to requirements pertaining to the integration of Ukraine into the European Community.

The total amount of investments, required for the stage-by-stage implementation of the program for backbone power networks development until 2030, will come to EUR 7.5 billion.

1.3 The financial, legal, personnel and scientific and technical support of power industry

The implementation of the strategic objectives of the development of fuel-energy complex, the introduction of large-scale development activities, technical renovation and modernization of fixed assets and consistent implementation of competitive relations in the energy industry and in the adjacent markets will be achieved through improved pricing and tariff policy through the introduction of economic levels of prices and tariffs energy.

Prices and tariffs for energy markets of Ukraine should be economically feasible to recover the costs of production, transportation and supply of energy to ensure the effective functioning and development of energy facilities, to encourage both domestic and foreign investment, as well as the introduction of energy-saving technologies, alternative and renewable energy sources.

The development and operation of the fuel and energy industry needs large investment resources, their quantities are given in the table.

Table. Investments in fuel and energy sector in 2011-2030, billion EUR. Ministry of fuel and energy

Destinations financing	**2011 - 2020**	**2021 - 2030**	**Total**
Total including:	67.3	71.2	138.5
Heat energy	11.8	14.4	26.2
Hydropower	0.88	1.66	2.54
The development of electrical networks	6.84	4.05	10.9
Nuclear power	12.34	18.38	30.72
The development of renewable sources of electricity generation(excluding hydro)	0.46	0.47	0.93
Nuclear fuel cycle	2.08	0.69	2.77
Coal industry	13.73	14.3	28.01
Gas & Oil	19.16	17.5	36.7

Major areas of funding in the electricity industry – EUR 78 billion:

- Modernization, reconstruction, improving the safety of existing nuclear power plants;

- Lengthening the life of the plant;

- Commissioning of new nuclear power plants, Tashlinsk HPSP and decommissioning of units who have served and continued the project life;

- Support facilities in the thermal energy by extending the useful life of existing units, the completion of the projects on reconstruction of pilot TPP units, the output of worn-out and introduction of new facilities;

- Complete reconstruction of thermal power plants with the introduction of new power plants and conservation of power, exploitation of which is impracticable;

- Reconstruction of existing and new capacity hydroelectric power station, power plant;

- Modernization and development of electrical networks including integration activities of the United Energy System of Ukraine to the power systems of Europe;

- Development of renewable energy sources for electricity production.

In the Nuclear Fuel Complex funding of $ 21,7 billion will be made in the areas of:

- Production of zirconium and uranium production, ensuring the production of uranium concentrate to the full to ensure the needs of nuclear power;

- Construction of the plant to produce nuclear fuel.

For non-conventional and renewable sources of energy (NRSE), whose implementation is effective and the technology are exploited in Ukraine (off-balance sheet sources of energy, the direct burning of waste wood and crop production, thermal power plants solar hot water, etc.), financing must provide the owners of enterprises (reinvested profits of enterprises, the use for this purpose depreciation, credits, etc.).

For renewable energy that is potentially effective, but there is no sufficient experience of their operation (geothermal energy, using the heat of the environment, technology of pyrolysis of waste wood and crop production, solid waste, etc.) should involve funding through grants international funds, the target state and local budgets at a level that will be determined by the relevant legislation and the state budget and the like. The introduction of such technologies after their development on an industrial scale is expected by the owners of the investment companies.

Fuel and energy complex is characterized by high science-intensive production processes, so its performance is determined by the intellectual level of personnel, which provides scientific support and academic support in all areas of industrial activity, which is implemented by the branch of science. This should be resolved problematic issues, carried out scientific support of the introduction of the prospective developments and emerging technologies, forming prospects Fuel and Energy Complex.

However, to date the leading role of science in almost all sectors of the Power Energy Complex is largely lost. It was stopped a development of important scientific, technical, and research and development work, aimed at modernizing the existing and the creation and introduction of new equipment, design and development of new technologies. Thus total financing of scientific and technological revolution and calves per artist in the 50-80 times lower than in the developed world, but rather with Russia - in 3 times. The outflow of personnel and, above all, young people, substantially changed the staffing of scientific and technical sphere, and brought him to an unacceptable aging. The energy region have already reached almost to the border, beyond which is the physical decay of the labor force and its inability not only to development but also to a simple self-renewal, there is also an insufficient level of information security. Critical is the state of the existing fleet of scientific instruments and equipment. Unreasonable adjustments legislation led to the termination of funding of industrial science and practice taking it out of the operation and development of Power Energy Complex. Lost training system, training engineers and technical workers and professionals conducting trades, lost link between the generations in the workplace.

To play made in the pre-crisis level of scientific and technical support Power Energy Complex and its further increase demands for international scientific and technological progress need to take urgent and promising multidisciplinary activities to increase funding for scientific and technological researches.

The main objective of the legislation on energy saving is to create favorable conditions for the efficient use of energy resources, avoiding direct intervention in economic activities of economic entities.

Legal regulation of the state's economic support for the effective use of energy resources must comply with the principles of market economy.

1.4 Problems and prospects of integration of Ukraine in the energy grid of the European Union

Integration of Ukraine in the energy grid of the European Union is made in two ways:

1. Adaptation of legislation and appropriate institutional transformation;
2. Integration of networks and harmonization of standards.

Adaptation of Ukrainian legislation to EU energy legislation should assist the creation of competitive energy markets in Ukraine, integrated to the European markets. The establishment of such markets is based on the principles:

- Ensuring the reliable supply of energy;

- Expansion of competition, respectively, the principles of freedom of movement of goods, services, capital and labor;

- Protection of the environment and civil protection in the field of technological security.

Legal regulation of the electricity and gas fields of the EU aimed at improving the existing wholesale electricity market and the creation of a competitive market for natural gas.

Markets should ensure that full liberalization of relations in the supply of natural gas and electricity (in the EU Member States to all consumers, taking into account the household, should be afforded the right choice of supplier)

Adaptation of Ukrainian legislation in the sphere of nuclear energy needs to adopt legislation aimed at:

- Confirmation of conformity of products, which are supplied to the nuclear energy;

- attraction and use of financial resources for decommissioning nuclear power plants and transmission for long-term storage / disposal of radioactive waste;
- introduction of sanitary rules and regulations for nuclear power plants;
- construction of storage facilities for spent nuclear fuel and radioactive waste;
- extension of operating nuclear power plants;
- providing credit facilities to build new nuclear power;
- implementation procedures for the preparation and transfer of radioactive waste disposal companies;
- final disposal of radioactive waste in deep geological forms;
- treatment with worked fuel after his long-term safe storage.

Given the experience of Central Europe on the adaptation of energy legislation, its effect is to alter the key bases of operation of energy:

- Monopoly – competition;

- Public Administration – state regulation;

- Central planning – liberalization;

- State ownership – private property.

Until 1993, the United Energy System of Ukraine has worked in the energy system of Ukraine “Mir” in parallel with the power systems of Poland, Hungary, Slovakia and the Czech Republic, Bulgaria and Romania, which by this time carried out the relevant EU directives and the activities included in the European power system UCTE.

Since 2001, the United Energy System of Ukraine works in parallel with the power Russia, Moldova and the Baltic countries.

Since July 2002, part of the Ukrainian energy system, the so-called "Island Burshtyn TPP", works in parallel with a unified European energy system UCTE.

Geographical location of Ukraine enabled it to construct a considerable number of high-power transmission lines of international importance, which connect Ukrainian UPS to power systems of neighboring countries – Russian Federation, Republic of Moldova, Republic of Belarus, Poland, Slovakia, Hungary, Romania. About 30 billion kWh per year were exported to European countries until 90-s, while in 2005 export of power amounted to 8.4 billion kW/hour.

Implementation of the project for construction of back-to-back stations (BBS) will be a real impetus to considerable increase in power export to European countries in the process of interconnecting Ukrainian UPS with UCTE.

In order to ensure stable export volumes and increase it in the future until 2010 it will be necessary:

- to upgrade power networks and increase generating capacity of the "Burshtynska TPP Island";
- to complete Dobrotvorska TPP-2;
- to solve the problem, related to transmission capacity of power networks at crossing of Ukraine – Moldova frontier by means of construction of additional power networks in Odessa subsystem.

Image. Scheme of power exchange with other countries. Strategy of development of power and energy complex. 2006

Commissioning of Southern and Northern 750 kV transit transmission lines, as sells as renewal of 750 kV transmission lines to Isakcha and Zheshuv will ensure parallel operation of the UPS of Ukraine with the European power systems and formation of technical prerequisites for increase in power export up to 20 – 25 billion kW.h by the end of forecasted period.

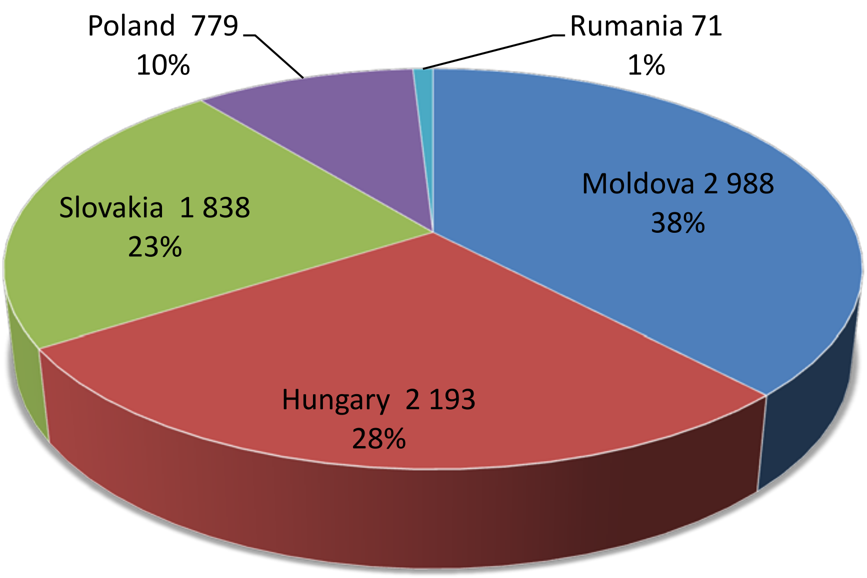
Table. Interstate Power Transmission Lines of Ukraine and Power Export (to neighboring countries) Capacity. Ministry of fuel and energy complex. 2008

Country	Quantity of overhead transmission lines (by voltage grades)					Transmission capacity of PTL (billion kW/hour per year)
	750 kV	400-500 kV	220-330 kV	110-0.4 kV	Total	
Russian Federation	1	3*	10	18	**32**	26.3
Moldova			7	18	**25**	1.5
Belarus			2	6	**8**	6.1
Poland	1		1		**2**	UCTE
Slovakia		1		1	**2**	5.0**
Hungary	1	1	2		**4**	4.8
Romania	1	1			**2**	49.0***

* - one 400 kV DC transmission line;
** - subject to "Burshtyn TPP Island" operation;
*** - subject to parallel operation.

During January – December of 2008 was exported 7 868 millions of kW.h of electricity (Dynamic of electricity generation, 2009) and export price of electricity in 2010 was 40 EUR/MWh (Management, 2010)

Table. Export of electricity for 12 monthes of 2008, mln. kWt.h. Dynamic and structure of electricity generation. Ministry of fuel and energy complex of Ukraine. 2009



There is a need for the increase of the transferring capacity of interstate electricity as in Ukraine, and in the territories of the EU, which requires coordinated actions of the domestic and foreign entities.

CHAPTER 2 THE UCRAINIAN SCENARIO

Last years in many countries there is a big interest for nuclear energy. It is caused, first of all, by increasing of prices for oil & gas. Ukraine is not an exception.

Nuclear power energy already now has a determining position in electricity production in Ukraine. Today, a share in electricity generation by NPP has already 50% of total energy produced in the country.

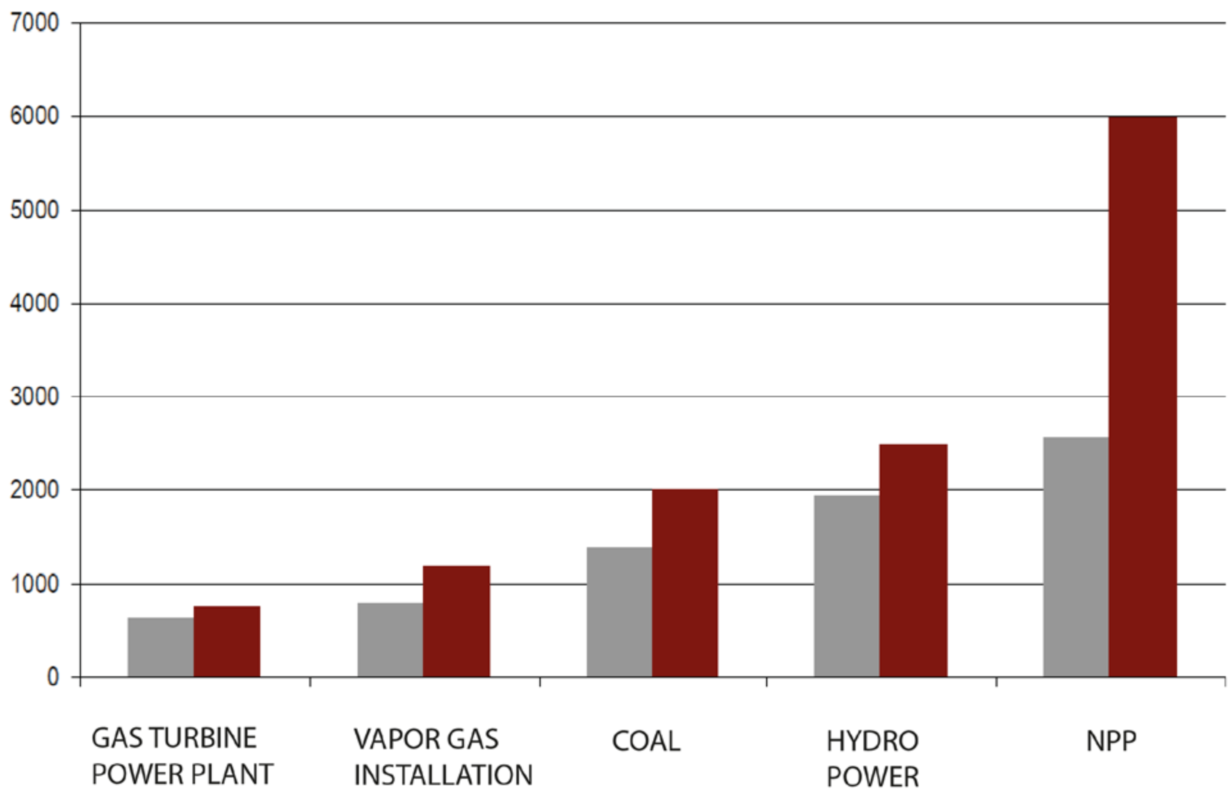
This chapter analyses information for possible investments into building new nuclear power plant with some deliberately small stand alone reactors or one large power unit.

Image. Rivne NPP. Energoatom

2.1 Generation costs

Head of "Agency about forecasting balances in power energy industry" noted, that a price for construction of 1 kW of new capacity for NPP of Russian reactors should be between 2500 – 2700$. (Kozhuhovksy, 2010). A price for building new generation capacities are similar for construction NPP with Russian reactor in Ukraine and other CIS countries (Commonwealth Independent States – ex Soviet countries). For example, during estimation of construction of NPP in Belarus, which border with Russia and Ukraine, was put a price of USD 2500 (EUR 1790) per installed 1 kW of generating capacity. (Economical profits from NPP in Belarus, 2010) Bellow in the table is shown data of cost of generation capacities according to projects green field in Russia and EMEA (A'Lemar, 2010)

Table. Minimal and maximum costs (in USD) for building new generation capacities according green field projects in Russia and EMEA (Europe, the Middle East and Africa). (Investments to power generation capacities. Investments group "A'Lemar".2010)



Providing synthetic analysis of costs of construction of Russian NPP with large reactors is possible to write following information about costs of construction of real NPP. Kaliningrad NPP with two power units of 1,17 GW each has a planned costs of EUR 4 850 millions (RUB 194 billion; USD 6 554 mln). So a price of installed capacity of 1 kW is about EUR 2000 (2830$). It is more expensive than other projects in the country. For example planned capacity of 3rd and 4th power units in Rostov NPP will have EUR 1805 (2490$) for 1 kW of capacity. (Enel is going to invest in Kaliningrad NPP, 2010). Costs of construction of 1 kW in Seversk NPP is planned in 2008 at the level of EUR 1620 (2240 $). ("AtomEnegergoProekt", 2009)**.**

Construction costs of analyzed power plants shows, that estimated generation costs of 1 kW of new NPP in Ukraine are about EUR 2000.

2.2 Construction

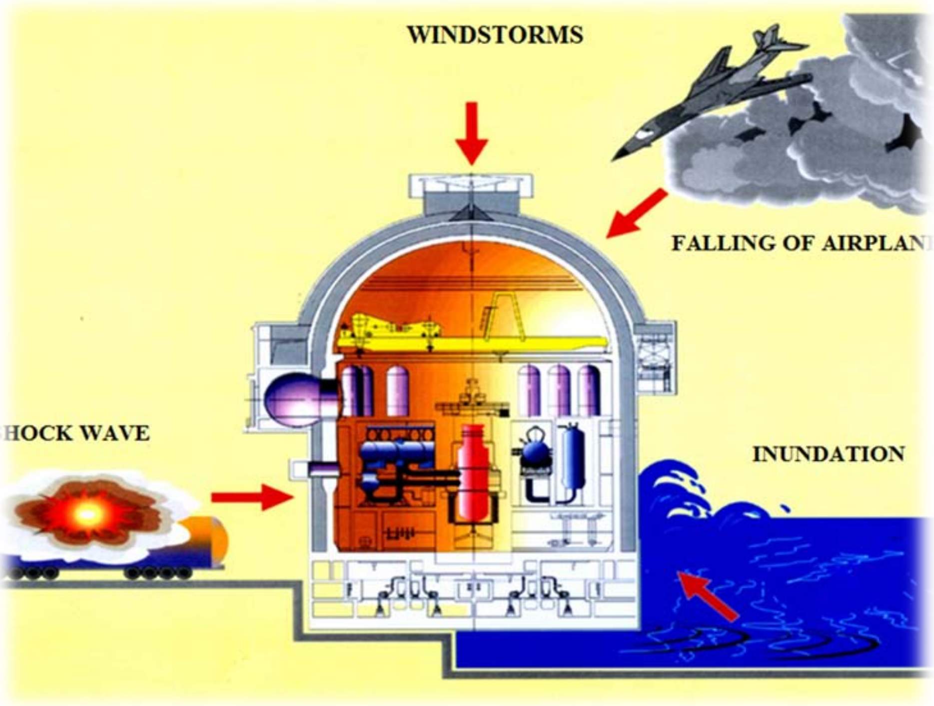
2.2.1 List of project objectives

- A project must be created on the basis of the already existing projects of VVER-1000, and should be its evolutionary type;
- A project must include all the best design solutions tested and approved by scientific, design and engineering enterprises;
- A project should not require significant research and development work;
- Increase of a percentage of fuel burning (usage);
- Increase of a power capacity, efficiency factor;
- Ensuring of work in flexible conditions;
- Optimizing of use of passive and active security systems;
- Ensure a reduction of material capacity;
- Provision for the reduction of construction time

Responsible for Project NPP 2006 (Russian enterprises):

- Main engineer and planner is “Atomenergoproekt” (JSC SPAEP)
- Main designer is “Gidrospress” ("GIDROPRESS")
- Scientific project manager of “Research institute of Kurchatsk” (Kurchatsk)

Image. Protective Envelop – a means of protection against external natural and anthropogenic factors. (Novak, 2006)



2.2.2 Project "Seversk NPP"

On the example of "Seversk NPP", which will have similar as Ukrainian NPP reactor VVER – 1000, is shown a general scheme of construction of nuclear power plant. Construction of Seversk nuclear power plant should become a guarantor of future economic development of the Tomsk region, which was originally an energy shortage region (energy deficit region).

Image. Mapping of Ukrainian NPP with reactor VVER-1000 and planned Russian NPP in Seversk

Moreover, according to forecasts by the Federal Tariff Service of the Russian Federation annual consumption of electricity in the Tomsk region will increase and will reach in 2010, 10.4 billion kWh. (In 2008 was 8.4 billion kWh). In 2020, electricity consumption will reach 16.9 billion kWh, that means increase almost in 2 times, which associated with the implementation of major projects to increase production in petrochemical and timber processing industries.

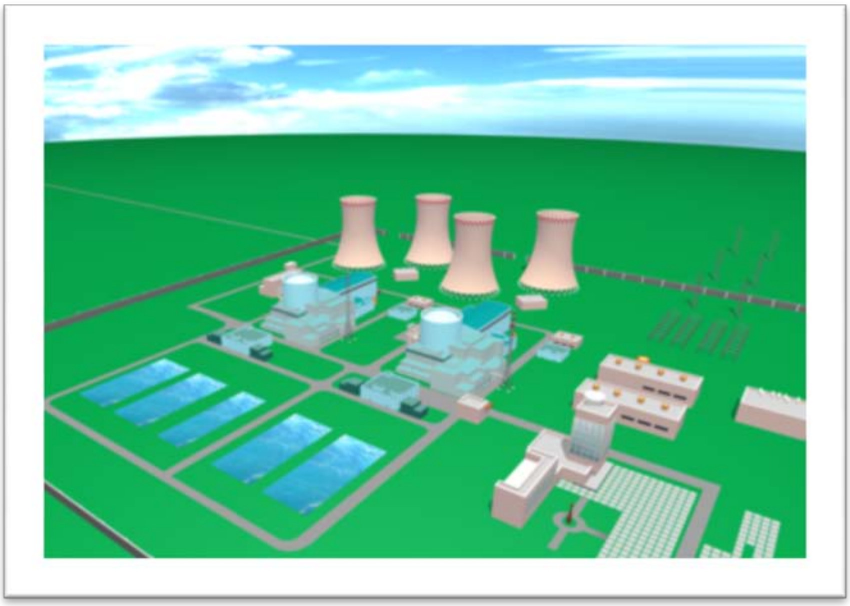


Image. Project of Seversk NPP

To solve future energetic problems in 2007 was developed and in 2008 was approved an “Energy Strategy of Tomsk Region till 2020” (Polushkina, 2008). Its main objectives:

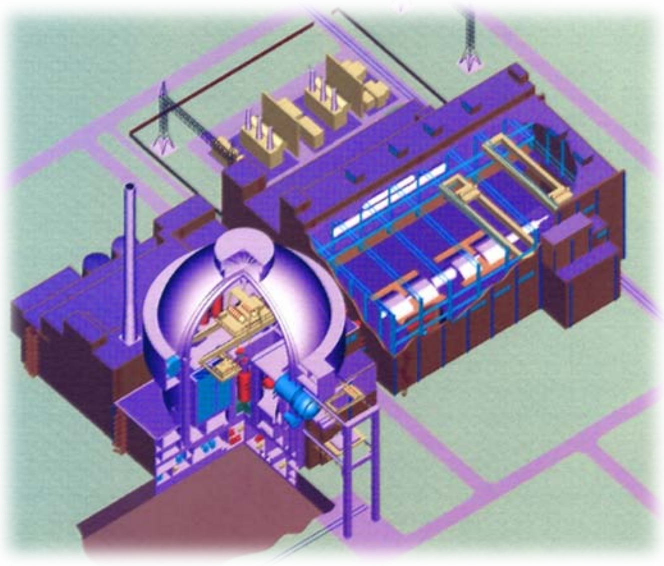
- create conditions for energy saving region, transformation from energy deficit region to energy surplus region;
- construction of new and sustaining electrical and thermal power capacities with integration of innovative technologies;
- building energy efficiency incentives in the production, transport and consumption of heat and electricity, natural gas;

Maximum levels of electricity consumption in the Tomsk region can only be achieved through the construction of a new energy generating source.

The Energy Strategy provides for the commissioning of new power units at nuclear fuel plant at Seversk, which fundamentally solve the problem of energy security in the region 2015 - 2020 respectively.

In this case, the region will not only go to self-balance of power, completely covering their needs, but also be able to supply electricity to neighboring regions in the order of 2.5 - 4 billion kWh. (Polushkina, 2008)

Image. Project NPP-2006 . (Novak, 2006)



Proposed for construction in Tomsk Region Seversk NPP fully meets the requirements of Russian and international regulations on safety - this is the third generation nuclear power plant, which has a high level of security, but in its probabilistic indices core damage very near to the fourth generation of nuclear power plants. (Kopytov, 2008)

Commissioning of the plant will enable to:

- develop the economy of the region, region, cities of Tomsk and Seversk;
- radically solve the environmental problems related to energy;
- develop construction, scientific and educational, health-care databases of Tomsk and Seversk region;
- solve socio-economic problems related to the upcoming shutdown last operating reactor in the power plant in region;
- under the exhaustion of reserves of fossil fuels and its rising prices to ensure long and reliable energy supply Tomsk and region.

Table. Main Indicators of "Seversk NPP", Investment Project Seversk NPP, 2008

Name of Indicators	Value
Installing power capacity of NPP, GWt	**> 2x1,15**
Planned period of work of energy units, years	**50**
Annual indicator of usage of installed capacity, average for all working period time of NPP, %	**90**
Annual output of NPP: **- electricity TW.h (billion KW.h.)**	**17,3**
- heat power energy, mln. Gcal.	**1,2**
Period of work, years	**50**

2.2.3 Construction time of Seversk NPP

There is a certain sequence of actions, required for realization of big investment projects (Factory, 2008) :

- Formulation of investments plan
- Development of supporting documentation
- Construction
- Exploitation
- Decommission

General estimation period of formulation of investment plan, development and realization of investment project of Seversk NPP is about 10 years

Main phases and time period of development of documentation and construction (E.V. Evstratov, 2008):

- Development, concordance and agreement of technical documentation for development of project of Seversk NPP, development, expertise and confirmation of done work about choosing a place (territory) for NPP – 2 years.
- Providing of engineering work, development of a project, expertise and confirmation of a project, getting a license for NPP construction – 2 years (at the same time with getting confirmation with choosing a place for NPP)
- Preparatory period of construction – 1 year (at the same time with the last year of previous phases):
    1. Prepare a site for construction, including:
        - preparation of the territory – logging, vertical planning;
        - temporary fences, roads, buildings and;
        - creation of water systems for drinking and technical water usage etc.
    2. provide transport, social, construction and energy infrastructure of site for construction, including:
        - railway and highway to transport heavy loads;
        - temporary outdoor networks water and canalization systems;

- key buildings and facilities of construction industry - for temporary electricity substation, start-backup boiler for providing a construction with heating, hot water and process steam.

- Main period for construction of power units - 7 years (2011 – 2017)
- Commissioning of 1st power unit – 5th year after beginning of construction phase (2015)
- Commissioning of 2nd power unit – 7th year after beginning of construction phase (2017)

SCEDULE OF ACTIVITY FOR CONSTRUCTION OF SEVERSKY NPP

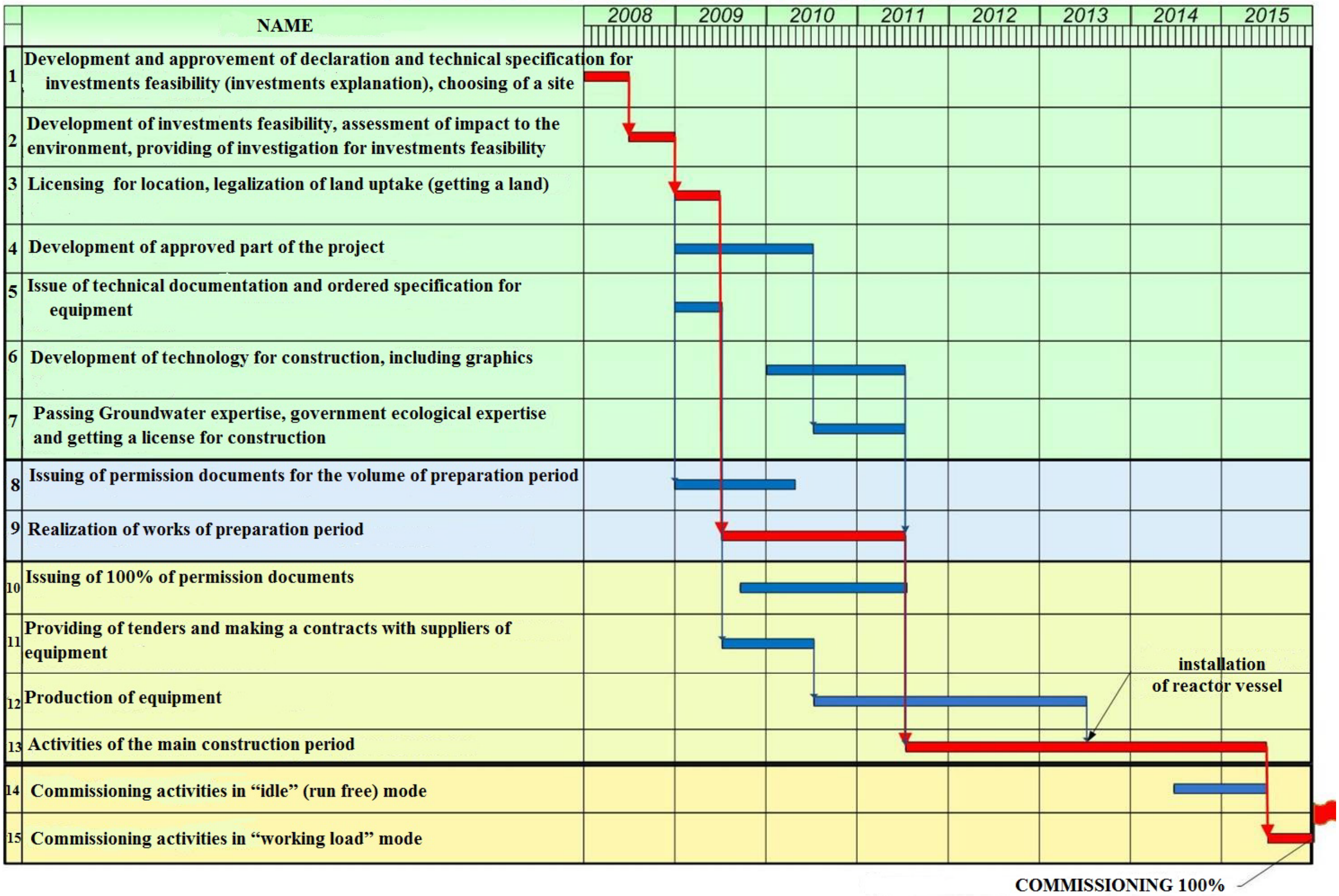


Table. Schedule of activity about Seversky NPP construction. (Logic of reaching goals; V. Novak; "RosEnergoAtom", 2008)

Schedule of activity for construction phase

1. Development and approvement of declaration and technical specification for investments feasibility (investments explanation), choosing of a site – 6 months

2. Development of investments feasibility, assessment of impact to the environment, providing of investigation for investments feasibility – 6 months
3. Licensing for location, legalization of land uptake (getting a land) – 6 months
4. Development of approved part of the project – 1,5 years (18 months)
5. Issue of technical documentation and ordered specification for equipment – 6 months
6. Development of technology for construction, including graphics – 1,5 years (18 months)
7. Passing Groundwater expertise, government ecological expertise and getting a license for construction – 1 year
8. Issuing of permission documents for the volume of preparation period – 15 months
9. Realization of works of preparation period – 2 years (24 months)
10. Issuing of 100% of permission documents – 15 months
11. Providing of tenders and making a contracts with suppliers of equipment – 1 year
12. Production of equipment – 3 years (36 months)
13. Activities of the main construction period – 4 years (48 months)
14. Commissioning activities in “idle” (run free) mode – 1 year
15. Commissioning activities in “working load” mode – 6 months

General Designer and Contractor

1. With order of Rosatom from 14.02.2008 #71 was defined a General Designer – “AtomEnergoProekt” Moscow.
2. According to the Federal law from 21.07.2005 #94 will be provided a tender for the definition of General Contractor for providing works for construction of 2 power units of Seversk NPP in Tomsk.
3. With a winner of tender will be concluded State contract for all the construction period. The same scheme is using for construction of NPP in 4 building sites. (Energy, 2008)

Approximate necessity of enterprise in raw materials

During construction and exploitation it is expected to use local and delivered materials, generally, from already existing production capacities, satisfied by quality and price.

Main equipment of NPP power units (reactors, turbines, generators) will be produced and supplied by Russian companies, secondary equipment by Russian and foreign producers.

Quantitative evaluation and main requirements about quality of equipment, components, materials and raw materials will be defined in "Investments feasibility" document and "project". (A. Tiutiaev, 2008)

Functions of building owner

For execution of functions of building owner on the land for building Severk NPP will be created a branch of "RosEnergoAtom" (Factory, 2008)

2.2.4 Oriented necessity in land resources

According to estimations a plottage (land) for new NPP is 250 hectares, land of the territory for industrial territory 100 hectares.

Taking in account a period of construction, exploitation period and disposal period oriented period of use of industrial territory is about 100 years. (A. Tiutiaev, 2008)

2.3 Operations & Maintenance

O&M

O&M costs are the costs for the decisions and actions regarding the control and upkeep of property and equipment. They are inclusive, but not limited to, the following: 1) actions focused on scheduling, procedures, and work/systems control and optimization; and 2) performance of routine, preventive, predictive, scheduled and unscheduled actions aimed at preventing equipment failure or decline with the goal of increasing efficiency, reliability, and safety. O&M costs include a labour costs, which takes about 50% of total O&M costs. (COMPETITIVENESS OF SMALL-MEDIUM, NEW GENERATION REACTORS, 2008)

Table. Annual sales and O&M cost of Khmelnitsky NPP in 2009 ("Energoatom", 2010)

Indicators	Year, 2009
Generation capacity, MW	2000
Output of electricity, M kW.h	12780,1
Revenue from selling electricity, EUR	166 151 700
O&M costs, EUR	59 280 000
O&M costs, EUR/MWh	3.81
Labor costs, EUR	29 640 000
Labor costs, EUR/ MWh	1.91

In 2009 Ukrainian Khmelnitsky NPP (KNPP) generated 12780,9 mln kW.h. of electricity and sold it to Wholesale electricity market of Ukraine with a price 0,013 EUR/kW.h, from these operations KNPP got revenue EUR 166,2 millions. Average salary in Khmelnitsky NPP in 2009 was 380 EUR/month and total amount of personnel is little more than 5000. Bellow is shown a table of sales and O&M costs of Khmelnitsky NPP in 2009. (Analysis of work of Energoatom in 2009, 2010)

Salary

Working in Nuclear power industry was always prestigious and their salaries were higher than an average in the country. Russian countries (now CIS – Commonwealth Independent States) are not an exception. Thus way an average salary in Russia in 2009 was EUR 648 (RUB 29000; $ 1115) (Average salary in Russia, 2010) and “Concern Energoatom”, which provide exploitation of Russian NPP, had average salary about EUR 1000 (RUB 40 000; USD 1350). (Shanzev, 2010)

In Ukraine average salary in 2009 was about EUR 175 (GRN 1906; $ 240) (Average salary in Ukraine in 2009 increased, 2010), while in “Energoatom” (company that owns Ukrainian NPP) was EUR 440 (GRN 4751 grn; $ 600) (Resolution #4. Report of conference of personnel meeting, 2010), which was 4% more than in 2008 (company promised annual increase of 25%, but because of the economic crisis increase was less than planned).

Average Salary at NPP

Annual average salary in Leningrad NPP was EUR 715 ($ 1000)(Russia, 2009). Leningrad NPP consists of 4 power generating units and in 2009 there worked 5760 people. From Smolensk NPP with installed power 3000 MW and working personnel about 5000, it is possible to get information about average salaries of engineers and operators (Smolensk NPP, 2009). Engineers received EUR 780 (RUB 35000; $ 1100) and operators about EUR 560 – 670 (RUB 25000 – 30000; USD 780 – 940). (Average salaries in NPP, 2010)

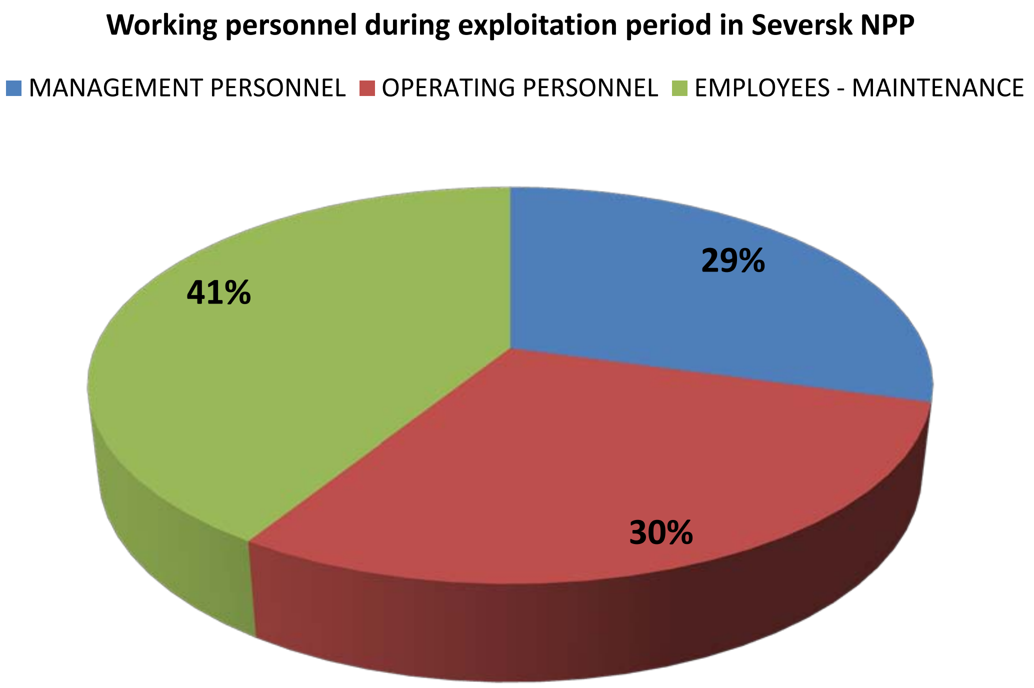
Ukrainian salaries of personnel in NPP is lower than in Russia, Energoatom (company that manages all Ukrainian NPP), reported that these years salaries of NPP will be increased. In 2009 average salary in Khmelnitsk NPP with installed capacity 2000 MW (KMPP) and more than 5000 of employees (dossier of the KNPP) was EUR 380 ($ 520) and in Zaporizhzhya NPP (ZNPP) in 2008 it was UER 390 ($ 535). (Average salaries in NPP, 2010).

Table. Average salary/ month of personnel in NPP. Proatom (Russia; 2010)

Name of NPP	Average salary, EUR	Average salary, USD	Country
Concern Energoatom	1000	1350	Russia
Energoatom	440	600	Ukraine
Leningrad NPP	715	1000	Russia
Khmelnitsk NPP	380	520	Ukraine
Zaporizhzhya NPP	390	535	Ukraine
Engineers (Smolensk NPP)	780	1100	Russia
Operators (Smolensk NPP)	560 – 670	780 – 940	Russia

From documents of construction of Seversk NPP is possible to see a percentage of people who will work in new NPP. The number of operating personnel for NPP exploitation for 2 power units is 1641 people, including 496 – staff management, 500 – operational staff, 645 employees – maintenance personnel. From these data a staff management has 30%, operational staff – about 30% and 40%. (A. Tiutiaev, 2008)

Table. Proportion of Personnel in Seversk NPP. Declaration about Intentions of construction Severky NPP in Tomsk Region. 2008



For complete a full quantity of exploitation personnel it is planned a preparation of specialists, mainly from a base of education system of middle and high professional level of Tomsk and Seversk cities and from systems of professional development (training) of “RosEnergoAtom”. (A. Tiutiaev, 2008)

Providing of personnel and their families with housing and communal services

According to preliminary data a necessity in housing and social infrastructure for building and assembly personnel and exploitation personnel is 90.000 m^2. Providing of personnel needed in housing and their families is provided by enlarging existing housing complex of Seversk. Construction of additional housing and objects of social infrastructure is defined by materials of “Investments feasibility of a project”.

2.4 Fuel

2.4.1 Necessity of enterprise in fuel and energy recourses

During a construction phase of the first power-generating unit energy will be provided by local regional electrical network and heat energy from temporary reserved boiler house. For construction of the second power-generating unit, is supposed to use an electric and heat energy from already set in exploitation first power unit of Seversk NPP. Further exploitation need in power recourses will be provided by a part of generating electric and heat energy of Seversk NPP. During a period of repairing works energy will be taken from working power-generating unit and heat station if it will be required. (V. Asmolov, 2008)

Transportation of fuel will be provided by special containers for transportation.

Image. resistance test of container

Image. Transportation of containers with fuel

During all history of transportation of radioactive materials there was no any accident, which had a result of going outside of radioactive materials from container. (Factory, 2008)

2.4.2 Average price of nuclear fuel for NPP

An exclusive supplier of nuclear fuel to Ukraine till this time was Russia. Nuclear fuel is supplying in fuel assemblies. Fuel assemblage is an engineering product, which contains nuclear materials and designed for getting a thermal energy in nuclear reactor by providing of a controlled nuclear reaction.

“Fuel assemblages” are prepared by “Machine – building plant” (city Elektrostal) and also by “Novosibirsk plant of chemical concentrates”. “Fuel assemblage” looks like six-sited bundle of fuel elements with length of 2,5 – 3,5 meters (it approximately correspond to the height of active zone) and has a diameter of 30 – 40 cm, made from stainless steel and zirconium alloy. Fuel elements are taken to the “fuel assemblages” for simplify calculations and movement of nuclear fuel in reactor. In 1 “fuel assemblage” usually is placed 150 – 350 fuel elements, in active zone of reactor usually can be placed 200 – 450 fuel assemblages. For reactor type VVER-1000 a construction of “fuel assemblage” consists of 312 fuel elements and for VVER-440 – 126 fuel elements.

(NPP with reactor VVER-1000, 2010).

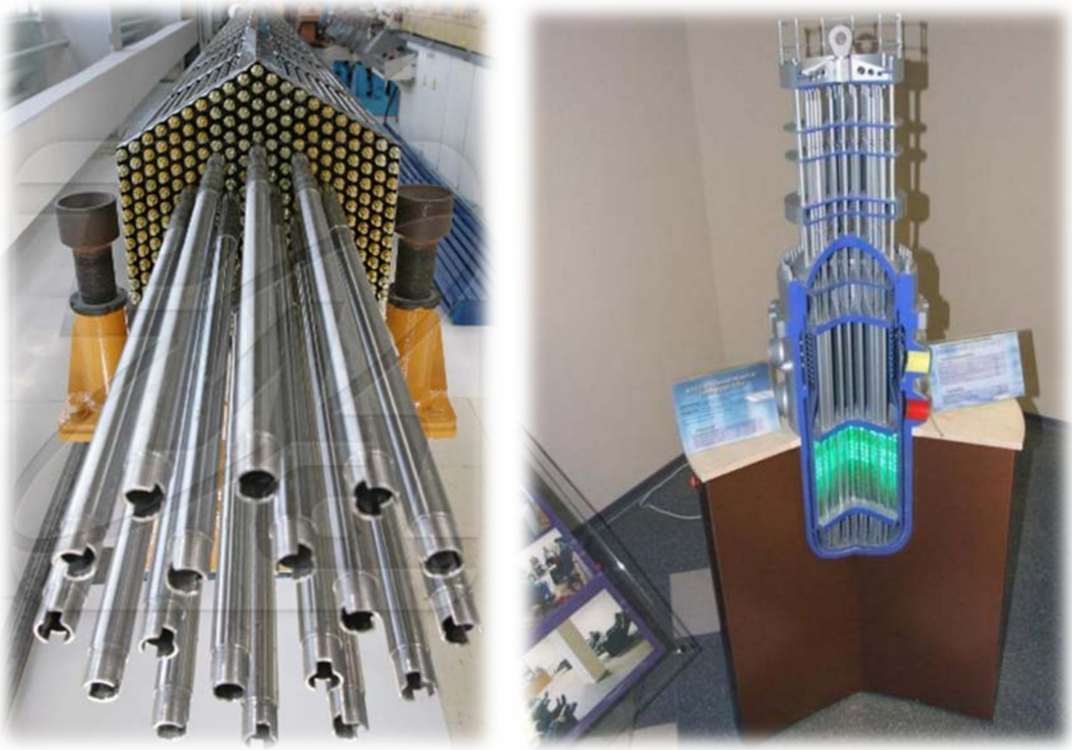


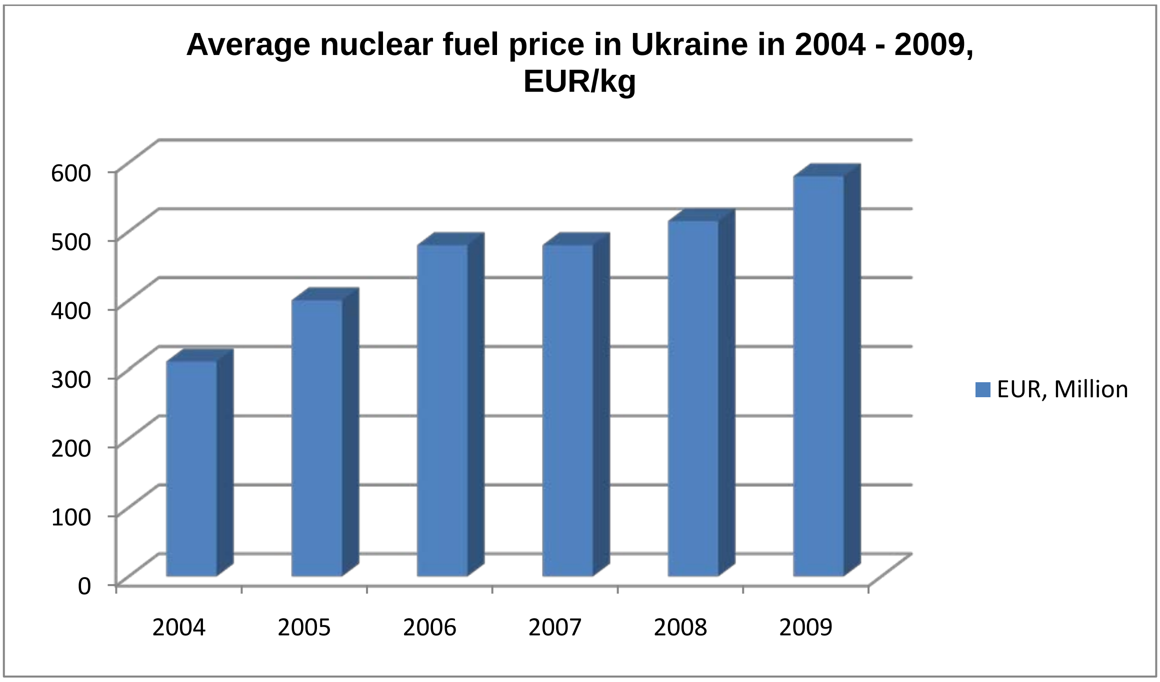
Image. Fuel assemblage

In 1997 “Energoatom” and TVEL (supplier of nuclear fuel) signed contracts for supplying nuclear fuel till year 2010. From the day of signing documents, both sides were revised annually its price. A price of nuclear fuel wasn’t open to the public.

Image. Nuclear fuel assemblage

For load a reactor with nuclear fuel required fuel assemblages. In 1 fuel assemble for reactor VVER – 1000, there are 312 fuel elements. Weight of one nuclear "fuel assemble" is 681 kg. From not official data, one fuel assemble of Russian producer has a price about EUR 360 000 ($ 500 000) and American one EUR 650 000 ($ 900 000). (Ravinsky, 2008). Price for nuclear fuel has a trend for increase. If in 2004 a price for Ukraine was about EUR 311 ($ 400) for kg, in 2005 – more than EUR 400 (500$), and in 2006 it was already more than EUR 480 (600$), in 2008 there was increase for 20% - more than EUR 515 ($ 700) per 1 kg. (J. Nedashkovksy, 2008) If to consider, that in 2009 an average price of nuclear fuel was 580 EUR/ kg (800$/kg) (Kabakova, 2009), then one "Fuel assemblage" will have a price EUR 395 000 = 681 kg * 580 EUR/ kg (544 800 $ = 681 kg * 800$/ kg). Annual need of Ukrainian NPP in "Fuel assemblages" is 620 pieces. In 2008 for fuel assemblies it was spent EUR 380 million (GRN 3 230 mln; $ 517 mln). (Nuclear fuel of Ukraine, 2009)

Table. Average nuclear fuel price in Ukraine in period 2004 - 2009, EUR/ kg (Nuclear fuel of Ukraine, 2009)



Almost all NPP in Ukraine use a nuclear fuel of Russian company "TVEL". For making the cooperation with Ukraine stronger, at the end of 2009 TVEL proposed to build in Ukraine according to Russian technologies a plant for fuel fabrication. In January "Ministry of fuel and energy of Ukraine" initiated a tender for choosing a partner for building a plant, and among participants was Russian company TVEL and its competitor Westinghouse. According to conditions of contract with TVEL, a company should supply Ukrainian NPP with nuclear fuel for 15 years, from 2011 till 2025. (Ukraine plans to build a plant for production of nuclear fuel, 2010)

Only power unit of South-Ukrainian NPP uses fuel of American company "Westinghouse". February 5, successfully finished a 4 years experimental-industrial exploitation of 6 fuel assemblages, which were made by American company Westinghouse in the 3rd power unit of South-Ukrainian NPP. A Ukrainian – American project was created in year 2000. Its scope was to study a possibility of use American fuel assembles in Ukrainian NPP. And also realization of the project of qualification of nuclear fuel for Ukraine was realized according to the Energy strategy of Ukraine till year 2030 with a main aim to diversify a sources of supply of energy fuel by collaboration with multinational company

Westinghouse. This company owns almost 1 quarter of the world nuclear fuel market. Financing of the project was made in terms of international program of fuel safety, where a main financing part is a government of USA. (Ukraine rinnovated an taking out to Russia spent nuclear fuel, 2010)

From part “energy price for nuclear fuel for NPP” is possible to see, that in 2009 Ukraine was paying for nuclear fuel for NPP 1,39 EUR/ MWhe.

2.4.3 Waste products and its utilization

Main waste products are fluid, hard (rigid) and gaseous waste.

A project of NPP provides processing of fluid and rigid radioactive wastes with use of modern technologies, which has an aim to provide a safe storage and transportation. Used technologies will ensure getting a final product, which will fit all technical norms for temporary storage and final burial of radioactive wastes.

Fluid radioactive substances will be passed through cleaning and processing processes. Fluid radioactive wastes are cured with usage of cement and other additives. For safety transportation, temporary storage in on the territory of NPP and final waste burial will be used ferroconcrete (reinforced concrete) protective containers.

Rigid (hard) radioactive waste will be crushed and compressed for further storage on the territory of NPP.

A complex of project decisions about treatment with radioactive waste, formed during exploitation, will provide a long-term storage of radioactive waste in special ferroconcrete protective containers NZK-150-1.5P. (Production of ferroconcrete protective containers, 2010)

Image. Ferroconcrete protective container NZK-150-1.5 P

Radioactive gaseous wastes after cleaning with special filters till a safety level, which is determined by regulating norms, will be thrown out in an atmosphere through a high-rise pipe.

For non radioactive production waste it is planned to use places for industrial and domestic waste determined by regional agency.

Waste nuclear fuel should be evacuated from NPP after technological processing for persistent storage for the next processing in the proper enterprises. (Evstratov, 2008)

Conclusion for treatment with radioactive wastes

Main principle of all radioactive waste in NPP – putting it to ecological safety status, using following methods:

- Packing treated radioactive waste into special containers
- Rejection of radioactive waste to the special cement matrix

Quantity of fluid radioactive waste for 1 power-generating unit WWER-1200 make up:

- Low-level radioactive waste – 10 m3/year
- Intermediate-level radioactive waste – 3 m3/year
- Vat residue (distillation residue) – 25 m3/year

Storage of rigid (hard) radioactive waste provided in special metal capsules, which are located in station depository. Size of depository of high-level radioactive wastes is timed for all exploitation period of NPP. (Pankina, 2008)

2.4.4 Spent nuclear fuel and liquidation costs

Today Ukrainian government company "Energoatom", who controls Ukrainian NPP, pays for liquidation of spent nuclear fuel. A price for removing of a spent fuel from Ukraine to Russia increases every year, going closer to the world price – EUR 720 (1000$) per kg of metal. (Construction of depository of spent nuclear fuel, 2007).

Thus in 2009 "Rosatom" (Russian government company for nuclear energy) increased on 17% prices for storage and processing spent nuclear fuel from Ukrainian NPP from EUR 260 (360 $) to EUR 305 (423 $) per kg (Economic calculation during NPP construction, 2009)

Till now, Ukraine doesn't has its own centralized storage of spent nuclear fuel, apart Zaporizhzhya NPP, which is independent from Russian policy of taking back and storage in Russia. Zaporizhzhya NPP is a unique NPP, who doesn't transport spent nuclear fuel to Russian Federation. All other send it to Russia and Ukrainian "Energoatom" pays for transportation and storage. According to different evaluations it pays from EUR 88 to 132 million (120$ to 180$ mln). (Kosharnaia, 2008)

Taking into consideration, that Russia in a world market has a share of 40% of capacities for uranium enrichment -17% of fuel market, 28% of total capacities for construction of NPP and 8% for uranium extraction. Also it owns a high technological and scientific potential. All this tells, that Russia can be a very attractive partner for Ukrainian energy company "Energoatom". (Nuclear fuel for NPP of Ukraine, 2009)

Storage of spent nuclear fuel in Zaporizhzhya NPP

In a global scale of storage of spent nuclear fuel from NPP is foreseen a creation of special all time storage, which could satisfy a safe keeping of spent nuclear fuel for some thousand years.

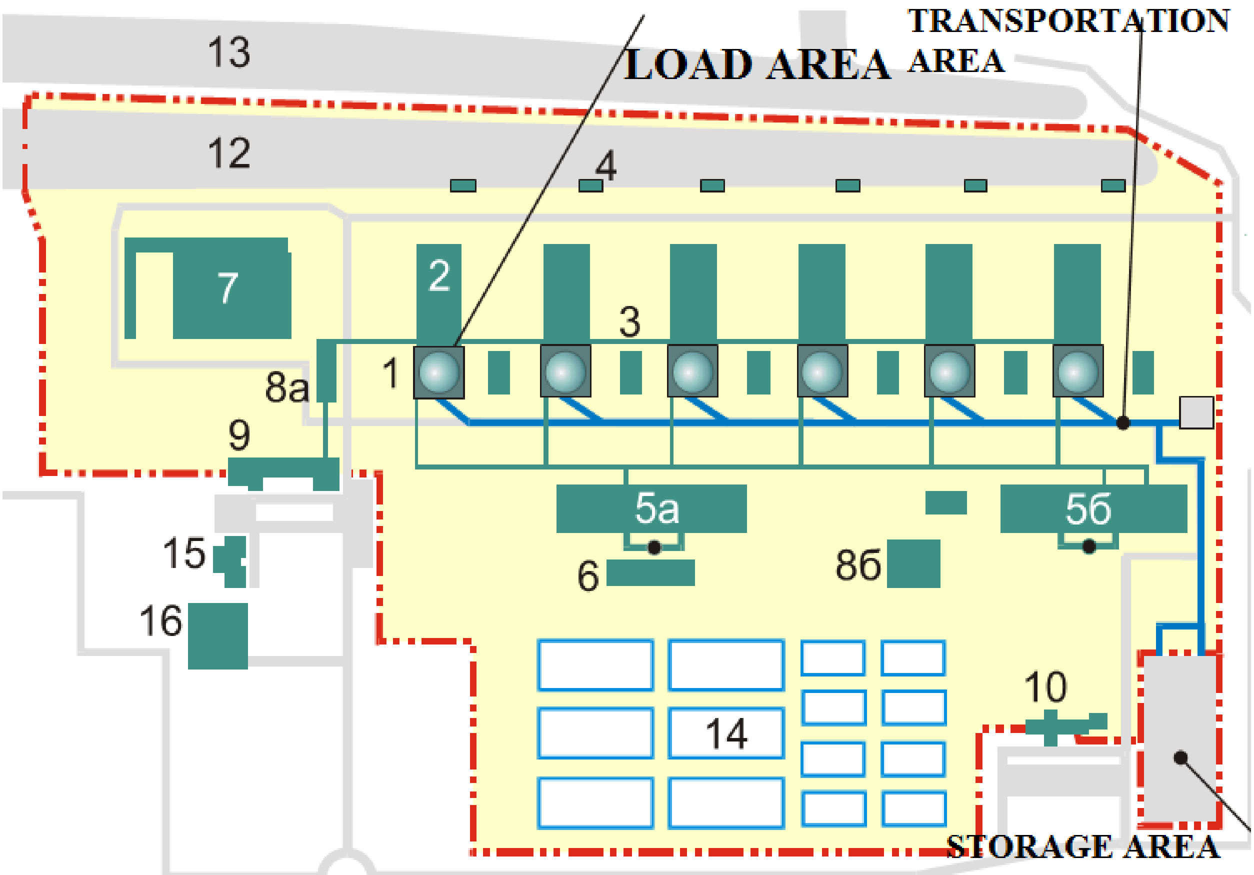
By the project decision of all Soviet NPP with reactor VVER – 1000, it was decided to make an import of spent nuclear fuel (after 3 years of keeping in special pools) to the stationary storage in Russia. But, even in the period of Soviet Union, it become understandable, that from limited high costs of such method, this problem should be solved by own funds of NPP.

In 1992, management of Zaporizhzhya NPP began to try to find a way for radical changes for the biggest NPP in Ukraine, because from the forecasts of specialists, from a deficit of “free cells” in pools of time exposure in 1998 a power units could be stopped and a one quarter of people of the country could be without electricity.

According to the agreement with atomic commission of Ukraine (Goskomatom) Zaporizhzhya nuclear power plant chose a project based on technology of dry ventilated container storage of the company DESS. The technology of the company has been recognized as the most environmentally friendly and more fitted the specific needs ZNPP.

Territorial objects of dry storage of spent nuclear fuel in Zaporizhzhya NPP are divided into 3 areas:

Image. Industrial Area of Zaporizhzhya NPP



Loading area is located in the buildings of reactors compartments 1 – 6, namely in the central hole and transport corridor. In these areas for loading and removal of spent fuel is used an existing transport – technical equipment: a polar crane and loading machine.

Transportation area is a network of roads, through which a delivery of spent fuel to the storage area is made. Spent fuel is transported to the storage by special transporter of containers, which was designed by this project.

Storage area – is an area of storage of a spent fuel, where concrete containers are placed. To place containers the same transporter of containers is used. Storage capacity is calculated for 380 containers, in which it is possible to put 9000 spent fuel assemblages. At the same time, according to conditions of licensing, it is possible to store a spent fuel only of Zaporizhzhya NPP.

After 3 – 5 years of keeping a spent fuel in the special pool its radioactivity significantly decreases. That fuel is possible to keep with a dry method in special containers. This method of intermediate storage of spent fuel is wide popular in the international practice during exploitation of NPP. (History of creation of storage of spent nuclear fuel, 2010)

So, Zaporizhzhya NPP is one of the first Ukrainian NPP, who has a practical experience of building and using of a dry storage nuclear spent fuel. Average price of storage of spent fuel in storage of Zaporizhzhya NPP is about 35$. (dry storage of spent nuclear fuel is profitable, 2003)If to compare to the price, that Ukraine was paying to Russia in 2008 – 360$ (EUR 260) and 423$ (EUR 305) in 2009, having own storage of spent nuclear fuel is cheaper more than in 10 times.

2.4.5 Program of building of a central storage of spent nuclear fuel

A price of fuel does not include a liquidation of radioactive waste. That is why Ukrainian energy company “Energoatom” insists on building a storage for spent nuclear fuel.

In 2001 in Zaporizhzhya NPP was built a “dry” storage of spent nuclear fuel according to technologies of American company DE&S. At that period of time, a quickly decision was made because of the threat of not in the right time taking out to Russia a spent fuel of Zaporizhzhya NPP. Commissioned storage gave an opportunity to Ukraine for annual money save about EUR 75 million ($ 100 mln).

Speaking about central storage for spent nuclear fuel of 3 Ukrainian NPP, should be noted that a price of the question is EUR 1.5 billion ($ 2 billion). This sum of money Ukraine should pay to Russia in a case that a spent nuclear fuel of 3 Ukrainian NPP during projected working period will be stored there. It will be in a case, if own storage wouldn’t be built (and this is without including of 20 new power units). (How to control radioactivity, 2009)

It is assumed, that a storage capacity of dry storage of spent nuclear fuel will be 16529 spent nuclear fuel assemblages, including 12010 pieces for VVER – 1000 and 4519 for VVER – 440. Lunching mechanism of storage is planned to build in 36 months (3 years). Its capacity will be for 3616 spent fuel assemblages (VVER – 1000 – 12010 pieces, VVER – 440 – 1105 pieces).

Contract between National Energy Company of Ukraine “Energoatom” and “Holtec International” foresees 2 phases.

- First phase provide
  - preparation of technical and economical description of the project,
  - evaluation by the government
  - necessary accept from ministries and other agencies
  - discussion with the public
  - concordance with local bodies of power

    - providing of referendum and confirmation by parliament
- Second phase include
    - Licensing
    - Building
    - Commissioning of a storage

Cost of first phase is 250 000 USD and a price of contract for building of dry storage for spent nuclear fuel is 146 million of Euro. So total cost planned to be round EUR 146,25 million. About 128 million of Euro (about 85%) is planned to attract from investments of general contractor “Holtec International”. (Building of a storage of nuclear spent fuel, 2009)

2.5 Decommissioning

2.5.1 Costs of decommissioning

All power units of NPP, which are supposed to be decommissioned in a short period of time, were constructed during a period of Soviet Union. And at that period of time didn't pay much attention to questions of decommissions (especially its financial part). It was supposed, that all appeared questions and problems would be solved through central department of Soviet Union. That is why special funds for accumulation of finance for decommissioning weren't done, like it is in western countries. (Burangulov, 2005)

Taking into consideration development of new nuclear strategy in 2007 in Russia there was a meeting of scientific – technical council of "Rosatom" (Russia) and concern "Rosenergoatom" (Russia), where questions of decommissioning of NPP and radiation hazardous objects were discussed. Along with the need to develop a Concept of the decommissioning of nuclear facilities, radiation sources and storage" and the revision of normative documents on decommissioning of nuclear power units, there was a focus on the need for fast finish to develop a new "method for calculating the decommissioning costs of preparing and execution of decommissioning of nuclear power units".

It is estimated that the total cost of decommissioning and dismantling of a nuclear power unit will take from 20 to 30% of new power unit costs. (Decommissioning of NPP: problems and ways out, 2008) Significant impact on the expenditures has national characteristics – this is volume of required work and also ways of treatment with radioactive waste components, methods of its processing and separation.

All work about decommissioning of NPP is financed from "reserve of decommissioning nuclear power plants", which is formed by revenue of the company which manages and controls NPP. Today a norm of charge is 1,6% which is definitely not enough. Funds from "reserve of decommissioning nuclear power plants" will be spent only for financing work about decommissioning and do not include expenditures for social and other programs. Approximate list of activities about decommissioning is shown in the table "structure of costs for decommissioning of power unit VVER – 440".

To replenish of "reserve of decommissioning nuclear power plants" in Russian case it is proposed to increase charges from revenue till 2,2%. Additional incoming cash flow to reserve will be prolongation of exploitation period of nuclear power units. Russian example of prolongation of power unit VVER – 1000 in Balakovsk NPP minimum for 15 years shows a cost of EUR 235 million (RUB 8500 mln; $ 327 mln). (Ivestment project of prolongation of 1st power unit in Balakovsk NPP, 2009)

Comparing Russian and Finland projects for decommissioning it is possible to note, that their data for total sum volume of work, time for decommissioning etc. are concurred. Decommissioning time from the moment of stop of power unit takes 12.5 years, quantity of people for preparatory period is 375 and total volume of work is evaluated as 2920 people/ years. Structure of costs for decommissioning is in the table "structure of costs for decommissioning of power unit VVER – 440".

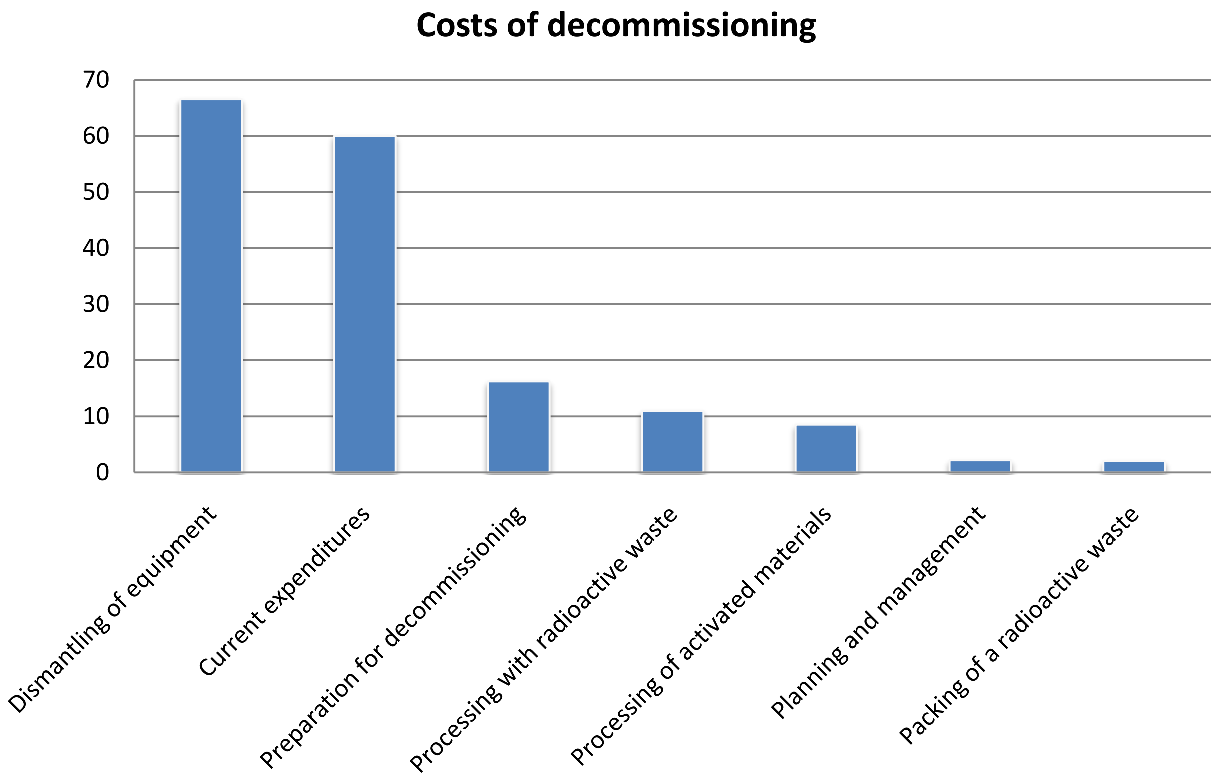
Table. Structure of costs for decommissioning a power unit VVER – 440. Decommissioning of NPP: problems and ways out. 2008

№	Activity	Costs	
		Mln $	%
1	Planning and management	2,17	1
2	Preparation for decommissioning	16,25	9
3	Processing of activated materials	8,53	5
4	Dismantling of radioactive equipment	66,54	39
5	Packing of a radioactive waste to containers	2,04	1
6	Processing with radioactive waste	11,00	6
7	Current expenditures	60,00	36
Total		166,53	100

Execution of works in the radiation–dangerous conditions require a large amount of research, design, technology and development activities, manufacturing, testing and introduction of devices for deep deactivation and radiation–resistant robotic devices.

Construction of storages facilities and burial ground for radioactive waste, containers for transportation, means for conditioning waste – without solving these questions is not possible to create a technology of work and hence the whole concept.

Table. Costs of decommissioning of a power unit VVER – 440. Decommissioning of NPP: problems and ways out. 2008



Costs of decommissioning of NPP, beside such items as capacity of power units, exploitation time and time till final stoppage, depends also from lot of other factors (generally it is a type and condition of NPP, problems associated with handling and storage of residual materials, methods of obtaining licenses, personnel costs, schedule of work).

Dispersion of decommission costs is significant. It is possible to have only estimated data and this is conditional data. Thus, cost per unit 540 EUR/kW (750 $/kW) may be considered as a first approximation and be used as orient during development decommissioning projects of different nuclear power units.

Bellow showed costs of decommissioning of "Lovis" NPP in Finland. (Decommissioning of NPP: problems and ways out, 2008)

Table. Decommission of Lovis NPP in Finland. Muratov, LTD "TVELL". 2008

№	Expenses	Cost, mln. $
1	Planning and management of project	2,39
2	Expenses in preparation phase	17,90
3	Treatment with radioactive material	9,39
4	Treatment with impure material	70,83
5	Treatment with wastes of serving NPP	0,12
6	Containers for wastes	2,25
7	Building for burial	10,89
8	Personnel expenses for decommissioning phase	66,10
9	Unexpected expenditures (10%)	17,99
	Total	197,85

Bellow is shown a table, where is possible to see a financing of decommissioning NPP in different countries.

Table. Financing of decommissioning of NPP (Decommissioning of NPP: problems and way out. 2008)

Country	Existence of a special fund	Who provide financing, management of a fund
Belgium	–	Exploitation organization
Germany	+	Exploitation organization
Finland	+	Government
France	+	Exploitation organization
Great Britian	– for government NPP + for private NPP	Government, Exploitation organization
Italy	–	Government
Japan	–	Exploitation organization
Canada	–	Exploitation organization
Netherlands	+	Government
Russia	+	Exploitation organization
Ucraine	+	Exploitation organization
Sweden	+	Government
Switzerland	+	Government
Spain	+	Government
USA	+	Exploitation organization

2.5.2 Prolongation of exploitation period of NPP and economic effect.

On the example of Ukrainian Rivne NPP is shown economic result in the case of prolongation or decommissioning of 1st and 2nd power units with nuclear reactors VVER – 440.During calculations of economic feasibility about prolongation or decommissioning of 2 power units of Rivne NPP, should be taken into consideration that, expenses of "Wholesale market of electrical energy of Ukraine" for purchasing electricity, which is produced by thermal power plant will increase annually on EUR 70 million (GRN 70770 mln.; $ 96 mln). Such calculation is made as average product of numbers of electrical energy, which is generated by power 1st and 2nd power units of Rivne NPP and difference between generation of electrical by nuclear and thermal power plants between 2007 – 2009.

In addition, for decommissioning of 1st and 2nd power nuclear power units of Rivne NPP in first 10 years after stop working it is necessary to pay EUR 28.5 million (GRN 308,1 mln; $ 38.5 mln) and a full cost of decommissioning of two reactors is EUR 165 million (GRN 1785,5 mln; $ 223 mln). (Feasibility study of prolongation of power units in Rivne NPP, 2010)

Table. Economic losses of “energy buying company” in a case of substituting of NPP electricity generation by Thermal power plants in Ukraine. Feasibility study for prolongation power units in Rivne NPP. 2010

		Name of indicators	Unit	Rivne NPP			
				2007	**2008**	**2009**	**F 2010**
				(1st and 2nd power units) Rivne NPP	*1st and 2nd power units*	*1st and 2nd power units*	*1st and 2nd power units*
I	1.	Output of electricity, power units # 1 and 2 power units	Mln.kWt.h.	4 133,73	5 096,10	2 616,41	3 728,00
	2.	Tariff on electricity for NPP of “Energoatom” (average annual)	Grn./kWt.h	0.013	0.017	0.0125	0.015
	3.	Commercial output of power units # 1 and 2 (calculation from a tariff of electricity for NPP of Energoatom)	EUR, mln	54.5	77	33	55
II	4.	Average tariff of electricity for thermal power plants	Eur./kWt.h	0,035	0,04	0,033	0,036
	5.	Difference in tariffs Thermal PP and Nuclear PP	EUR./kWt.h	0,022	0,025	0,021	0,021
	6.	Increase of expenses of “Wholesale electricity market” for buying electricity in a case of replacement of 1st and 2nd power units of Rivne NPP with thermal power plants	EUR, mln	91	126	54	78

According to the technical-economic calculations, expenses for continue of exploitation could be EUR 505 ($680) per kWt of installed capacities of NPP depending from dimension of modernization and reconstruction of primary and secondary systems of power unit. For example, according to the analysis of 2006, a cost of kWt.h of new power units was – EUR 1480 ($2000), that shows an economic benefits for prolongation of exploitation period of existing power units. Today, according to the analysis of research for continue of exploitation is determined, that cost per unit of kWt will be EUR 265 ($358). In Russia according to information of “Rosenergoatom” forecasted cost per unit of prolongation of power unit with type of reactor VVER – 440 (Kolsk NPP) is EUR 207 ($ 279) per kWt and VVER – 1000 (Novovoronezh NPP) – 260 EUR/kWt (350 $/kWt). (Economic efficiency of prolongation of NPP's exploitation period, 2010)

Taking into consideration a decommissioning (first years about EUR 2.9 million; GRN 31 mln) and annual expenses of “Wholesale electricity market of Ukraine” for buying electricity, that is generated by thermal power plants in the case of decommissioning 2 power units of Rivne NPP (annually EUR 71 million (GRN 770 mln.), payback time of investments of power units #1 and #2 of Rivne NPP for fuel and energy complex will be a little more than 3 years. (Feasibility study of prolongation of power units in Rivne NPP, 2010) From the economic point of view, this term is considered as medium term payback project and acceptable for industry.

2.6 Financing and Revenue

2.6.1 Investments plan of construction of Seversk NPP

On the plan investment of the construction of Seversk NPP in Tomsk is possible to see more detailed costs of construction by periods of time. It is planned to invest EUR 1 869 millions (RUB 67 300 mln; $ 2 588 mln) for construction of first power unit and EUR 1 852 millions (RUB 66 700 mln; $ 2 565 mln) for the second power unit.

Preliminary plan of construction of Seversk NPP in Tomsk is shown bellow. (RosEnergoAtom, 2008)

Table. Construction time and cost of 1st power unit in Seversk NPP, EUR million (RosEnergoAtom, 2008)

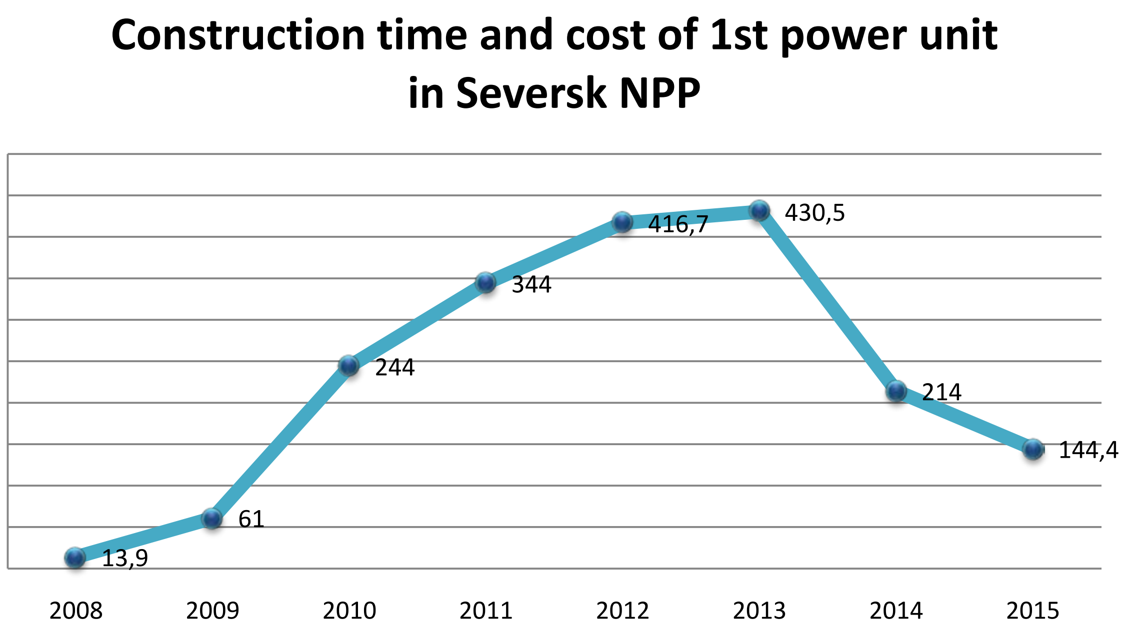
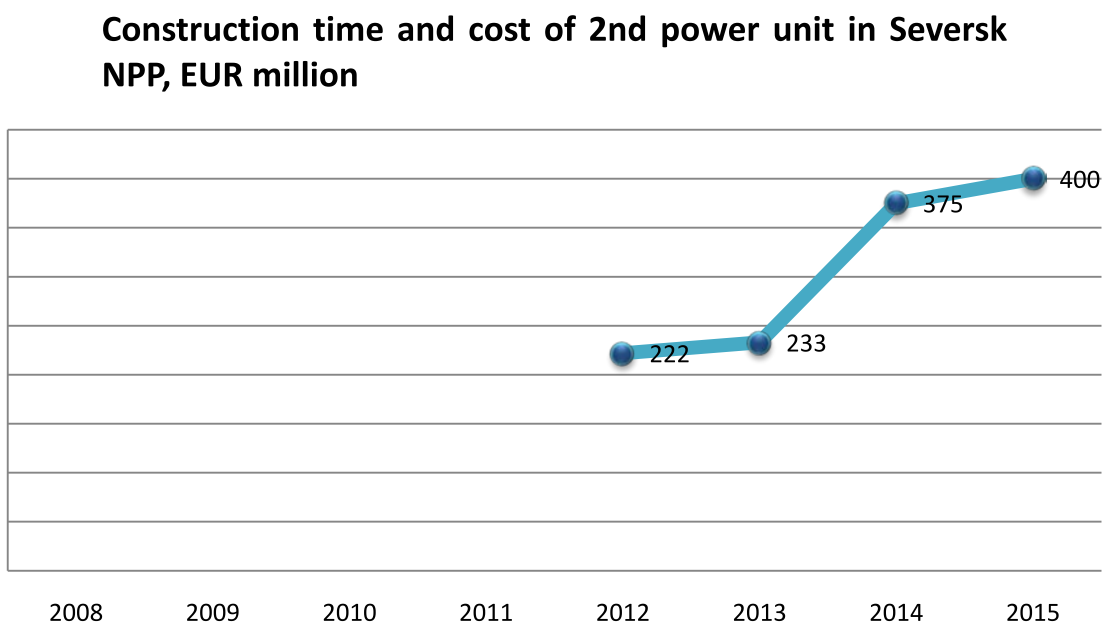


Table. Construction time and cost of 2nd power unit in Seversk NPP, EUR million (RosEnergoAtom, 2008)



2.6.2 Revenue

- WACC

According to resolution of the government, which defines price parameters of the long-term market of power generation capacities an WACC for new NPP will be at the level of 14%. (Putin, Government Resolution #238 from April 2010 about definition of parameters of long-term market of power capacities, 2010)

- Kd and Ke

For calculation of a profitability norm according to the contracts, it is defining:

  - Base level of profitability of investing capital fixes at the level of 15% – for suppliers of energy resources, which didn't increase their authorized capital by placing additional shares
  - Base level of profitability of investing capital fixes at the level of 14% – for other suppliers of energy resources
  - Base level of profitability of state obligations is 8,5% (Putin, Regulation of calculation a price for generation capacities, which ensure return of capital and exploitation expenses, 2010)

- Corporate Tax Rate.

From year 2009 a basic corporate tax rate in Russia is 20% (2% is paid to the federal budget and 18% to the budgets of subjects of Russian Federation). Before 2009 the corporate tax level was 24%. (Tax Code of Russian Federation, 2010). In Ukraine a basic corporate tax rate is 25% ("Juveko", 2010), but new government of Ukraine in 2010 is going to make basic corporate tax rate at 20%, the same as in Russia. (Legislative body of Ukraine gave to business tax benefits, 2010).

For example according to estimations of construction of new NPP in Nizhegorodsk with 2 power units of its power generation 1,15 GWt per each (totally 2,60 GWt), during exploitation period (60 years) is going to pay about 40 billions of RUB (1250 millions USD; 984 millions EUR) of corporate taxes (Shanzev V. , 2010).

Table. Currency exchange in Euro, USD, Russian Rouble (RUB) and Ukrainian Hryvna (UAH) by Central bank of Russia

Currency converter	2002	2003	2004	2005	2006	2007	2008	2009	2010
Russian Rouble (RUB) for 1 USD	31.22	30.5	28.31	28.44	27.22	25.5	26	32	29.67
RUB for 1 EUR	29.05	35	36.3	35.26	34.47	35.2	36	44.7	40.6
Ukrainian Hryvna (UAH or GRN) for 1 USD	5.3	5.36	5.37	5.2	5.1	5.05	6.25	8	8
UAH for 1 EUR	4.95	6.12	6.9	6.45	6.4	7.03	8.5	11.1	10.8

- Revenue

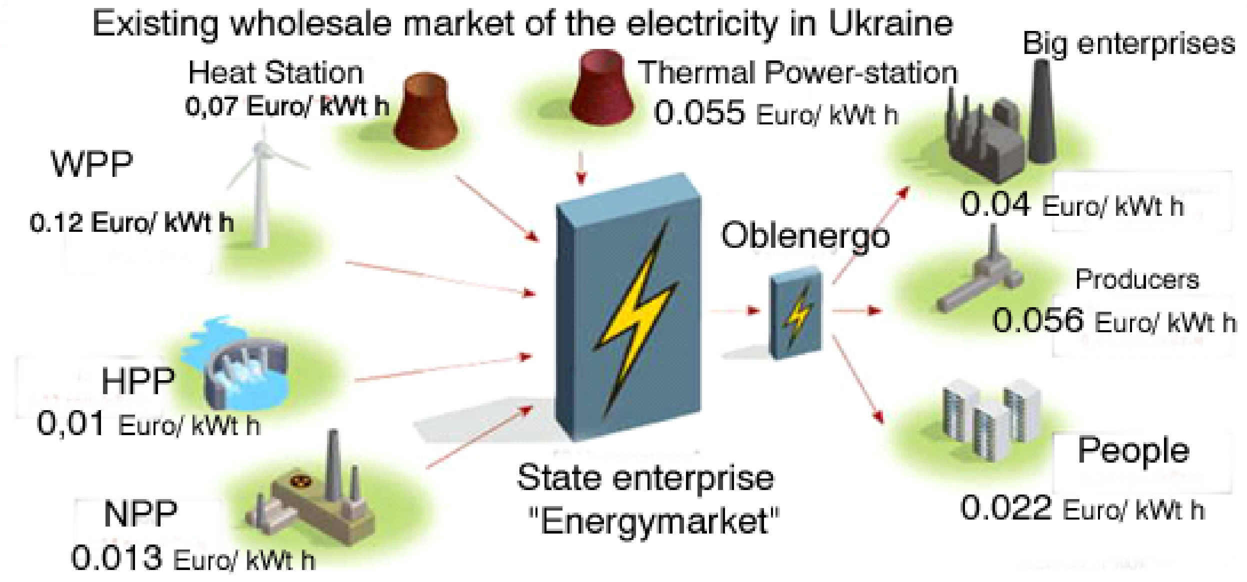
Last year Khmelnitsky NPP, where till 2016 are going to install 2 power units VVER – 1000 with total generating capacity 2000MW, delivered to wholesale energy market of Ukraine 12 781 mln kWh and got a revenue from selling electricity EUR 166,2 million. Total revenue of all Ukrainian NPP from electricity generation was in 2009 was EUR 1 081 million (83 153,9 mln kWh)

Table. Historical value of the price of EE paid to NPP in recent years

Name	Unit	2007	2008	2009	F 2010
Tariff on electricity for NPP of "Energoatom" (average annual)	EUR./kWt.h	0.013	0.017	0.0125	0.015
Tariff on electricity for NPP of "Energoatom" (average annual)	GRN./kWt.h	0,0942	0,1222	0,1384	0,1583

Trend of a price for 1 kWt.h shows annual increase. Only because of difference in exchange in Euro currency a forecasted price of 2010 seems to be lower than in 2009. Soon, when market will be transformed to the new model with bilateral contracts, it is expected a significant increase in the price for electricity, but this information will be available during transformation to the forth phase

Image. Selling price of electricity generation companies in Ukraine in 2009. Committee of statistics. 2010



- Other information

Government Enterprise "Rosatom" through its daughter company "AtomEnergoProm" intends to make big issue of obligations (bonds). Board of Directors of the "AtomEnergoProm" took a decision to issue bonds in years 2009 –

2010 with total sum of 195 mln. roubles (6,1 million USD; 4,36 mln EUR). Attracted funds company plans to direct into 2 directions:

- First, refinance a part of short-term debt, taken at the end of 2009 with high interest rates. Company can spend about 25% of its issues;
- Second direction (about 75%) of attracted funds will be spent to the financing of investment program about development of nuclear energy of the country, particularly in building of NPP. ("RosAtom" intends to make an issue of obligations, 2009)

A case of financing of new NPP in Belarus. For execution of this project a government of Belarus is going to take 100% loan from Russia – 9 billion of USD (6,45 billion EUR). Belarusian NPP is expected to have 2 power units with total capacity of 2400 MW (1200 MW each power unit). Cost of equipment is going to have about 60% of total costs. And according to the opinion of one of the experts 9 billion of USD (6,45 billion EUR) includes one of the cheapest solutions. For example a cost of one power unit is around 30% of from total amount and is calculating from the price of kilowatt (kW) of installed capacity. In average 1 kW has costs about USD 2000 – 3500 (EUR 1430 – 2500). Power unit in Belarusian NPP has a generation capacity of 1200 MW. With average price of kW from USD 2000 – 3500 we have a price for power unit from USD 2.4 – 4.2 billions (EUR 1,7 – 3 billions). During estimation of construction of NPP in Belarus was put a price of USD 2500 (EUR 1790) per installed 1 kW of generating capacity. Projectors in Belarus make estimations to return investments in 13 – 15 years. Also should be included interests, that Belarus should pay for Russian credit. For compensation, these costs will be added to the price of selling kW.h. (Economical profits from NPP in Belarus, 2010)

According to official government estimations, terms of payback of NPP – about 30 years. In this case for attraction private equity a government should present the best investment conditions. It is going about attraction of long term investments, and its offer is much less then short term. (Matvei Taiz, 2010)

A cost of production of electricity on different generation type plants, the same as costs of production, differs from each other. For example energy of NPP is much cheaper than for example thermal – power station. That is why an enlargement of share in production of energy in country will bring to the result, that a final consumer will pay less for energy resources. (Gobbasov, 2010)

Today in Russia work 10 NPP (about 31 power unit with installed capacity of 23.2 GWt), that were built in the period of USSR. In 2009 by Russian NPP was generated 163,3 billion kWt.h. This year began a construction of 11th Kaliningrad NPP (Baltiyskaia NPP). This NPP is constructing by “SUS” (nord department of management of construction). Shares of “SUS” belongs to engineering company “Atomenergorpoekt” (100% shares of company belongs to “Atomenergoprom” – integrated company, which consolidates assets of Russian atomic indutstry). And its terms 100% of shares of “AtomEnergoProm” belongs to “Rosatom” (government corporation, which manages all nuclear assets of the country) (Kaliningrad NPP. from idea to realization, 2009).

Image. List of Russian NPP. Energoatom.2010

Kaliningrad NPP can be a first nuclear power plant with foreign share capital. Russian government can give to foreign investors till 49% shares of new Kaliningrad NPP. At the end of April 2010 during a visit of V. Putin to Italy, was signed a memorandum, which suppose a participation in the project of Italian energy company ENEL. Thus way ENEL can be a first foreign investor in Russian nuclear energy. (Radio Liberty. bright future of Russian nuclear energy, 2010)

CHAPTER 3 FINANCIAL/ ECONOMIC RESULTS

3.1 Static result

Feasibility study of construction of a new NPP in Ukraine shows, that with input data of the paper an internal rate of return (IRR) of a project for LR will be 9,68%, while for SMR's will be 6,22%. The internal rate of return is a rate of return used in capital budgeting to measure and compare the profitability of investments. Generally speaking, the higher a project's internal rate of return, the more desirable it is to undertake the project. (What Does Internal Rate Of Return - IRR Mean, 2010) Increase of IRR can be by increasing a price of electricity. For example to have Internal rate of return 15% a price of electricity should be raised on 60% from EUR 0,013kWh to EUR 0,02kWh for LR and EUR 0,031kWh for SMR's scenario.

A price of electricity increasing is an actual now days in Ukraine. Today Ukrainian electricity market is in the process of implementation of bilateral contracts form of market (UkrBusinessConsulting, 2010), politics tells about increase of tariffs in electricity. (Rise of electricity price, 2010) Besides, Ukrainian Khmelnitsky NPP is going to increase a price for selling electricity. (Construction of new power units of KNPP, 2010) All this facts shows about possible changes in increasing of selling price by nuclear power plants, which can give a positive effect to investor and make investments to nuclear energy in Ukraine more attractable.

IRR in Ukrainian scenario for LR is 35% higher than for SMR's (9,68% for LR and 6,22% for SMR's). With IRR equal to 9,68% NPV for LR equal to 0 and NPV for SMR is negative. To get higher results in Net present value the electricity price should be higher or cost of equity should be lower.

During modeling of static results, when IRR equal to 9.68 % for both cases (LR and SMR) and price for electricity equal to 13 EUR/kWh profitability index to the firm for LR shows 162% and for SMR 79%. Positive cumulated cash flow to the firm for LR starts from year 22, when cumulated cash flow for SMR starts from year 29. At the year 29 cumulated cash flow to the firm for Large Reactor makes already EUR 2 465 mln.

Positive Cumulated cash flow to the equity for LR starts from 30 year period, while for SMR from 48 years period. During 48 years a cumulated cash flow to the equity of LR should be around EUR 26 000 mln, while cash flow to the equity of LR will only begin to become positive.

Today in Ukraine operates four nuclear power plants (NPP) with 15 nuclear units in total. These units have been in operation, on the average, about half of their design service life. From 15 nuclear power units operating in Ukraine 13 of them are LR's with VVER – 1000 type and 2 reactors with VVER – 440 type. Ukraine has experience in exploitation of both LR and SMR's, but the majority belongs to LR.

According to power and energy strategy of Ukraine till year 2030, the expected capacity of the newly constructed nuclear power generation units should be within the range of 1000 to 1500 MW. (Power energy strategy of Ukraine till 2030, 2006) A specific decision on the design capacities and types of the new power units is based on the following main considerations and prerequisites:

- thorough additional assessments of the actual conditions of the Ukraine's power system;
- comparative analyses of the relevant engineering and economic indicators;
- studies and assessments of the designing and operation of nuclear units in other countries.

When selecting a type of the newly constructed power generation units for selected construction site, the decision-makers should ensure that the selected units are of the same type. (Development of new nuclear power generation capacities, 2008)

To achieve objectives of Strategy about planned generating volume of electricity, in Ukraine till 2030 should be built 20 – 21 GW of new and substitute capacities of NPP. (Development of new nuuclear power generation capacities, 2008)

Within the period of 2011 - 2030, the following works need to be completed:

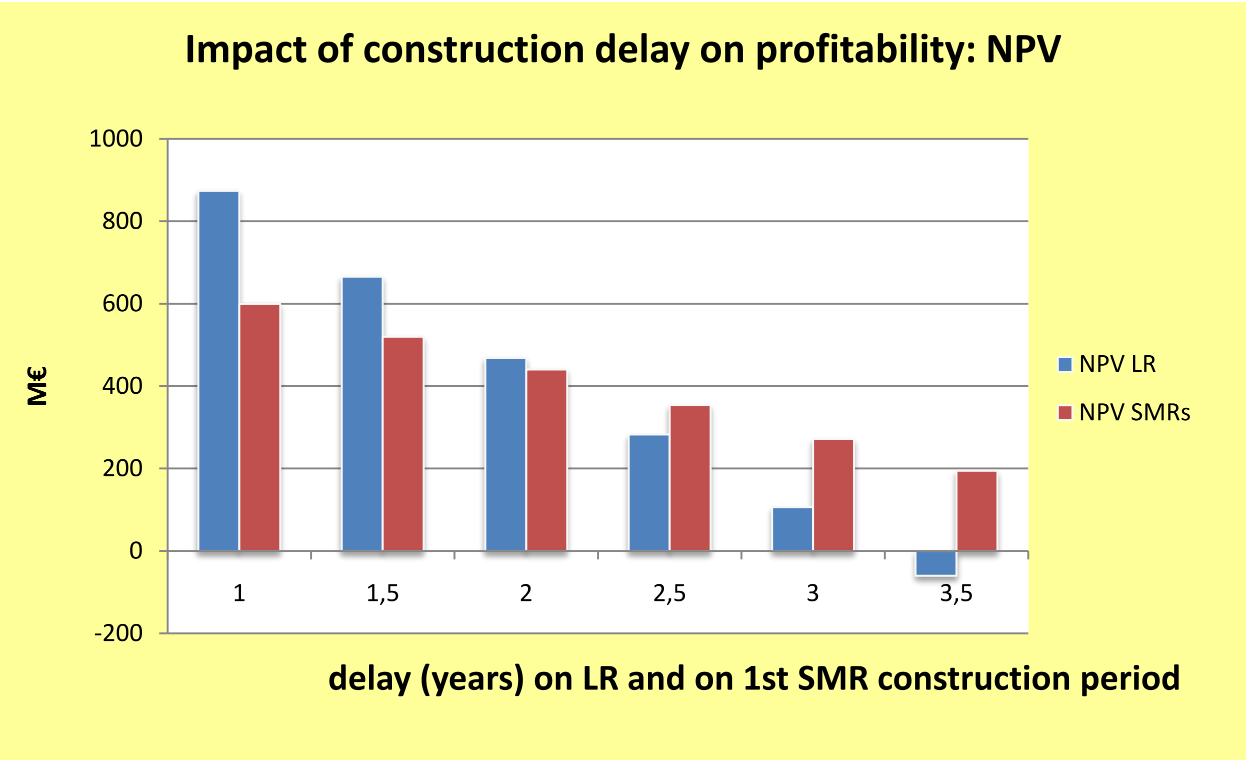
- to commission, by the end of 2016, new power generation units with total capacity of 2 GW at Khmelnitsky NPP (Power Units #3 and #4);
- to commission, within the period of 2019 - 2021, nuclear power generation facilities with total capacity of 6 GW on the new construction sites;
- to commission, within the period of 2024 - 2030, replacing and additional nuclear units with total capacity 12.5 GW;

All power units which are planned to commission in Ukraine till 2030 are planned to have LR 1000 – 1500 MW.

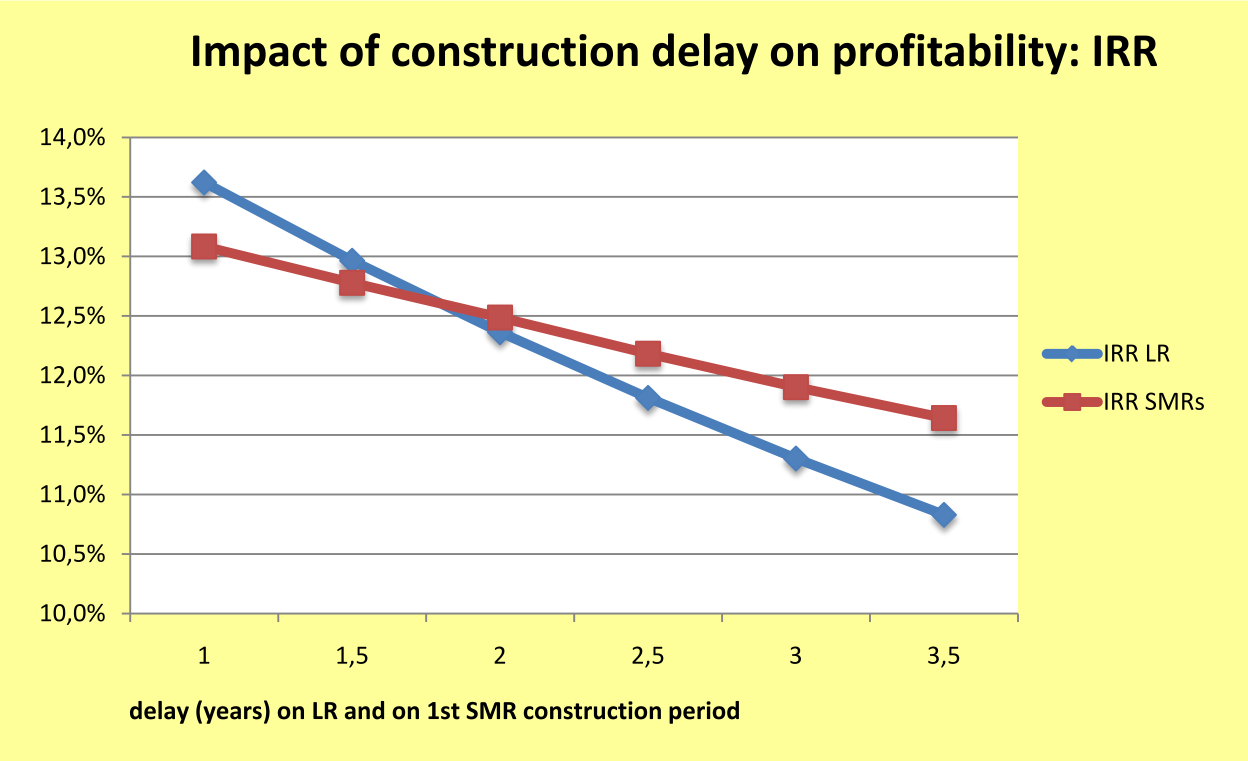
Static analysis shows that in Ukrainian scenario LR is more profitable for investor then SMR’s choice.

3.2 Synthetic analysis result

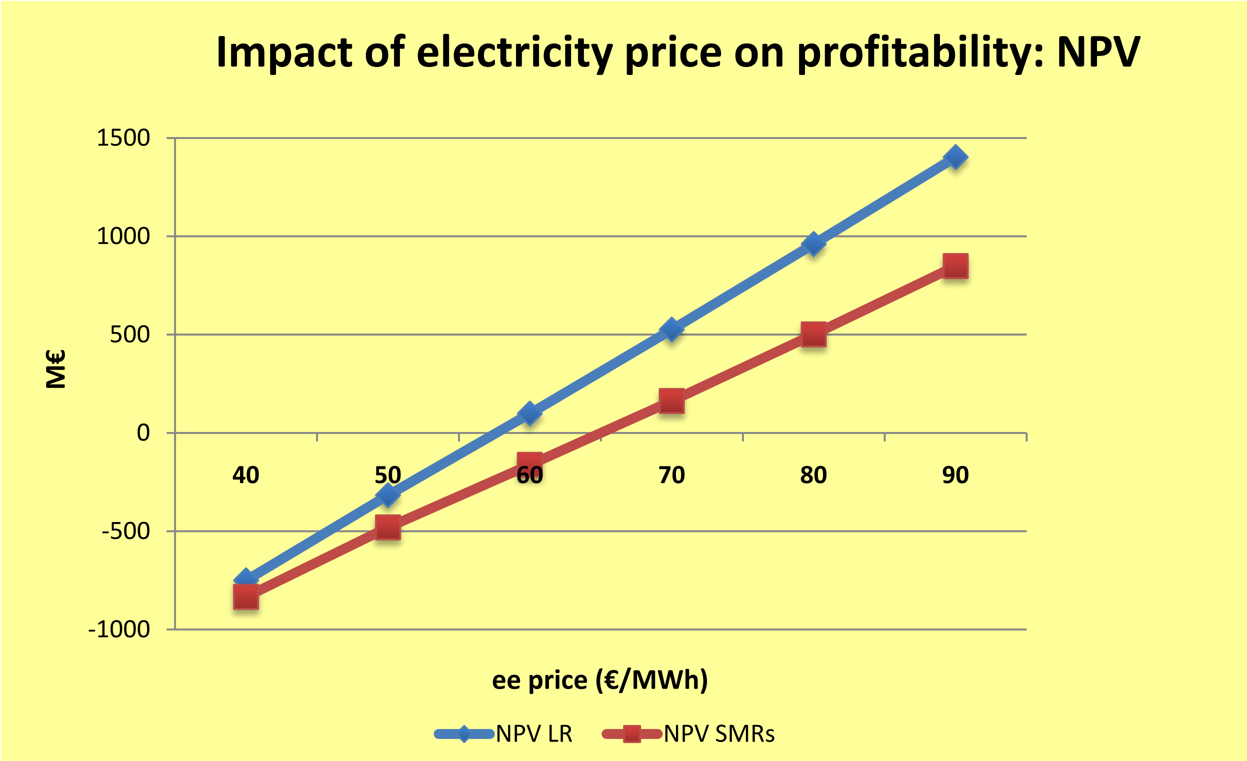
Statistics shows that over 50% of projects, were run behind a schedule. Delay overruns is common in construction projects, which has negative consequences. Of course effective project planning, controlling and monitoring should be established to enhance project performance in order to minimize or avoid delay in construction projects. Bellow is shown an impact of construction delay on profitability (NPV) between LR and SMR. From a table is possible to see that first in 2 years of delay LR reactors has higher NPV than SMR, but already from second half of the 2nd year advantage is taken by SMR, which shows higher positive NPV (SMR – M€ 355, LR – M€ 282). After 3,5 years of delay a Small reactor still has a positive NPV (M€ 195), while Large reactor has already negative indicator (M€ -60).

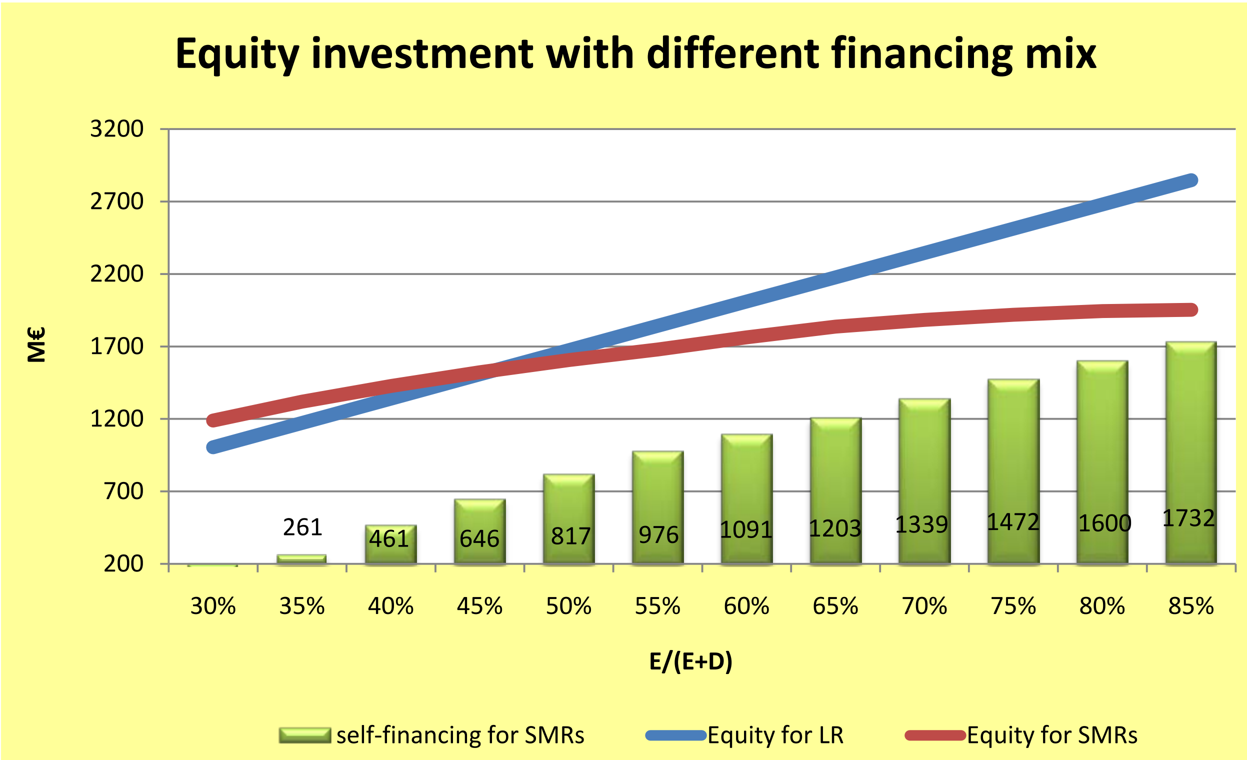


Internal rate of return is an important indicator of the quality of an investment and is used extensively by companies to determine whether or not they should make a particular investment. It reflects the quality of an investment. In this case it is used to make comparisons among different investment options: LR and SMR. Impact of construction delay on profitability shows, that during a first year of delay a difference of IRR between SMR and LR is 0,5%, between 1,5 and 2 years they become equal and from the second year of delay IRR of SMR is higher than LR. At 3,5 year of delay a SMR has 11,6% of IRR, while LR only 10,8%. Impact on construction profitability shows, that the higher delay the higher advantage of SMR is.



Bellow in the table is shown an impact of electricity price on profitability of SMRs and LR. Analysis shows, that impact of electricity price on profitability is higher for LR. In the graphic table bellow is possible to see, that a positive NPV starts from 56,5 EUR/MWh for LR and from 65 EUR/MWh for SMRs.

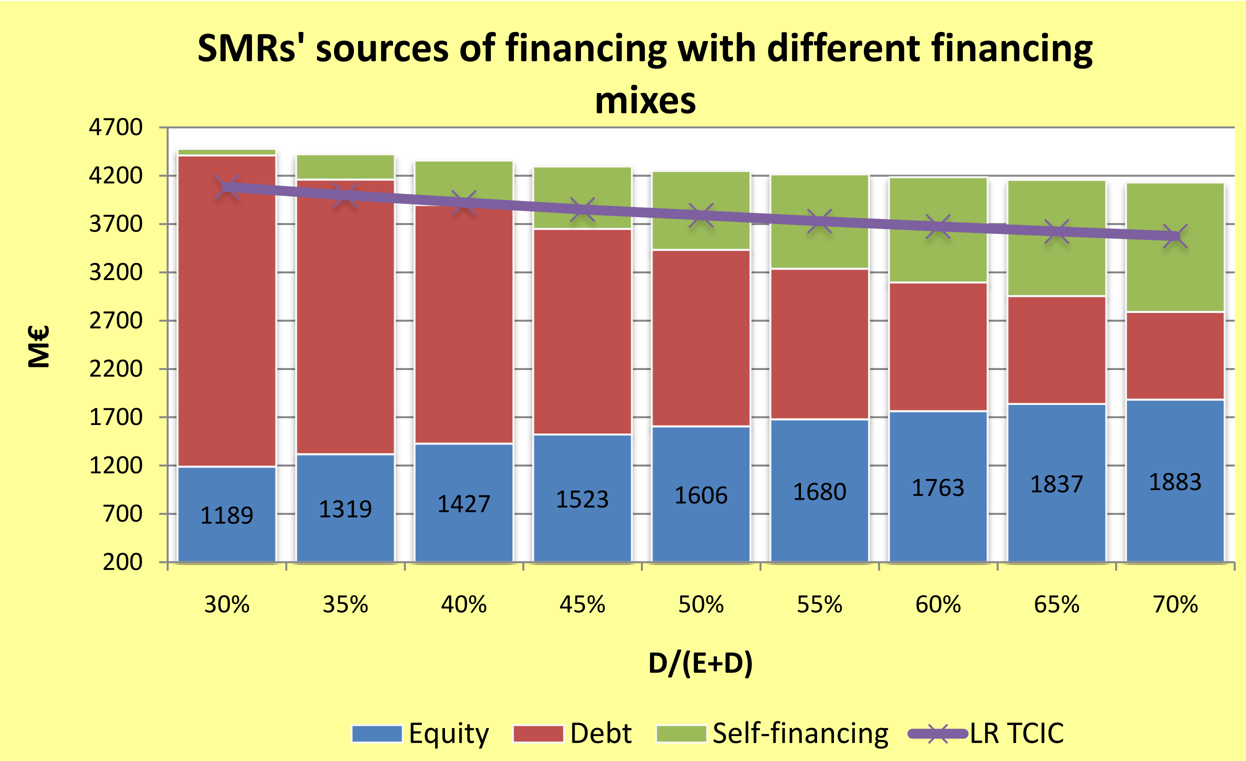




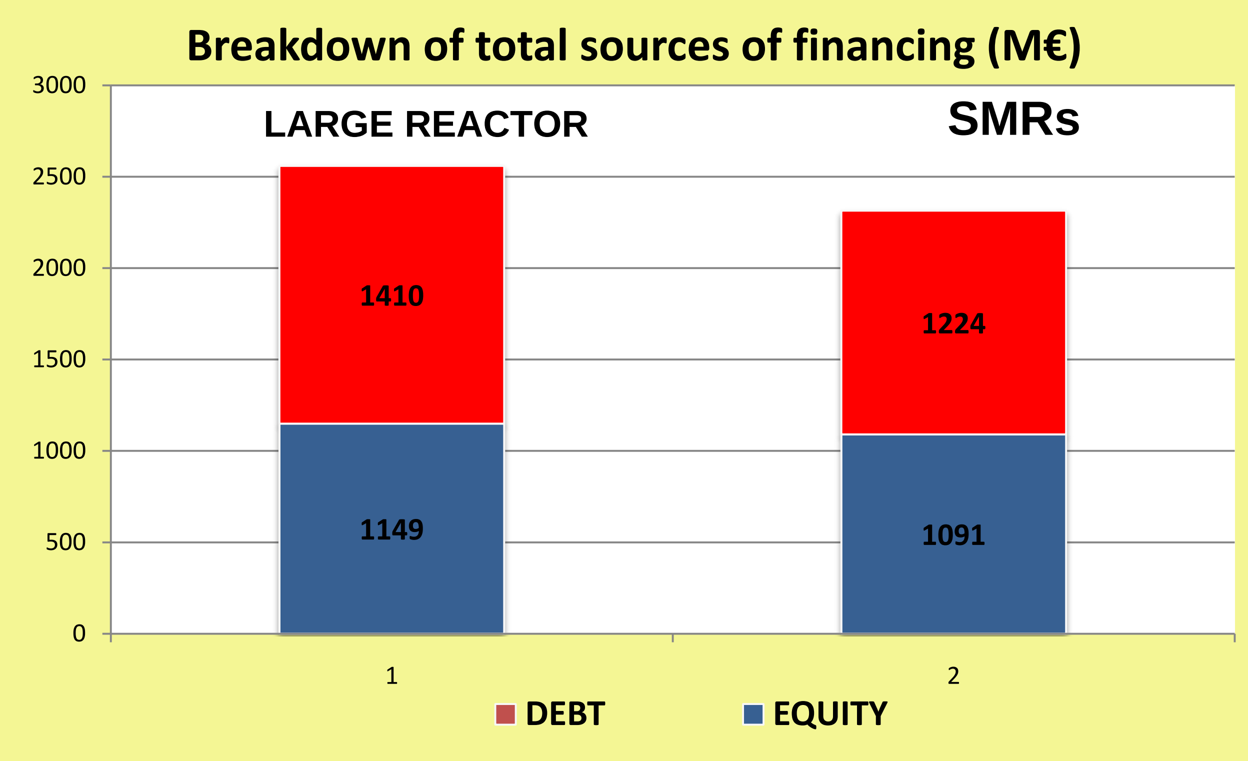
Above in the table is represented an equity investment in SMRs and LR with different financing mix. Till 50% of self for SMRs equity financing for both cases is similar. From 45% of self-financing, SMRs requires less equity than LR. For example with 45% of self-financing both two types of reactors requires about M€

1500 and with 75% of self – financing LR requires M€ 2500, when SMRs (M€ 1900) requires M€ 600 less than large reactor.

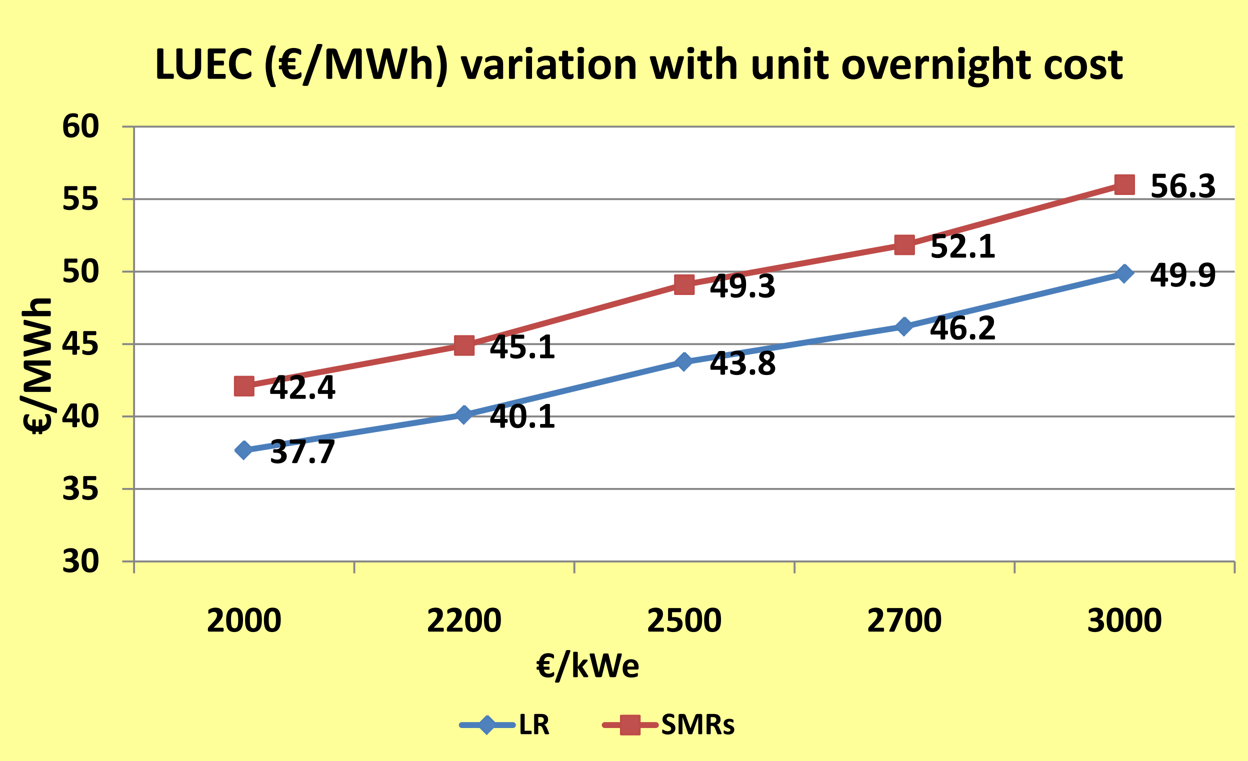
Small reactors sources of financing with different financing mixes show equity, debt and self-financing investments to SMRs. Analyzed data shows, that increase in equity and self-financing decrease debt financing and automatically reduces total sum of investments required.



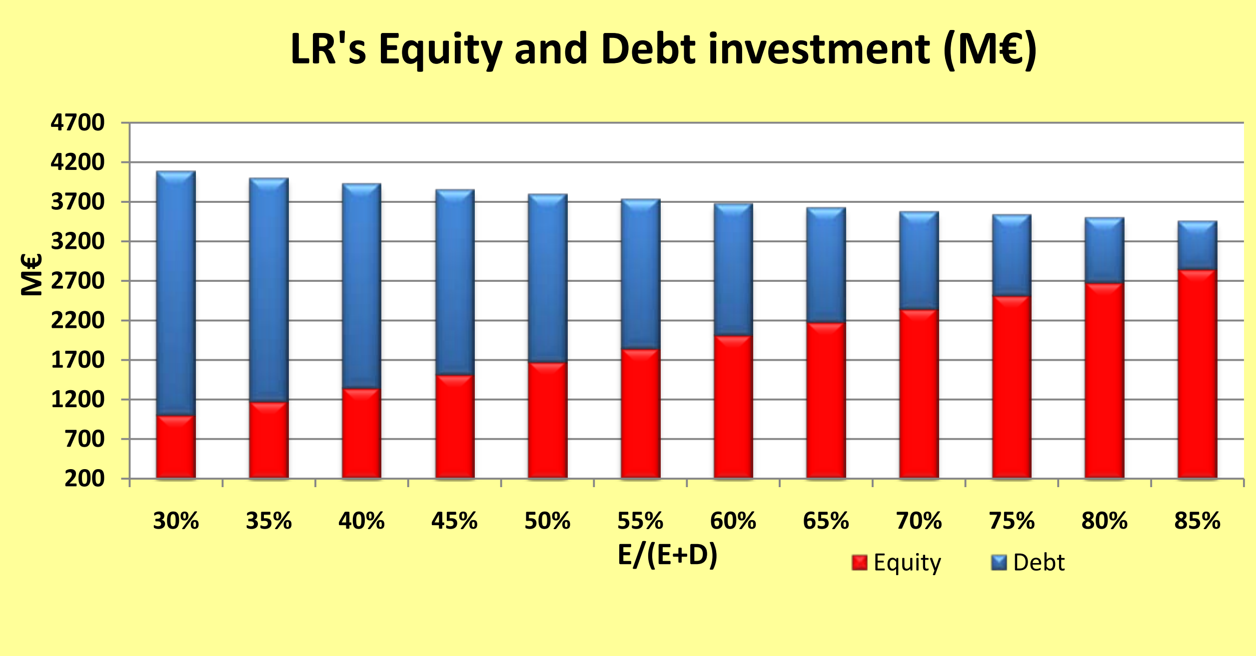
Analysis of “Breakdown of total sources of financing” shows that SMRs requires less equity and debt than LR.

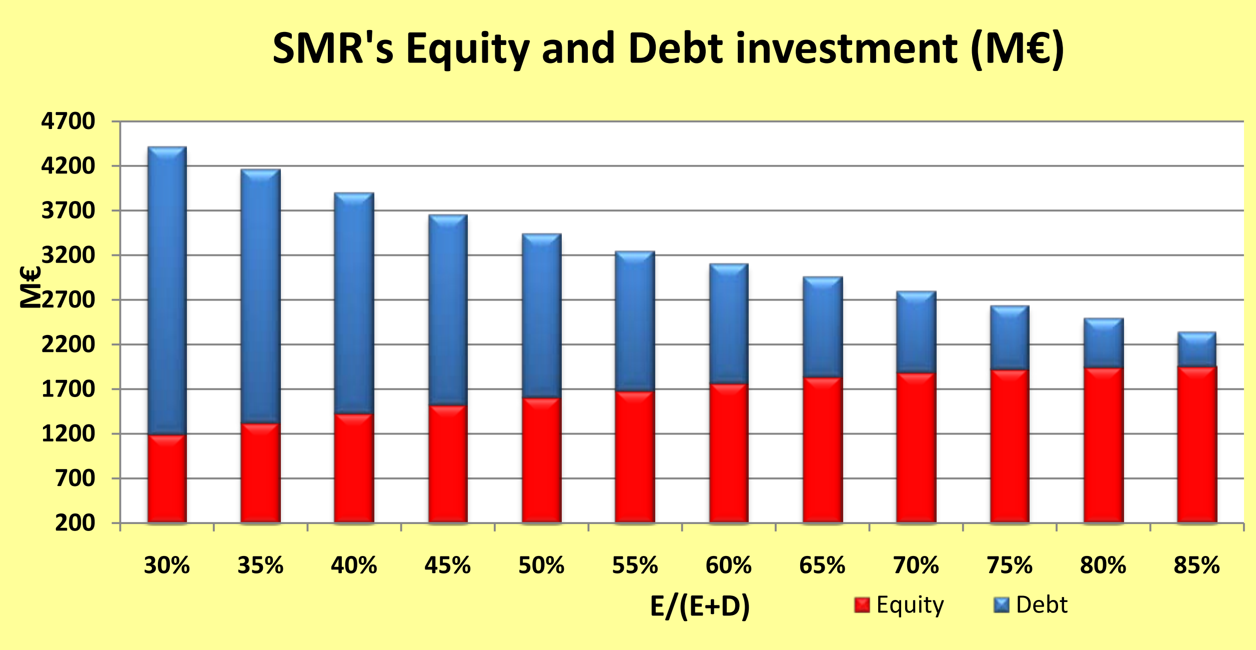


The Levelized Unit Energy Cost (LUEC) is a means for calculating the cost of a unit of energy. It does this in a manner that allows one form of technology to be compared with another. Table bellow describes LUEC variation with unit overnight cost. With increase of costs for generation capacity there is a parallel increase of unit overnight cost of Large and Small reactors. SMRs unit overnight costs are higher than LR.

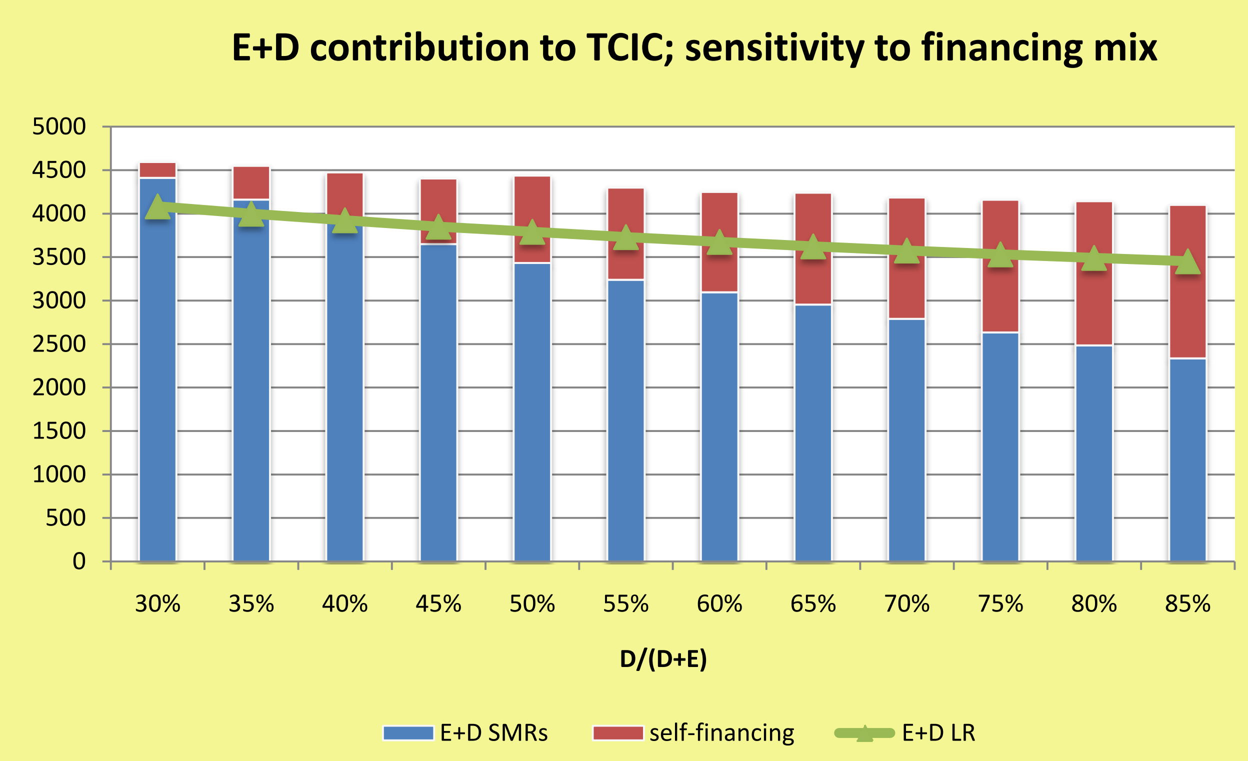


Investing 30% of Equity and 70% of Debt to LR and SMR, there is almost the same investments required, SMR needs even a little more investments: LR – M€ 4084 and SMR – M€ 4412. At the same time if to increase % of equity investments a situation changes in both cases with advantage of SMR's choice. For example increase of LR's equity from 30 to 85% reduces only by 15% (M€ 631) of total investments, while increase the same percentage of equity (from 30 to 85%) in SMR's reduces total investments by 47% (M€ 2075). Investing in SMR's become more profitable

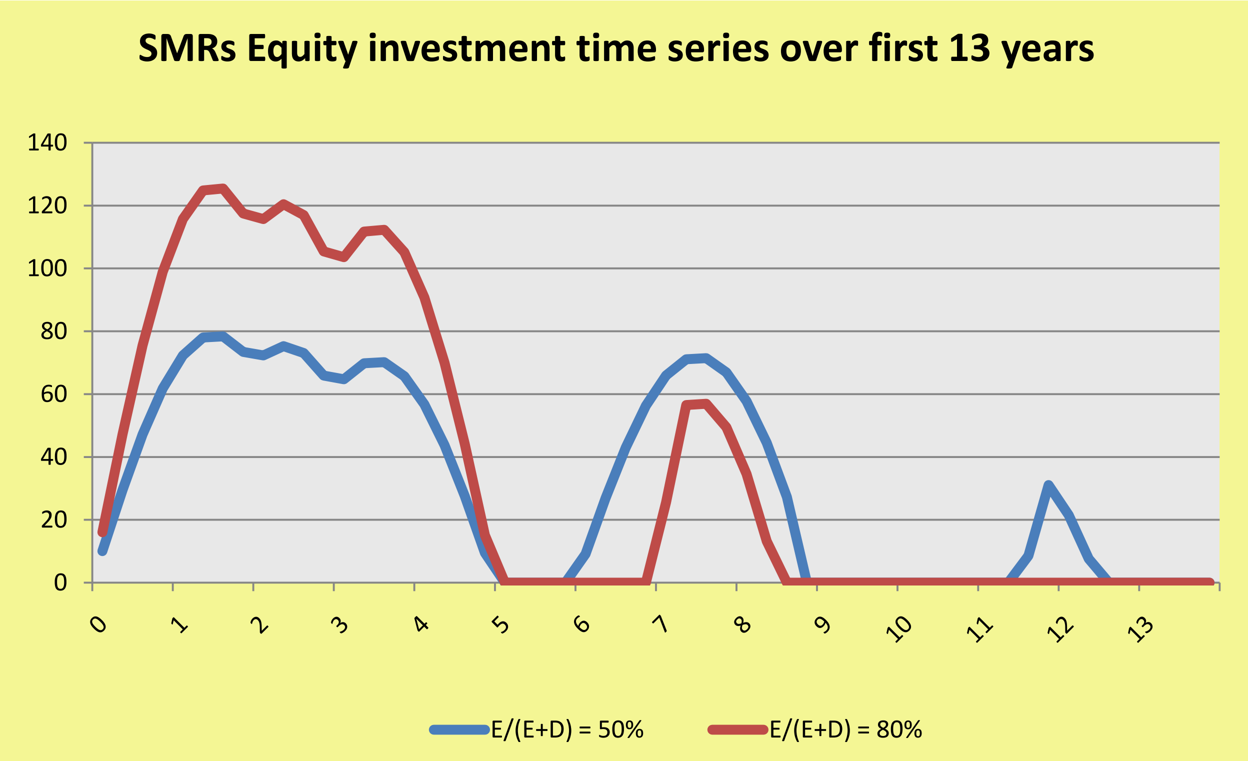




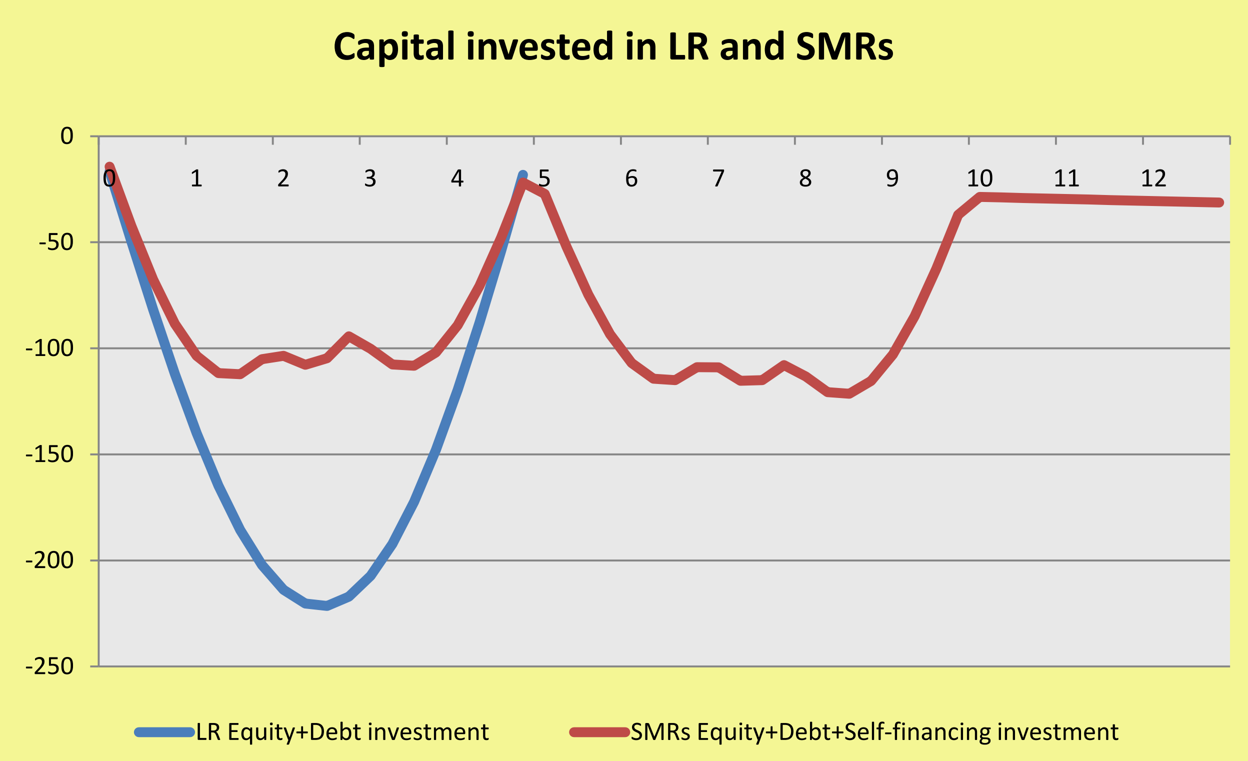
Equity and Debt contribution to TCIC decreases with increase of self–financing. Sensitivity to financial mix is shown bellow in the table.



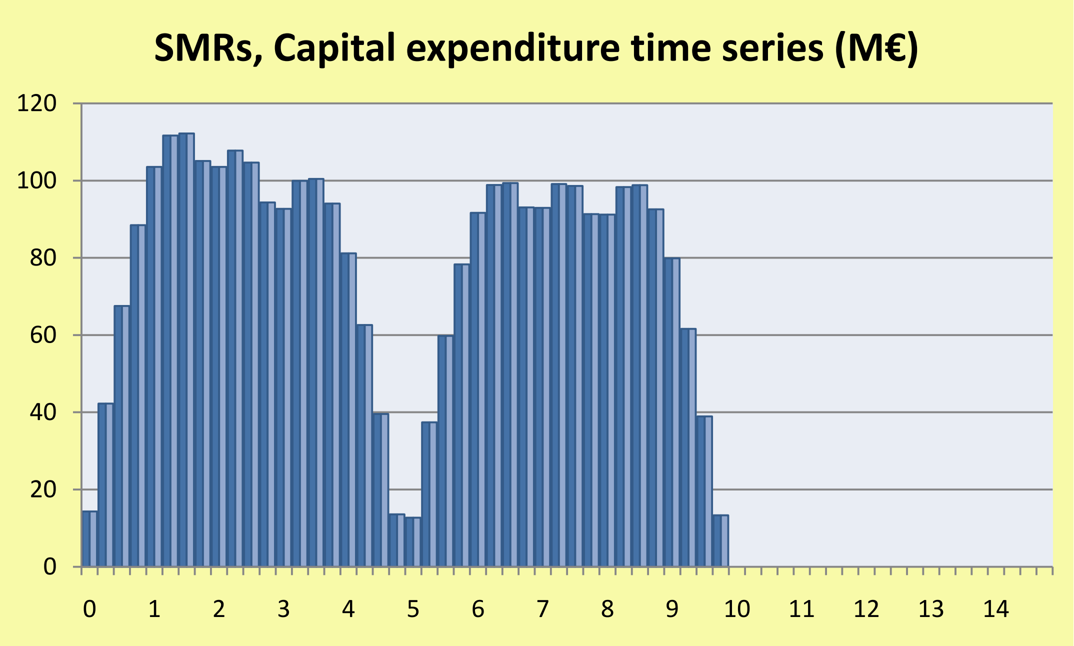
Time series of SMRs equity investment table over first 13 years represents, that with 50% of equity first 5 years will be required less investments than with 80% of equity, at the same time next 5 years periods situation changes vice-versa to invest less with 80% of equity and more in a case with 50% of equity.



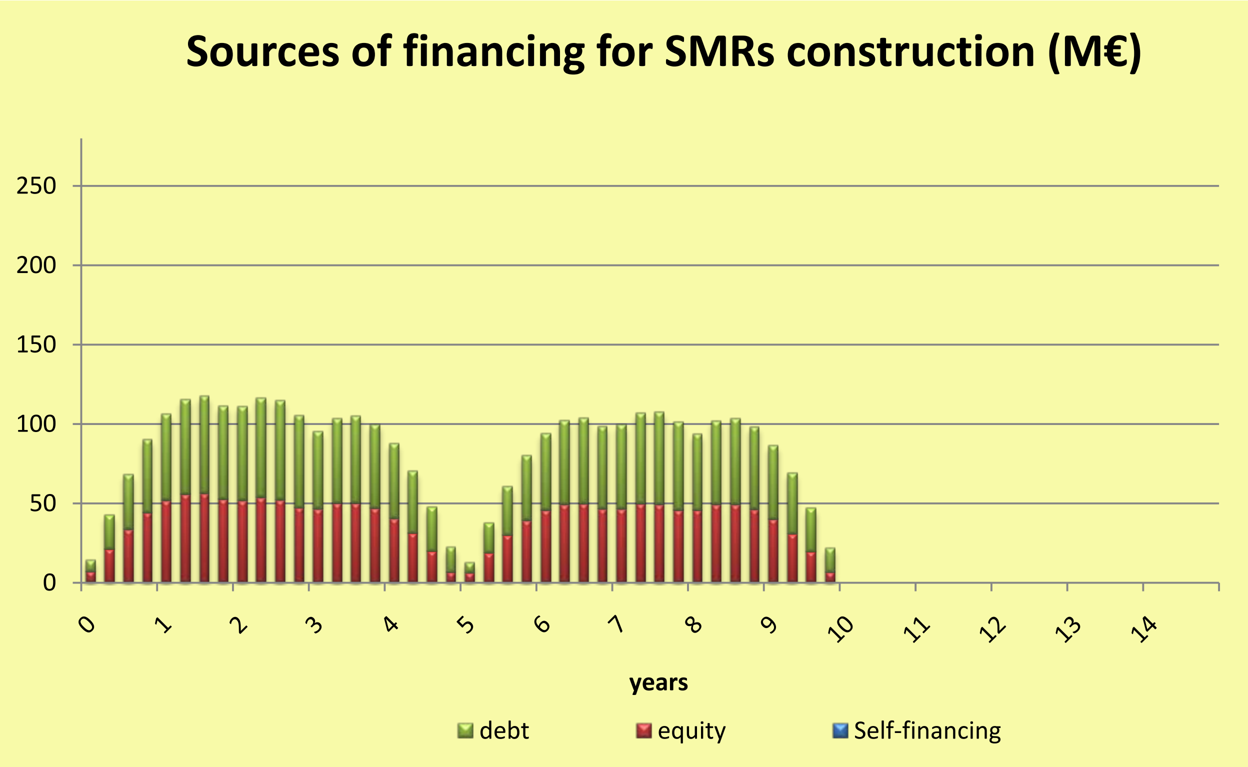
The difference between Large Reactor and Small Reactors capital invested is that in a case of LR all finance is invested during first 5 years and in a case of SMRs investments are extended for some periods and requires less capital invested per one period than in a case of LR. The result is shown bellow.

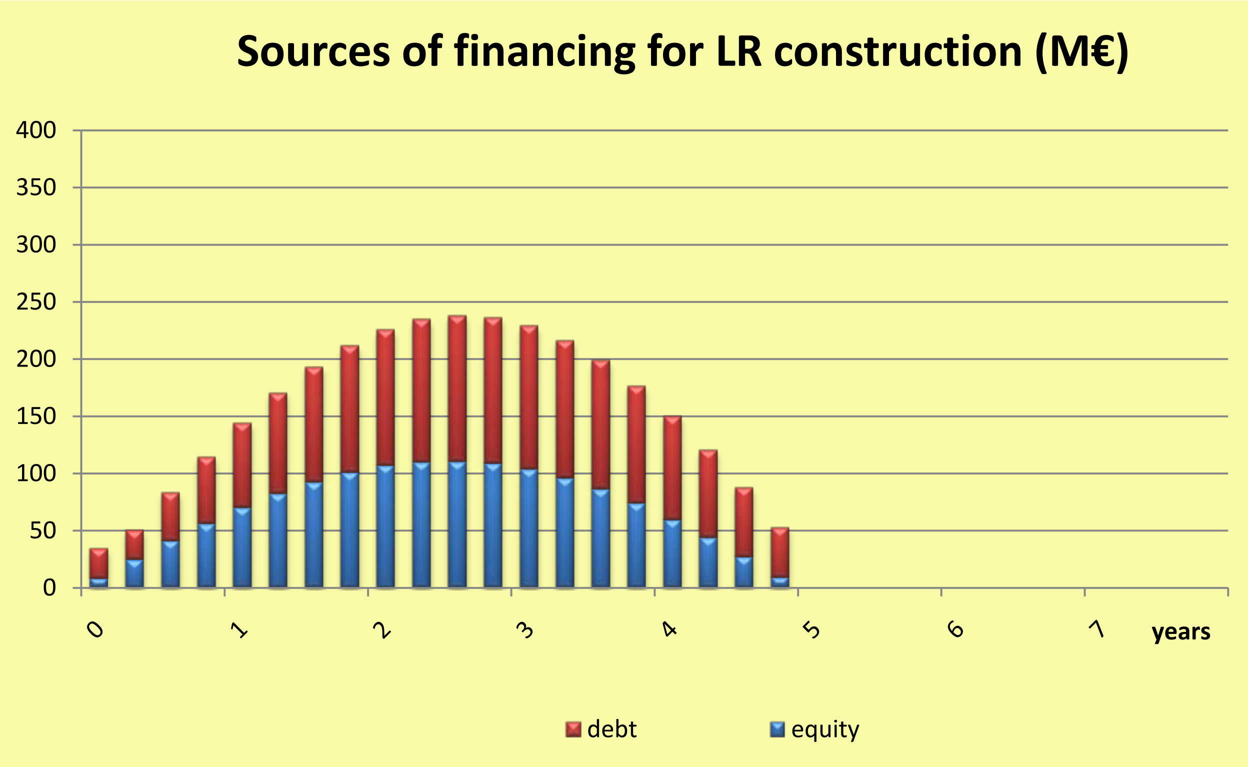


The next table shows more in more detailed periods of Capital expenditures in Small Reactors.

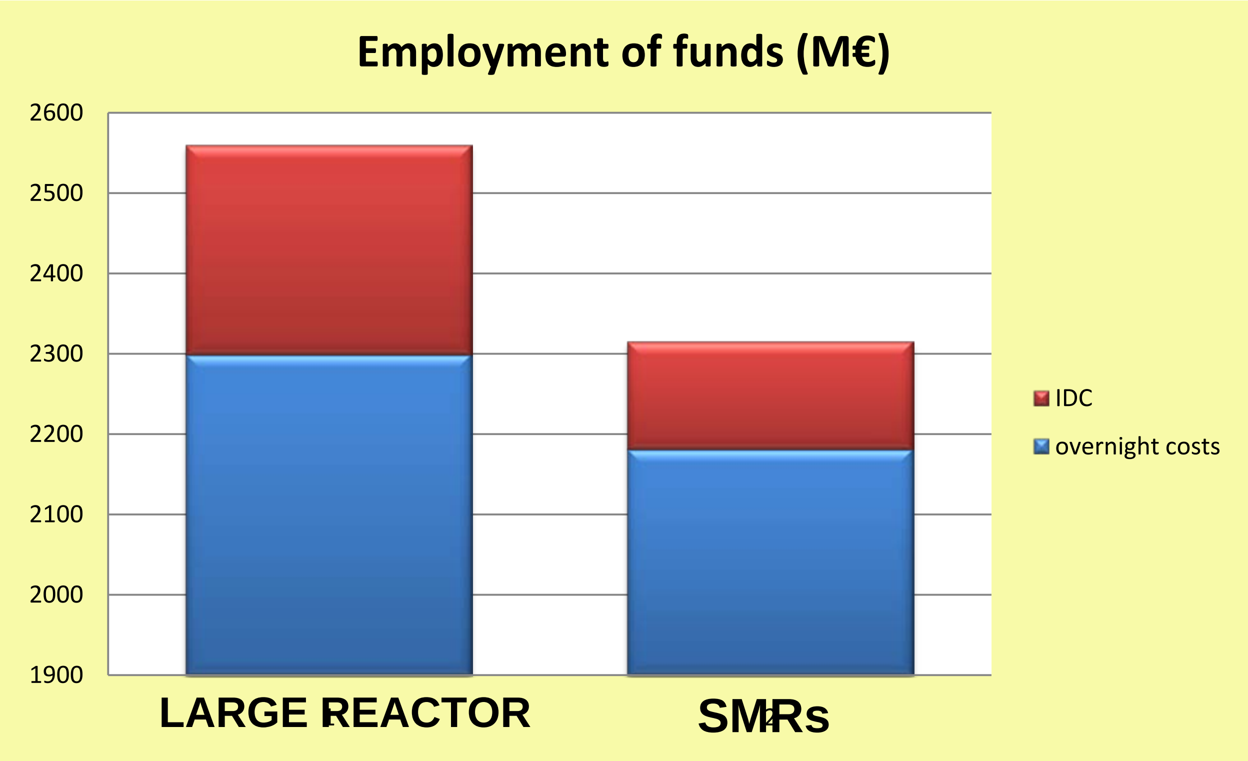


Sources of financing for SMR's and LR construction are represented in the following two charts. Construction of SMR's requires fewer investments at the same 5years period of time, as in the case with LR.

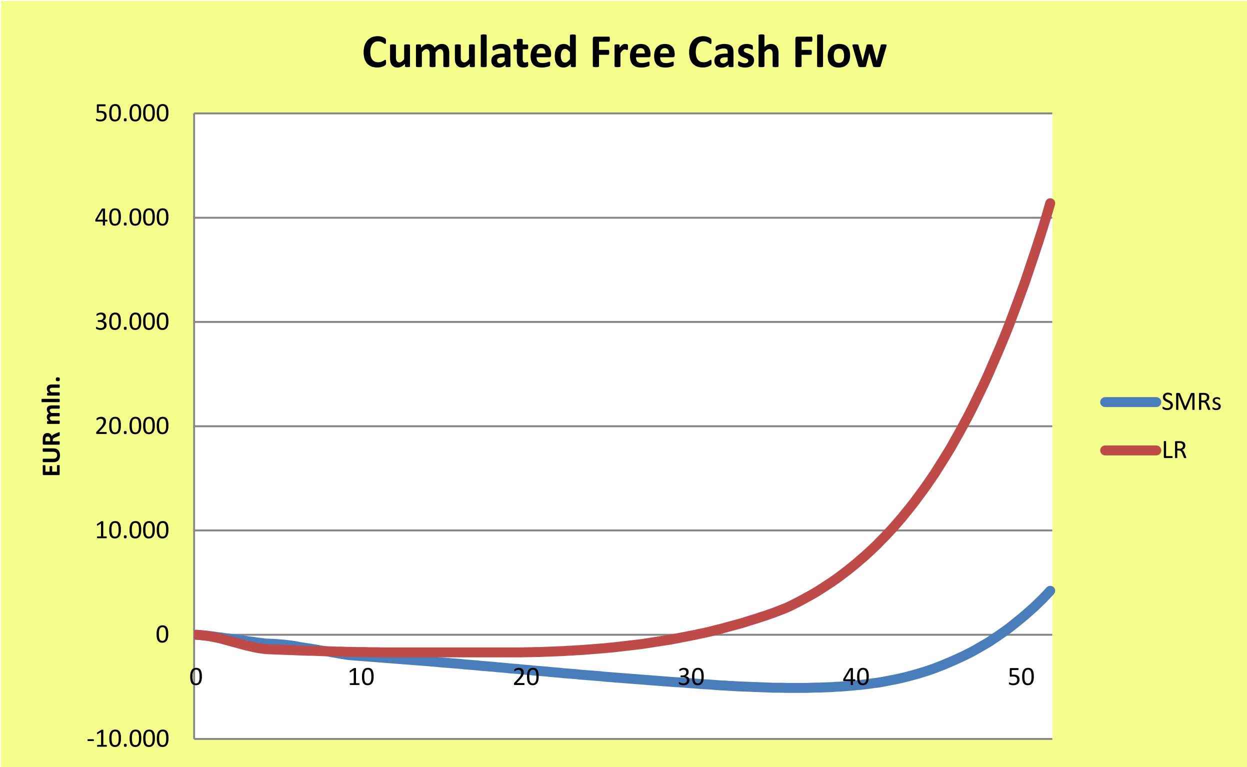




Employment of funds in a case of construction of Large Reactor is higher than for Small Reactors in IDC and overnight costs. This data is shown bellow in the chart “Employment of funds”.



From chart about Cumulated Free Cash Flow is possible to see that first years cumulated free cash flow remains negative and becomes positive after 30 years. According to the national strategy of fuel and energy complex NPP has 30 years payback time. Changes in payback time or increase of electricity selling can make a positive cumulated free cash flow become before than 30 years period.



Cumulated Free Cash Flows for LR becomes positive after 30 from construction and for SMR after 48 years.

Nuclear energy is an important industry of Ukrainian economy. Atomic power energy has enlarging prospective in a situation of decreasing of hydrocarbon energy resources and non stability of energy resources markets. That is why question, which type of NPP reactor to chose is important for potential investor. A "Financial / economic result" shows, that in Ukrainian case construction of LR is more profitable then SMR's.

CHAPTER 4 EXTERNAL FACTORS ANALYSIS

Analysis of external factors will be provided by using INCAS's module "External Factors", which published in paper "Introducing nuclear power plants in an OECD country: size influence on the external factors". This model is developed by Politecnico di Milano, cooperating with the IAEA and designed to analyze the choice of the better nuclear power plant size as a multidimensional problem and can be used in Ukrainian scenario for the comparison between Deliberately Small Reactors (SMRs)" and "Large Reactors (LRs)".

There is a list of factors which will be analyzed, they are:

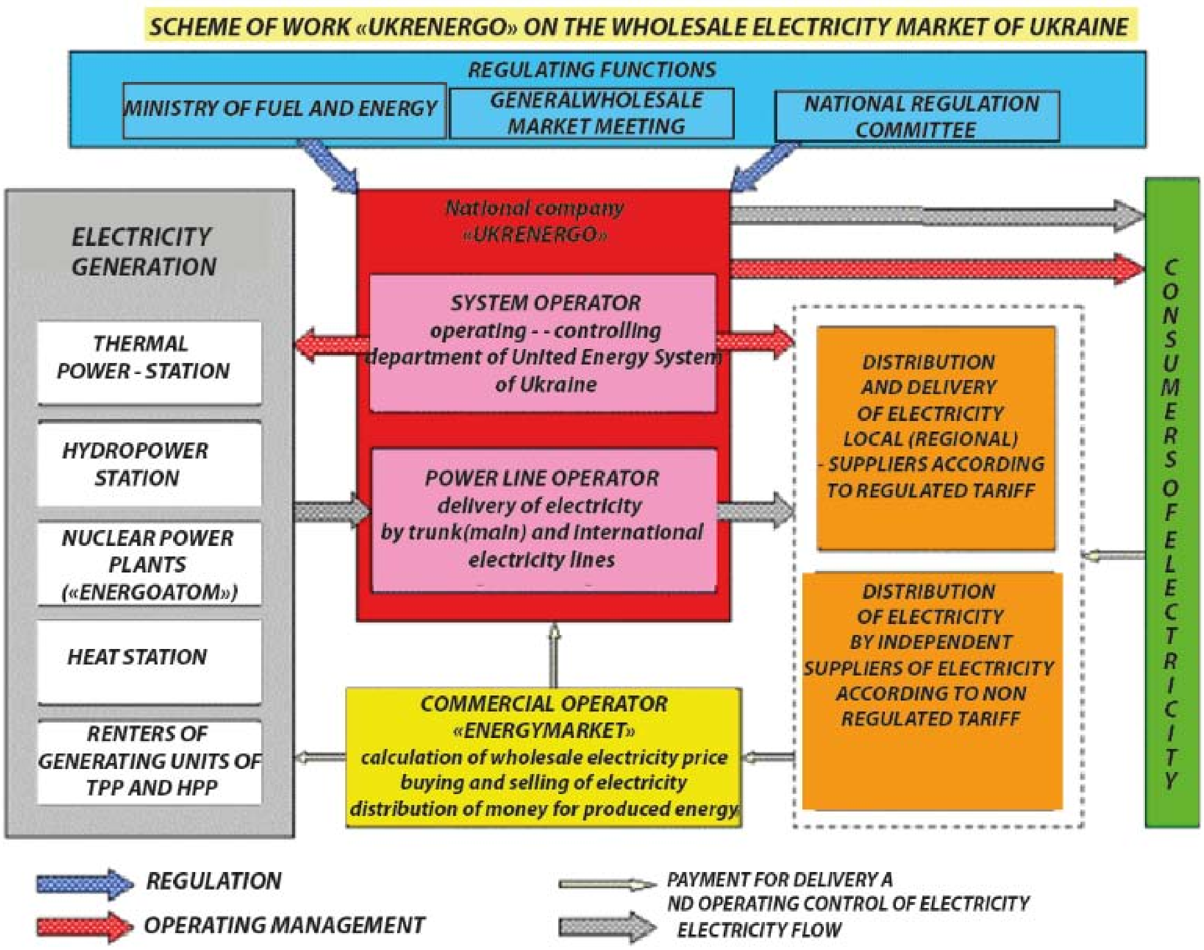
- Spinning Reserves Management;
- Electric Grid Vulnerability;
- Public Acceptance;
- Technical Siting Constraints;
- Risks Associated to the Project;
- Impact on National Industrial System;
- Time-to-market;
- Competences Required for the Operations;
- Impact on Employment;
- Design Robustness and Historical and Political Aspects

4.1 Spinning Reserves Management.

Activity for generation electricity in Ukraine should be licensed and realized according to the Rules and Conditions of electricity generation, which tells that all electrical energy, which is generated in Ukrainian power stations, should be sold in Wholesale electricity market of Ukraine. In this case a producer of electric energy makes contracts with wholesale deliver of the energy – government enterprise “Energymarket”. (Ukrainian electric energy sector. Brief description, 2010)

Today in Ukraine exists a unified centralized control system of operative – technological management of production, transmission and delivery of electric energy. Functions of electricity supplier are provided by Transmission System Operator – enterprise “UkrEnergo”. (Supervisory control of Energy system of Ukraine, 2010) Bellow is shown a scheme of work of “UkrEnergo” in the Wholesale electricity market of Ukraine.

Table. Sheme of work of Ukrenergo in the wholesale market of Ukraine



Transmission System Operator – enterprise “UkrEnergo” has following functions:

- Provision centralized dispatching control;
- Monitoring of schemes and regimes of work of United energy system of Ukraine, forecasting and management of power consumption;
- Prevents accidents and removing its consequences in the “United energy system” by supporting necessary balance of power and energy etc.

Image. Information analytical center of Ukrainian transmission system operator (UkrEnergo, Information analytical center, 2009)

In Ukraine, like in Italian scenario, in case of outage, primary reserves are exploited automatically after an immediate fall of frequency. And it must be restored as soon as possible by next reserves, according to UkrEnergo forecasts base.

For Ukrainian scenario, electric system of UkrEnergo was divided into isolated 7 areas. They are (Ukrainian energy system of Ukraine. Map, 2010):

1. Central-North region – Kiev, Chernigov, Cherkassy, Zhitomir;
2. Western region – Rivne, Volyn, Lviv, Ivano Frankivsk;
3. Western – South region – Khmelnitsky, Ternopol, Vinniza, Chernovtsy
4. Southern region – Nikolayev, Odessa, Kherson, Crimea;
5. Nord – East region – Kharkov, Sumy, Poltava;
6. Central – South region – Zaporizhzhya, Dniepropetrovsk, Kirovograd;
7. Eastern region – Donezk, Lugansk

Bellow in the table is shown the largest Ukrainian generating units for Largest Contingency.

AREA		ACTUAL WE	ACTUAL LC	1 LR			4 x 1 SMR		
№	NAME, AREA			WE	LC	DIFF.	WE	LC	DIFF.
1	Central – North	300 + 444	744	1340 + 444	1784	1040	335 +444	779	35
2	Western	1000 + 1000	2000	1340 + 1000	2340	340	As actual	2000	0
3	Western – South	1000 + 1000	2000	1340 + 1000	2340	340	As actual	2000	0
4	Southern region	1000 + 1000	2000	1340 + 1000	2340	340	As actual	2000	0
5	Nord – East	300 + 300	600	1340 + 300	1640	1040	335 +300	635	35
6	Central – South	1000 + 1000	2000	1340 + 1000	2340	340	As actual	2000	0
7	Eastern	880 + 300	1180	1340 + 880	2220	1040	880 +335	1215	35
SUM			10524		15004	4480		10629	105
RATIO					+42,6%			+1,0%	0

Table. Actual and differential reserves in the Ukrainian scenario

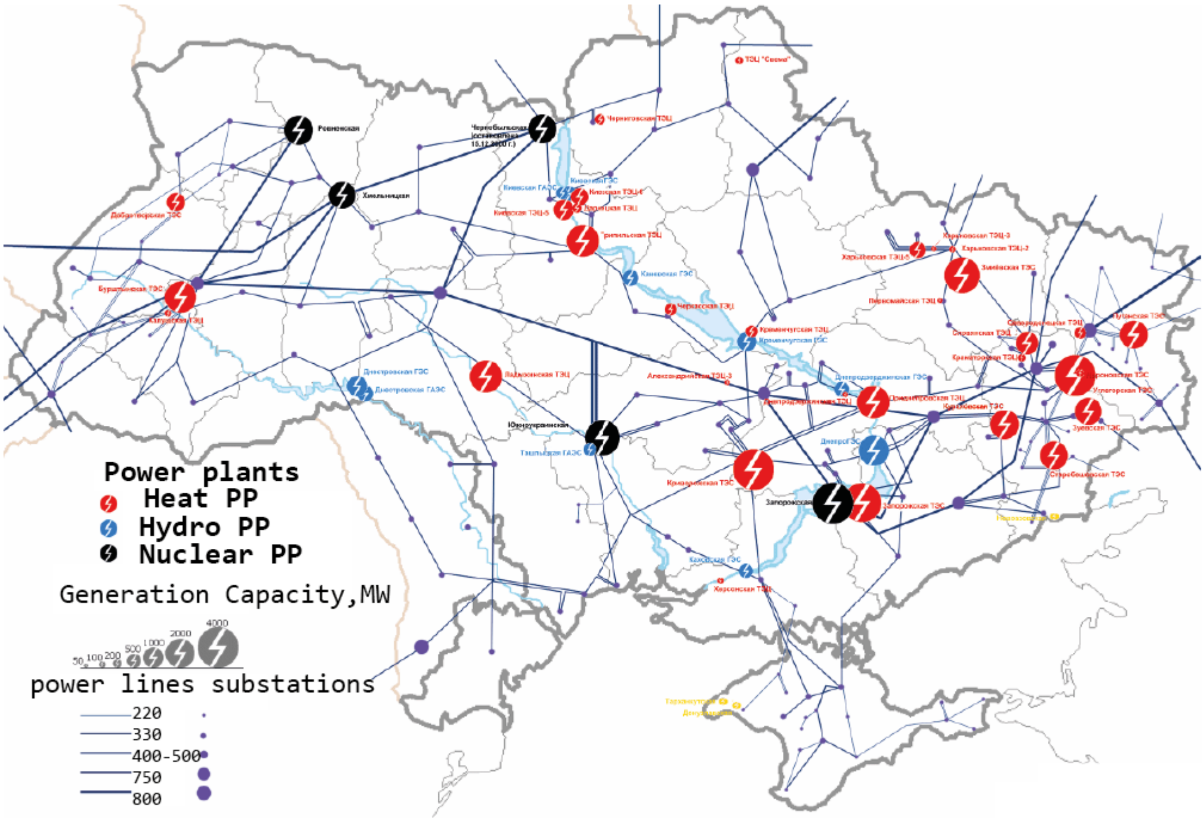
From the table of “Actual and differential reserves” is possible to note that Large Reactors (LR) would require 42,6 % higher reserves, while Small reactors (SMR) do not vary the actual situation, their ratio between sums is equal to 1%. So a result of analysis of “Spinning Reserves Management” method shows that in Ukrainian scenario small reactor (SMR) choice is better than LR.

4.2 Electric grid Vulnerability

Electricity is a specific product. Electric energy is not possible to stock in the warehouse like other products and its consumption is characterized by immediate interconnection between generator and final consumer of electric current and takes place in the regime of a real time. In this case a process of delivery electric energy to the customer through a "power line" becomes one of the most important features of a whole industry and a product itself. Today a successful activity of major enterprises depends on stable work of secure system of electricity delivery. (Analysis of electric grid conditions, 2010) That is why during analysis of external factors for construction new NPP is important to evaluate electric grid vulnerability, which can play also an important role during the final decision.

Transmission networks is one of the main components of United power system (UPS) of Ukraine, which includes 22 700 km, of them 4 900 km are of 400 – 750 kV, 13 200 km - 330 kV, 4 600 km - 220-110 kV and 132 power substations (PS) of 220 – 750 kV. (Description of the Present State and Development of Power Networks, 2006)

Image. Map - scheme of electric energy of Ukraine. UkrEnergo. 2010



Insufficient allocation of funds for upgrading and rehabilitation of operating power networks and substations, and for construction of new ones results in lowering reliability of the United Power System operation.

Serious problems arise due to insufficient line capacity for realization of NPP potential (Rivne, Khmelnitsky, Zaporizhzhya); insufficient reliability of power supply to the Crimea, South of Odessa oblast, Eastern Donbass; impossibility to transmit excess power from Western region to the center and East of the country; uncompensated power network of Ukrainian UPS as regards reactive power and maintaining necessary voltage (Western, Central and Southern power systems).

Year by year the state of transmission networks is deteriorating: 34% of 220-230 kV overhead transmission lines (OTL) have been operated for more than 40 years, of them 1 700 km of 330 kV OTL (13% of total length) and 1 600 km of 220 kV OTL (52%) require rehabilitation, 76% of switch-yards main equipment worn up its designed useful operating life. (Description of the Present State and Development of Power Networks, 2006)

There is always a risk of electric grid vulnerability. Also a probable risk of electric grid vulnerability can be because of bad weather conditions, such as icing (there is a big probability, that electric line can get ice formation in winter) etc. In a case of 4 stand alone SMR's, if for example ice formation in winter will arise a brake of power line for one SMR's, then other SMR's could continue to supply electricity.

Putting 4 small reactors in different sites, instead of 1 large reactor, reduce risk of grid vulnerability. All these factors, shows that "Electric grid Vulnerability" forwards the Small choice.

4.3 Public Acceptance

Ukraine in accordance with its energy strategy closely links the development of the country's power energy complex with nuclear energy. It is planned to build about 20 new power units, the development of the uranium industry, development of nuclear science and technology. (Power energy strategy of Ukraine till 2030, 2006). External analysis is included to the list of external factors, because public acceptance of nuclear power is the attitude of the public towards the deployment of this technology. It's possible to evaluate an overall population's attitude and a local population's one. The two different sides of public acceptance have different impacts on the choice of size.

One side is considered to be an overall population's attitude. Even if the technology is intrinsically safe and there are not externalities, the public could be against supporting nuclear energy. This is because, in the public's mind, a system with small probability of failure and large consequences is seen as more risky than the opposite, as the common fear of air crashes.

Another side of Public Acceptance is local population's attitude. The main cause is the Not-In-My-Backyard (NIMBY) syndrome: even if public does not oppose building of new NPPs, it's possible a fierce opposition from local communities who will have to host them.

In Ukraine there is a positive and negative impact on the public opinion about NPP construction. The most important reason of positive attitude to the NPP construction can be in the region with negative social-economic level of life. In this case for population the most positive attitude lies in possibility to increase a social – economic situation in the region and people's own prospective for the future in that region. In Ukraine there are a lot of economically depressed regions, with a low possibility for improving a life in the future. And people understand it. That is why such region is considered to be as a region with decreasing population: young people leave that region, leave also men of active age, little birth rate. Such region can be considered in Russia – “Navasynsk” and in Ukraine – “Volyn” region. (Construciton of NPP - social project, 2009) If such situation will continue for 10 – 15 years, then there will remain a little part of working population. Construction of NPP can give to the local inhabitants to get a good paid job, to increase a social infrastructure – roads, kindergarten, schools – all is made because of the project of nuclear power plant construction. Young inhabitants of such regions, which are economically active support NPP construction and those who is older (who is retired for example) has a lower level of support. That is why a construction of new NPP is welcomed mostly by young people, especially by those, who don’t have a job now.

Among negative causes in Ukraine on the public opinion is possible to mention so-called "Chernobyl syndrome", lack of effective industry and public policy in creating a positive public opinion about the significant contribution of nuclear power in the country's economy.

According to a “pool” for support of NPP construction was the next one – “support if, requirements will be satisfied”. (Meeting about "Ecological evaluation of situation for Nizhegorodsk NPP construction", 2009) So, requirements of population were close linked to the worrying of people, but not in the sphere of safety. Local population believes that during NPP construction a technical, including ecological part, will be realized successfully, but they are worried that social part will not be carried out. Many people are afraid (reason of not supporting) that for NPP construction will be attracted not local population, but “migrant labor”. But when it was promised to give a new job places for NPP construction and solved a question of future job placement of their children in the future, then a quantity of people who support NPP construction has increased. For example according to the exit poll of Novashyvsk region (Russia) in august 2009 about 60% of local population supported NPP construction. In Ukraine according to exit poll results, which was made in 2007, shows that 35,8% population of the country agree that “further development of nuclear energy for greater energy independence” and 32,8% were against, the rest withhold comments. (Construciton of NPP - social project, 2009)

Economic benefits of the region from NPP construction

Bellow, on the example of Seversk NPP construction, is shown what will get a Tomsk region after construction of NPP:

- Increase of investment attractiveness of the region because of the guaranteeing energy supply at least 50 years ahead. Thus way will be ensured energy independence of the region;
- Increase of Gross domestic product (GDP) on EUR 380.6 million (RUB 13 700 mln; $ 527 mln) annually;
- Direct investments to the region will be more than EUR 4 722 million (RUB 170 000 mln; $ 6 538);
- Additional receipts to the budgets of all levels will be:
  - During construction – about EUR 250 (RUB 9 000 mln; $ 346 mln);
  - During exploitation – more than EUR 180,6 million (RUB 6 500 mln; $ 250 mln);
- Creation of new jobsites:
  - During construction – in peak period 8000 people
  - In NPP – 1641 people
  - In service sphere – till 10000 of regular jobsite (1 jobsite in NPP create till 7 – 10 jobsites of personnel in services, social and construction sector).
- Construction of the NPP will be supported by building of infrastructure objects – roads, housing, social buildings
- Will be benefits for construction industry of Tomsk region
- More than 75% of the electric energy will be consumed on the territory of local region. (What will get Tomsk region from construction of Seversk NPP, 2009)

Analysis of “Public Acceptance” shows that quadruple sites are less desirable, than a case with one power unit.

4.4 Technical Siting Constraints

Technical Siting Constraints can be divided into 2 categories:

1. Constraints differential only if a single power unit is compared to four stand-alone SMRs
2. Constraints differential in every configuration

First category includes Water usage, Grid connections, Population density and other factors.

- Water usage

A smaller sized plant produces less power: it results in a smaller water demand. So, low flow-rate rivers can be used as sources of cool water: it could be the simplest and cheapest solution in warmer climates too, instead of exploiting the technologic-advanced expensive solutions required for LRs.

In Ukraine there are a lot of rivers – 71139 with length of 248 264 km and 11 biggest river pools. (Rivers of Ukraine, 2008) So in Ukrainian case rivers create desirable conditions for both cases – four stand alone units or one large reactor.

- Grid connections

A site for a LR must have a grid connection able to receive a huge amount of power. On the opposite, a stand-alone SMR can fit where is not feasible an extension of the current electric grid or the extension is very expensive.

In this case like in the situation of Electric Grid Vulnerability for Ukraine small reactors reduces risks and considered to be more desirable then large one.

Second category analyzes Constraints differential in every configuration, which include seismic robustness and transport infrastructure.

- Seismic robustness

The smaller size of SMRs’ nuclear island facilitates the use of seismic isolators similar to those used for conventional buildings. They permit to standardize NPP seismic protection: it is less expensive if compared to the site-specific requirements of LRs.

- Transport infrastructure

In some instances large vessels and modules used in LRs limit the siting of new plant to coastal areas or along major rivers. In contrast, many SMRs' components can be transported by smaller river barges, rail or trucks: smaller components allow a higher flexibility in siting for SMRs.

For Ukraine Seismic robustness and transport infrastructure factors promotes advantages for SMR's choice.

Final conclusion in Technical Siting Constrains shows, that "Small reactors" choice is more efficient than "Large reactor".

4.5 Risks Associated to the Project

Risks associated to the project, which are dealt with risks in the delivery of NPP, were divided to three categories: FOAK (first-Of-A-Kind), supply chain and construction risks.

- FOAK risks

They are risks with the same probability of occurrence for both SMRs and LRs, but they have differential magnitude in the two cases. In fact, these risks impact on the capital employed in the single FOAK: it is smaller for SMRs, therefore size does not reduce probability, but reduces the impact of risks. The major FOAK risks are Authority activities on FOAK, NIMBY (not in my back yard) and political risks. All the three classes have the same probability to impact on SMRs or LRs, but capital on which they impact is always lower in the SMRs case.

- Supply chain risks

These risks include all the uncertainties on having the right resources (components, modules and equipments) on the right place at the right time. The exploitation of pre-fabrication, modularisation and standardization in SMRs' design can further control these risks.

- Construction phase risks

A considerable vulnerability of large plant construction is the amount of work that must be performed on site.

Image. NPP construction. Consulting center. 2010

In Ukraine, many people still remember an accident in Chernobyl NPP in 1986 and because of not enough information by government about safety of nuclear energy, they afraid of repetitive scenario even if it will not happen. Some politics use it in their programs to attract and get more votes in the elections and to increase a rate of politic party or is used by opposition. (Chernobyl route, 2009)

Construction phase risks, like less usage of special equipment as for example heavy cranes and more simple assemble operations during construction process in Ukrainian case give advantages for construction NPP with small reactor.

FOAK risks, supply chain risks and construction phase risks of building new NPP in Ukraine supports a small reactor construction.

4.6 Impact on National Industrial System

This factor is important especially for a public investor: the higher is the percentage of manufacturing and construction work content assignable to national industries, the higher the positive effect on GDP of the country will be.

Ukraine has experience in building reactors with generating capacity 1000 MW and 440 MW and during construction of NPP is ready to supply till 60% of equipment for power units. For example, now Russia is ready to credit Ukraine in construction of 2 power units of Khmelnitsky NPP and it was announced that during construction Ukrainian enterprises will supply till 50 – 60% of equipment, that will give economic benefits to Ukrainian companies and to the national GDP of the country. (Possible cooperation of Ukraine and Russia in construction of Khmelnitsky NPP, 2010) Totally is planned to invest about USD 5 – 6 billion, so from 2,5 till 3,6 is going to be paid to Ukrainian site. This fact makes a positive impact on national industrial system.

Image. NPP, Russia invited Ukraine to Atomic Union. 2010

It is planned to involve domestic contractors in designing works and also to use turbo – installation and a complex of automated systems of technological processes management by domestic suppliers. Besides, according to the statement of vice minister of power and energy complex, Ukraine is interested to do not less than

60% of total construction works. (KNPP is waiting for investments from Russia, 2010)

In Ukrainian scenario both cases with small reactors and large reactors choice are acceptable and during NPP construction a country can deliver more than 50% of equipment required.

4.7 Time to Market

Time to market is the time required to license and build planned NPPs, and so to sell the first MWh to the electric system.

Licensing time. Since all the SMR in the same site are identical, it's oblivious that the same steps in the licensing process, after the first units, become redundant.

Construction time. The differential part of time-to-market is the construction timeframe: it includes the pre-construction and site preparation activities, plant construction (from first concrete to fuel load), fuel load and pre-operational testing. Site preparation and procurement for a LR take 1.5 years, while field installation and pre-operational tests take 3.5 years: the total construction time for a LR is five years, considering the most common design installed worldwide. On the other side, construction of a Deliberately SMR takes three years.

For Ukraine "Time to market" is an important factor. Commissioning of Large Reactor VVER – 1000 requires 5 years (E.V. Evstratov, 2008), while Small Reactor 3 years. So a difference is 2 years. During these two years Ukrainian NPP with installed capacity 1000 MW can generate more than 12 000 million kWh, which will give revenue more than EUR 160 million.

In a case of construction SMR's will be possible to begin to launch selling electricity two years before than with LR and this is better for investor and other stakeholders.

Ukraine and Russia made a deal for cooperation in building 3rd and 4th power units in Khmelnitsky NPP. A contract foresees, that Russian side will finance a part of new power units construction and other part will be financed by Ukrainian side. And a part of investments will be agreement between Russian and Ukrainian ministry of Finance and part of investments will come from commercial banks. And return of taken loan will be provided from revenue of electricity selling. (Ukraine and Russia dealed for power units construction, 2010)

Image. Ukraine and Russia made a deal for new nuclear power units construction. Ukrainian news. 2010

Faster commissioning will let to generate more early electricity, to pay faster for credit that is taken for NPP construction, pay less interest to commercial banks, because a part of work is financed by commercial banks. (Kirienko, 2010) Time-to-Market gives benefits for SMR’s choice.

4.8 Competences Required for the Operations

Fuel and Energy complex of Ukraine is characterized with high – intensity of technological processes, that is why efficiency of its work is determined by intelligent level of personnel. In next years the world will face a shortage of people with high level of knowledge and skills in the nuclear field. Nuclear education and training have been decreasing for several years with declining of university enrolment, dilution of university course content and high retirement expectation.

In the classical six-roles nuclear operations team, we can identify two kinds of operators according to their skills: high-level operators for the central control room (CCR), and medium-level operators for routine checks under the direction of the CCR team. High-level operators are the bottleneck from the competences point of view: their train could be difficult.

Constraints for high-levels operators training are not time or cost: cost is a negligible percentage in the life cycle and the eight years conservative period for licensing and construction is sufficient to train an engineer. The real constraint is the education system of the country: it must give a sufficient background of engineers' competences and a following nuclear-grade education, so that training could be able to develop high-level operators.

Deliberately SMRs can be the key feature for countries with low nuclear-grade-training capabilities, because "the qualification and training requirements for staff of the new SMRs have the potential to be lower than those required by the current reactors, however training of staff should be to the level demanded by the design and operating requirement of the SMRs.

Ukraine has experience in construction and operation of NPP. There are institutes, which prepares specialists for work in nuclear sites. Nine years ago Ukrainian Zaporizhzhya NPP (6 power units VVER – 1000) got a license for training and preparation of personnel. Selection and professional training of personnel is considered to be the most important element of safety work of NPP. For supporting professional skills of personnel on the base of training point was created a scientific – training center (STC). (Preparation of personnel at international level, 2009)

Image. Training center of Zaporizhzhya NPP. Energoatom. 2009

The structure of STC includes center of preparation of operating personnel and center of preparation of repairing personnel. For training of operating personnel is used full scale training simulator, that is analog of block boards for management. STC has unique in Ukraine full professional equipped complex for training of repairing (maintenance) personnel. (personnel policy of ZNPP, 2009)

Preparation of personnel for Ukrainian NPP is provided in training centers, which are created in every NPP. Total quantity of personnel in 4 training centers is about 500 people and about 200 of them are instructors.

Personnel are prepared in training centers that are provided according to typical programs, where special attention is paid to preparation and support of qualification of licensed personnel. With overall amplification of USA, Russia and Ukraine was created a training base for preparation of personnel. (Professional development of personnel in NPP, 2010)

Ukrainian training centers give a possibility to train personnel for operating in nuclear power plants with large and small reactors.

4.9 Impact on Employment

This aspect is important especially for a public investor because welfare of the country is an important objective of his mission.

However, a private investor will be interested to the government's support following a higher number of new jobs created. Impact on employment consists of construction time phase and operation phase.

In construction time phase, there are three different impacts on employment:

- Direct

People employed in the manufacturing of components and modules, on-site construction and operation of NPP;

- Indirect

Jobs created in the extended nuclear supply chain: suppliers of equipment manufacturers, suppliers of machineries and building materials, agencies for inspection and safety controls.

- Induced

Jobs created in non-nuclear industries due to the new jobs added in the previous categories. They are the sum of nonnuclear jobs that would be created because of industry growth, such as additional grocery store employees, school teachers and residential construction workers.

Impact on construction employment promotes the SMR choice.

1. The SMRs in co-siting configuration create 11% more man years content than LRs. Major part of new jobs opportunities created by SMRs are related to the major percentage of work content transferred off-site, through modularization and pre-fabrication approaches.

2. The literature shows that one of the biggest challenge is finding qualified people, including craft laborers and technicians (qualified boilermakers, pipefitters, electricians, ironworkers), to support construction. SMRs' demand is more time-leveled, therefore it will be easier to face the shortage of qualified construction workers, even if the total number of man years is higher than LR.

In Ukraine employment level is not full. (Unemployment of Ukraine, 2010) INCAS module of “External factors analysis” shows that construction staff during SMR’s NPP construction requires 11% more of personnel than for LR construction and SMR reactors create more job places during operation phase. More people will be employed – more benefits will be given to welfare of the families and region where NPP will be built.

Impact on Employment gives more advantages to SMR choice.

4.10 Design Robustness

A high level of safety is the result of a complex interaction between good design, operational safety and human performances, but design features are able to impact on all these three dimensions. By the concept of design robustness the objective is to combine and to evaluate three key strategic performance areas: reactor safety, radiation safety (public and occupational) and safeguards according to Reactor Overnight Process.

1. Reactor safety considers accidents leading to significant, unmitigated releases from containment. Core Damage Frequency (CDF) and Large Early Release Frequency (LERF) are the most important indicators for this dimension. The implementation with an acceptable cost of safety features as passive systems and design simplification are possible only on SMR. Such features drive the elimination of several classical event initiators and passive safety guarantees higher availability of mitigating system.
2. Occupational Radiation Safety refers to operators' overexposure risk. Plant workers can be exposed to a high-level radiation during the maintenance of reactor coolant pumps, pressurizes, water chambers of steam generators and during refueling. So, operator's exposure is strictly related to capacity factor of reactor, as it is clear from World Association of Nuclear Operators (WANO) performance indicators.
3. Public Radiation Safety considers collective radiation exposure to liquid and gaseous effluents from routine nuclear reactor operations. Size does not impact on technological solutions for the control of these releases.
4. Safeguards refer to physical protection of the facility and proliferation resistance.

Design robustness is strictly design-specific but simplification, standardization & compactness of SMRs permit to obtain certain improvement on reactor safety and physical protection.

In Ukraine, like in other countries with NPP, a nuclear safety of power units depends first of all from situation of exploitation safety. Analysis and Evaluation of exploitation safety of NPP is provided by the results of reports of failures and errors of NPP work, annual reports of current situation of exploitation safety and also results of inspector's controls.

Failing in work of NPP brings to necessity of stopping reactors, which leads to negative results. Among the most important errors in work of safety systems in Ukrainian NPP are the following (Nuclear safety, 2006):

1. Failure of control systems, which are responsible for management and safety of power unit
2. Failure of safety systems of security mechanism

Ukrainian government and "Energoatom" (NPP exploitation Company) are taking care about continuous improvement on safety of NPP exploitation. Simplicity, standardization and compactness of small reactors let Design robustness to promote a SMR choice.

4.11 Historical and Political Aspects

Historical and Political Aspects is another factor for choice of reactor for NPP. All Ukrainian NPP were constructed with close cooperation of Russia. Nuclear power units has VVER model (VVER – 1000 and VVER – 440), which is supplied by Russia.

Image. Rivne NPP. Energoatom. Ukraine. 2010

After collapse of Soviet Union Ukraine got a big and technologically homogeneous complex of atomic energy. Today in Ukraine work 15 nuclear power units, from them 13 are VVER – 1000 type and 2 VVER – 440. Share of electricity generation by NPP is about 50% from total energy generation in the country. (Nuclear way of Ukraine, 2010). In 2010 it was written an agreement to build 2 new power units of type VVER – 1000 with total generation capacity 2000 MW in Khmelnitsky NPP. Main constructor of two new power units will be Russian company “AtomStroyExport”. (Construction of Khmelnitsky NPP, 2010). At the same to the Ukrainian “Strategy of development of power – energy complex till 2030” it is supposed to reduce country dependence on energy resources by differentiate suppliers, including suppliers of nuclear fuel. That is why in 2005 “Westinghouse” company supplied fuel assemblages for South-Ukrainian NPP of American production, which should be substitute Russian “TVEL” fuel assemblages. (Fuel assemblages of "Westinghouse" in South-Ukrainian NPP, 2010) Ukraine, in spite its close historical and neighboring relations with Russia tries to be independent in nuclear energy complex by collaborating not only with Russia, but also with other countries in development of nuclear energy industry.

In the history of mankind there was no scientific event, which was more distinguished by its consequences, than discovering of nuclear fission of uranium and acquiring nuclear energy. The man got in his disposal a new powerful source of generating electrical energy. “External Factors” were analyzed in this paper to evaluate if it is better to invest in SMR’s or LR:

- Analysis of “Spinning Reserved Management” promotes a Small Reactors choice (SMRs). It showed that construction of LR will require 42,6 % higher reserves, while SMR do not vary the actual situation and their ratio between sums is equal to 0.
- Electric Grid Vulnerability analysis resulted that putting 4 small reactors in different sites, instead of 1 large reactor, reduce more risks of grid vulnerability.
- Public acceptance is important in both cases whether it is SMR or LR, and in a case of SMR will be given more job places.
- In a case of Technical Siting Constrains “Small reactors” choice is more efficient than “Large reactor”. For Ukraine Seismic robustness and transport infrastructure factors promotes advantages for SMR choice.
- Risks associated to the project. FOAK risks, supply chain risks and construction phase risks of building new NPP in Ukraine supports a small reactor construction. Construction phase risks, like less usage of special equipment (e.g. heavy cranes) and more simple assemble operations during construction process in Ukrainian case give advantages for construction NPP with small reactor.
- Impact of National Industrial System for Ukrainian scenario in both cases with small reactors and large reactors choices are acceptable. During NPP construction a country can deliver more than 50% of equipment required.

- Faster commissioning will let to generate more early electricity, to pay faster for credit that is taken for NPP construction, pay less interest to commercial banks, because a part of work is financed by commercial banks. Time-to-Market gives benefits for SMR’s choice.
- Competences required for the operations. Ukrainian training centers give a possibility to train personnel for operating in nuclear power plants with large and small reactors.
- Impact on Employment gives more advantages to SMR choice.
- Simplicity, standardization and compactness of small reactors let Design robustness to promote a SMR choice.

The result of made “External Factors” analysis promotes the SMR choice.

CONCLUSION

Today Power Engineering can be considered as one of the most important factors of the world development process. Nuclear energy can make the greatest contribution to meet energy needs and ensure sustainability of socio-economic development of humanity in the XXI century.

The new interest in nuclear energy is determined due to the recent sharp increase of price for hydrocarbons. Compared with coal, oil and gas, nuclear energy resources are much compact and more efficient. It is enough to say that 1 kg of nuclear uranium fuel substitute 3000 ton of coal for thermal power plant. Construction of hydropower plants, especially in lowland rivers require unacceptably large flood of expensive mineral areas. Regarding to wind power and solar panels, behind them undoubtedly there is a great future, but, alas, still distant.

Share the same atomic energy can be expanded by eliminating hydrocarbon dependence. Nuclear power plants do not emit any harmful substances, unlike coal and gas energy sources.

Nuclear power energy will not permit to have sharp increases in price tariffs. If the price of gas will increase three times, this will automatically lead to an increase in tariff for electricity of heat electro power station in 3 times. At the same time, if a price for uranium will increase in 3 times, a price of electricity generation by NPP will raise less significant (20 – 30%).

There is another advantage of the power plant. Where there is no nearby coal or gas, nuclear power is indispensable at all, because there is no need to import fuel every day. Fuel deliveries only about every five years and its volume compared with coal is negligible.

The last, but not less important factor, which makes an impact on the development of nuclear energy, is the safety of nuclear power units. Today safety of NPP is a necessary requirement of nuclear energy development. Modern power units vary from old one with high level of safety. Power units of new generation are supplied with advanced systems of “passive” safety. That means that in a case of accident operator will not need to take any actions. Power units are projected in such manner, that their safety stop is made automatically. Thus way, today for safe and reliable exploitation of NPP in Ukraine, are created all necessary conditions.

Construction of new NPP in Ukraine will give a significant synergetic effect:

- Development of nuclear energy will contribute to ensuring energy security, the achievement of which in the long term is impossible without the diversification of energy production. This will significantly reduce or eliminate dependence on imported electricity, which in terms of possible fluctuations in commodity prices and the projected growth of the multiple needs of electricity is a big plus
- Nuclear power plant today is one of the most environmentally friendly energy producers. Nuclear energy will increase energy production, while respecting the ecological balance. This will lead to the exclusion of additional harmful emissions into the atmosphere and to ensure that the international commitments made in addressing global environmental problems
- Guaranteeing of energy resources will provide sustainable socio-economic development of Ukrainian regions
- Development of nuclear energy objective will increase the technological level of domestic machine-building, strengthening of scientific and technological potential of the country and the creation of new high-tech industries

This paper provides investments analysis for Nuclear power plant construction in Ukraine with LR or SMR’s.

Results of financial analysis shows, that in Ukrainian scenario it is more profitable to invest into LR. Financial indicators such as IRR, NPV for LR are higher than for SMR’s and payback time is shorter in a case of LR choice.

External factors analysis gives more benefits for SMR's choice, which according to the results is more attractive then for LR.

Study shows that in Ukrainian scenario it is more profitable to invest into LR choice. Even if external factors analysis promotes small reactors choice, financial/economic analysis promotes Large Reactor choice. In this case for investor it is more profitable to invest into Large Reactors. Ukrainian scenario promotes to invest into nuclear power plants with Large Reactors.

In tote nuclear energy has a significant prospective in Ukraine and its development significantly increases a potential of the whole power energy complex.

Acronyms

CHPP	Heat electric power station
CIS	Commonwealth of Independent States
EMEA	Europe, Middle East and Africa
FEB	Fuel and Energy balance
GDP	Gross domestic product
HPS	Hydro Power Plant
IAEA	International Atomic Energy Agency
KNPP	Khmelnitsky NPP
LR	Large Reactor
NFC	Nuclear fuel cycle
NIMBY	Not-In-My-Backyard
NNEGC	National Nuclear Energy Generating Company
NPP	Nuclear Power Plant
OECD	Organization for Economic Co-operation and Development
OTL	Overhead transmission line
RNPP	Rivne NPP
SMR	Deliberately Small Reactor
STC	Scientific training center
SUNPP	South Ukrainian NPP
TPS	Thermal Power Plant
UCTE	Union for the Co-ordination of Transmission of Electricity
UPS	United power system
VVER	Water-Water Energetic Reactor (WWER)
WANO	World Association of Nuclear Operators
ZNPP	Zaporizhzhya NPP

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