4 ALTERNATIVES

The proposed economic activity is the construction of a new nuclear power plant (NNPP) in the vicinity of the existing Ignalina NPP. The total electricity production capacity of the new NPP will not exceed 3 400 MW. The new NPP will consist of one to five units depending on the plant size and reactor type to be chosen.

In this chapter the alternatives for executing the proposed economic activity are presented and compared. However, also the options excluded from the investigation as well as the non-implementation alternative are presented. The evaluated alternatives include the following:

- location alternatives;
- cooling alternatives (direct and indirect (cooling towers) cooling; alternative scenarios for electricity production levels; location of the cooling water inlet and outlet channels);
- technological alternatives (types of reactors);
- non-implementation alternative;
- options excluded from the investigation.

4.1 LOCATION ALTERNATIVES

There are two options for the location of the new NPP. The alternative sites are located in the territory of the existing Ignalina NPP (Figure 4.1-1):

- Site No. 1: location east of the Ignalina NPP unit 2,
- Site No. 2: location west of the switchyard.

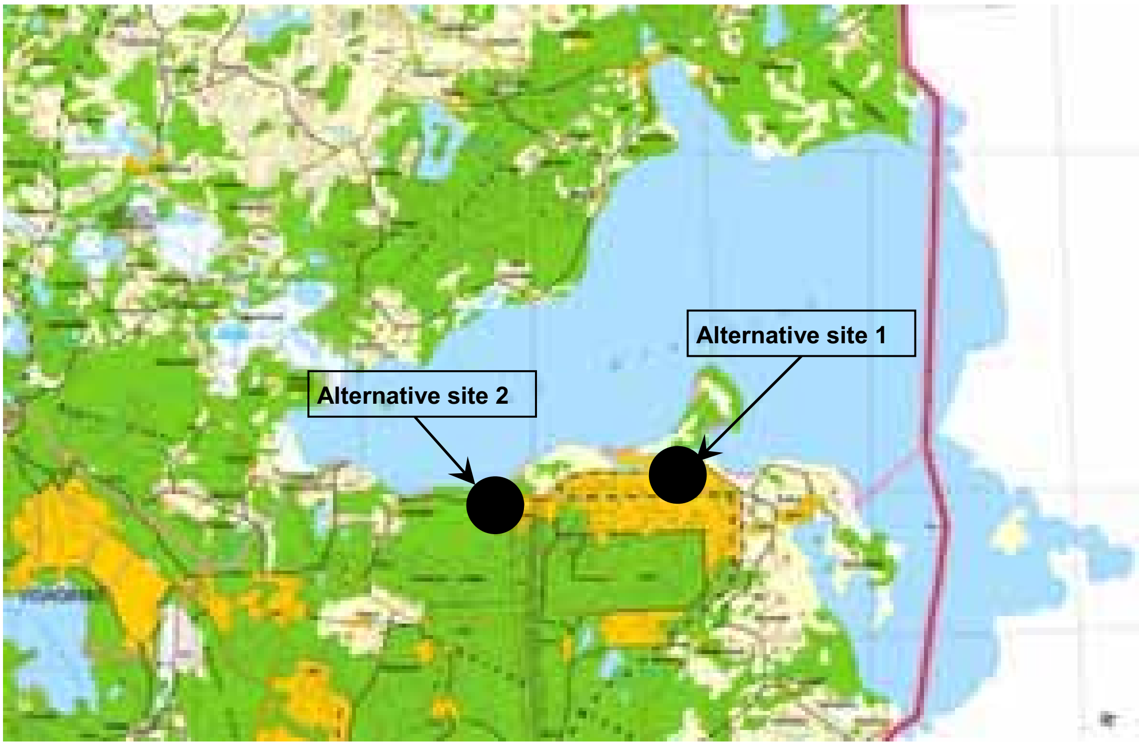

Figure 4.1-1. Location of Site alternatives No. 1 and No. 2.

The construction of the nuclear facilities in the territory was started in 1974. Ignalina NPP has been in operation since 1983, using Lake Druksiai for cooling. The first INPP unit was shut down in 2004. In 2009 also the second INPP unit will be closed. The decommissioning process will continue at least until 2030. Therefore the purpose of the site, to produce electricity by nuclear power, will remain the same also after the new nuclear power plant is constructed.

The current territory of the INPP is the only territory in the Republic of Lithuania, with existing electricity transmission, cooling water, transportation roads and auxiliary facilities, which are necessary for the operation of the nuclear power plant. In addition there are other nuclear facilities planned as well as under construction including the facilities for radioactive waste management and disposal facilities.

4.2 COOLING ALTERNATIVES

4.2.1 Inlet and outlet locations

Three alternative inlet and two alternative outlet locations have been studied with a 3D-flow model. Alternative inlet locations were the present location, a location about 2 km to the west from the present location and a tunnel from the deep part of the lake. Alternative outlet locations were the present outlet location in the middle of the lake and an outlet to a bay in the southern part of the lake. Additionally, an outlet alternative where the cooling water flow was divided into these two outlets was studied. The locations are shown in Figure 4.2-1.

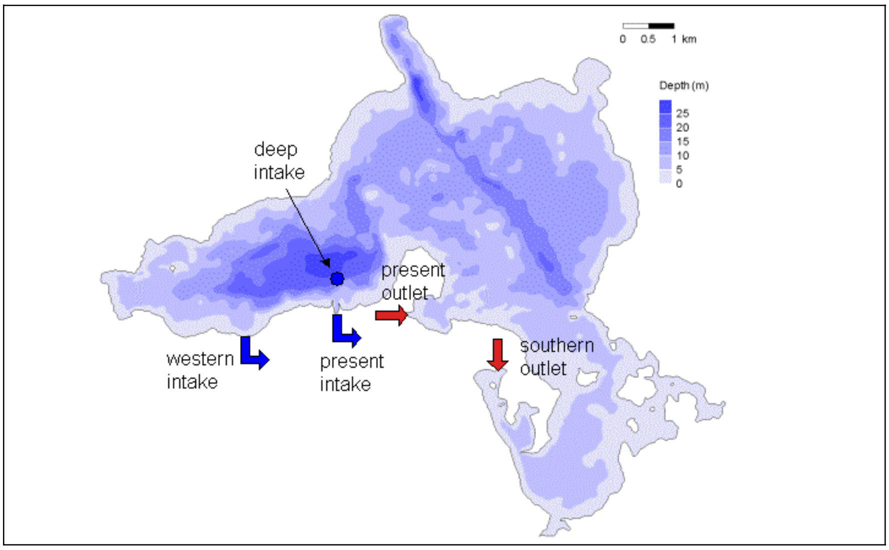

Figure 4.2-1. Alternative inlet and outlet locations.

Present inlet and present outlet were chosen for modelling since the existing infrastructure would be adequate also for the new NPP. Additional locations were chosen based on expert estimate on how to assess in the modelling as wide a variety of thermal impacts as possible.

The deep inlet option was selected to assess the possible advantages of obtaining cooler water from the deep water layers. The western inlet is located close to the alternative site No. 2 and additionally the distance to the outlet locations is longer than from the present inlet. It was estimated that longer distance between inlet and outlet might give a different thermal impact. Furthermore, it might decrease recirculation of cooling water which in turn would benefit electricity production. Also the southern alternative was selected since it would increase the distance between the inlet and outlet areas. The divided alternative was selected to assess the possible benefits of dividing the thermal load to two areas.

To investigate the effect of NNPP inlet and outlet locations on lake temperatures, six alternative NNPP inlet and outlet location combinations were computed (see Section 7.1.2 for modelling description and results).

4.2.2 Cooling water systems

The main duty of a power plant cooling system is to condense low pressure steam exiting from a steam turbine. The lower the cooling fluid temperature is, the greater the condenser vacuum and efficiency of the plant are. Selection of the cooling system has a substantial effect on this. Finding the most suitable system requires examination of many parameters related to equipment and plant location.

Once-through system (OTC), later referred as direct cooling, and wet cooling tower (WCT) are considered as wet cooling methods due to the fact that both use water as the primary cooling substance. Both systems have a high cooling efficiency and therefore they are the most commonly used cooling systems in power plants for energy production. Wet cooling tower can be either natural or forced draft type. Dry cooling systems can be direct, such as air-cooled condenser (ACC), which uses air as a primary cooling substance or indirect, such as Heller, where water is used as a primary and air as a secondary coolant. In the dry-cooling systems the cooling efficiency is lower than in the wet cooling systems but also the demand of water is lower. In the sections below, cooling systems are examined in more detail.

4.2.2.1 Direct cooling

In direct cooling the cooling water is taken e.g. from a lake or a sea, led through screening and directed to the condenser. Also an indirect construction of a direct cooling system is possible, where the primary cooling water (from the water base) is led through a separate heat exchanger which cools down the secondary (closed) cooling water flow that is used at the condenser. The primary cooling water will be returned to its origin.

The cooling water has to be pumped from the water base, which causes some power demand, but as there are no other power demands as fans, the power consumption is lower when compared with WCT. The investment cost of a direct cooling system is typically low, since no tower has to be constructed. However, it is essential that there is a water system with adequate water resources in the vicinity of the NPP.

4.2.2.2 Wet cooling tower

In WCT the cooling water is led to a cooling tower by spraying. Large amount of small droplets form a vast heat transfer area between water and cool air. The latent heat absorbed to the evaporating water, together with convection and radiation, creates the cooling effect. After contact with the air the cooled water trickles down the fill structure to a basin from where it is pumped back to the condenser.

The cooling tower can be either natural or forced draft type. Natural draft tower utilizes buoyancy via a tall chimney to create a current of air through the tower. Warm moist air in the tower is less dense than drier outside air at the same pressure. The air naturally rises due to the density difference, which creates a current trough the tower. A forced draft tower utilizes power driven fan motors to force air through the tower. A natural draft type cooling tower is typically a large construction, but does not require power to operate blowing fans. Forced draft cooling tower is significantly smaller in size, but requires electricity.

Especially in cool and moist climate conditions a visible plume is formed above the tower due to saturation of the exiting air. At freezing conditions special attention must be paid to the operation of the tower to avoid icing, as it reduces the heat transfer efficiency and might break the structures of the cooling tower. Anti-fouling chemicals have to be added to the water circulating within the cooling tower.

Wet cooling towers can also be used as a part of the direct cooling system to decrease thermal discharge to water base. With this solution, condenser cooling water discharge is led (entirely or partly) through this so called "helper cooler" which cools down the exiting water. This arrangement basically moves a part of the thermal discharge from water base to atmosphere.

4.2.2.3 Dry cooling methods

Specific features of an air-cooled condenser (ACC) and Heller system are insignificant make-up water consumption but also rather ineffective cooling. However, under circumstances where water is not available these cooling methods can be a reasonable solution despite the greater investment costs and the demand of large area.

ACC uses air as the cooling substance. The low-pressure steam from the turbine is led to the condenser, which consists of numerous finned tubes, usually mounted to an A-form. The steam condenses to water inside the tubes and cools down to the design temperature. The cooling occurs with convection and radiation. The air circulates through the condenser by fans, which require electricity. Because of the large diameter of the low pressure steam pipelines, the condenser must be located near the steam turbine. Due to relatively low heat transfer efficiency, ACC also requires a large area to be placed.

Heller is an indirect dry cooling method. There's a closed circulation between the condenser and the dry cooling tower whose structure is very similar to ACC's. The condenser is jet type which sprays the cooled water directly to the boiler water circulation. Therefore the cooling water has to be demineralised water. As the condenser is at vacuum, the cooled water from the tower is expanded at a regeneration turbine which regenerates a part of the pumping power needed for cooling water circulation.

4.2.2.4 Hybrid cooling tower

Hybrid cooling tower combines the features of both wet and dry cooling. The construction of a hybrid tower may vary significantly along the various manufacturers. The basic idea is, however, that the wet cooling part is located at the bottom of the tower and the dry cooling at the top. Typically the basic design criteria are to diminish the use of water under certain conditions and prevent the formation of a plume.

4.2.2.5 Cooling system comparison

The most essential factor in the cooling system selection process is the availability of a sufficiently large body of water. Other aspects include e.g. the effects on the plant efficiency and availability of required land area.

In the following Table 4.2-1 the examined cooling systems are roughly compared with each other. The wet cooling tower is set as a base system (evaluation factor 1 for all parameters) to which the other systems are compared. All the towers are presumed to be of forced draft type.

Table 4.2-1. Relative comparison of the cooling systems.

Parameter	WCT[1]	DC[2]	ACC[3]	Heller[4]	Hybr.[5]
Investment costs	1	<1	>1	>1	>1
Internal power consumption	1	<1	>1	>1	~1
Water demand	1	>1	0*	<1	<1
Chemical additions	1	<1	<1	<1	~1
Condenser pressure	1	<1	>1	>1	~1
Noise	1	<1	>1	>1	~1
Plume	1	<1	0	0	0
Required area	1	<1	>1	>1	>1

* If finned tubes are not sprayed (However, even with spraying <1)
[1] WCT – Wet cooling tower; forced draft
[2] DC – Direct cooling system
[3] ACC – Dry cooling system; air-cooled condenser
[4] Heller – Dry cooling system; heller
[5] Hybr. – Hybrid tower

The direct cooling system is the most efficient cooling system but it requires a water system with large capacity. Its advantages are the usually lower investment costs and higher plant efficiency. In the once-trough cooling the receiving water body acts as a heat sink from where the heat is transferred to air by evaporation. The discharge of heated water can have negative environmental impacts in the receiving water body. However, in once-trough cooling the cooling water does not necessarily need any other treatment than mechanical removal of larger solids whereas the cooling towers usually need treatment for biofouling, scaling and suspended matter, with acceptable biocides, antiscalants, and dispersants, respectively.

Wet cooling tower is the commonly used system at locations with finite water resources. It is the second most efficient cooling system after the once-trough system. It also has higher investment costs. Its power consumption as well as demand for area depend on the design type. The natural draft towers consume less energy but demand more space than the forced draft towers. A common feature of the wet cooling towers is the formation of a visible plume especially during colder months. Since most of the heat is evaporated to the atmosphere and not discharged to the water system, the effects on the surrounding water system remain smaller than with the direct cooling.

With the helper cooler solution the thermal discharge to a water base can be decreased. The efficiency of this system is highly dependent on the temperature difference between air (wet bulb) and cooling water discharge. As long as the air wet bulb temperature is 5 degrees or less lower than the exiting cooling water, helper cooler has no significant effect. E.g. with low cooling water temperatures, air wet bulb temperature must be zero or less to justify the helper cooler. With cooler air (or warmer cooling water discharge) the effect can be reasonable. The helper cooler can be a good solution for a secondary supporting cooling system, which can be used only during the warmest summer months.

The dry cooling systems are not regularly used as a primary cooling system in large (> 1000 MW) power plants since they demand a relatively large area (up to ten times as large as for wet cooling towers) and decrease the plant efficiency significantly. The electricity demand is also higher than in direct cooling due to the fans, which are required for air circulation. The investment costs of dry cooling systems are substantially higher than those for wet cooling. Also, the dry tower system alone can be unable to produce the needed performance required during periods of ambient high temperature. The advantage of the dry cooling systems is that they barely consume water at all, thus there are typically no evaporation losses. Since it does not produce any thermal discharges it does not cause any heat impacts on the surrounding water systems.

In conditions when water can be a limiting factor for some time periods it can be favourable to combine both dry and wet cooling methods. It is possible to use separate wet and dry towers or to incorporate both wet and dry cooling sections in the same tower design (hybrid). The cooling system can be operated based on the prevailing conditions. When sufficient amounts of water are available the dry cooling, which consumes more electricity, would be turned off and heat removal would rely on wet towers. During times of limited water resources the heat or, depending of the design, some proportion of it would be removed by the dry towers.

For comparison of the different cooling systems some central parameters for a plant with a gross production of 1700 MW are presented (Table 4.2-2). The gross production is set to be 1700 MW for a plant using once-trough cooling. The gross production for the other cooling systems is calculated by taking into account the efficiency losses due to the higher condenser pressure. The net production is calculated by deducting the internal consumption of the cooling systems (pumps, fans etc.).

Table 4.2-2. Indicative comparison of the different cooling systems.

Parameter	DC[1]	WCT (nf)[2]	WCT (forced)[3]	ACC[4]	Hybr.[5]
Electricity production (gross, MWe)	1 700	1680	1680	1642	1680
Electricity production (nett, MWe)	1678	1663	1646	1614	1644
Condenser pressure (bar)	0.032	0.04	0.04	0.062	0.04
Cooling water flow (m^3/s)	80	70	70	0	70
Evaporation (m^3/s)	0.75	0.75	0.75	0	0.73
Discharge to lake (m^3/s)	80	0.25	0.25	0	0.24
Required area (m^2)	na*	23 000	15 000	33 000	22 000

[1] DC – Direct cooling system
[2] WTC (nf) – Wet cooling tower; natural draft
[3] WTC (forced) – Wet cooling tower; forced draft
[4] DCS (ACC) – Dry cooling system; air-cooled condenser
[5] Hybr. – Hybrid tower
*Not applicable

The values clearly indicate that the direct cooling system is the best option when it comes to the electricity production. It also consumes less water compared to the wet cooling towers. The dry cooling option is clearly the most consuming system in terms of electricity and area. Wet cooling towers consume more energy than direct cooling, but are still significantly more efficient than the dry options. The estimated values for the hybrid tower are strongly dependent on the design and the amount of heat rejected by the dry cooling system. The ecological and hydrological effects and criteria affecting the selection of the cooling system are further discussed in Section 7.1.

4.3 TECHNOLOGICAL ALTERNATIVES FOR NUCLEAR POWER REACTORS

Nuclear power plants were first developed during the 1950's and 1960's. In the early days several different types were studied and built, but only a few designs ended up in wide commercial use. The first test and prototype reactors represent the first generation of nuclear power plants, created for the development of nuclear power in industry today. Most of the current operating nuclear power plants are Generation II (including the existing Ignalina NPP), constructed in the 1970's having evolved from Generation I technologies. These units have been found to be safe and reliable, but are being superseded by better designs.

Generation III reactors were developed during the later 1980s and 1990s. Generation III+ refers to the most advanced new power plant types currently available, remaining based upon the original concepts for fuel and plant design, operating at modest temperatures and pressures. Generation IV units are at the concept/ early development stage and are not expected to be viable as a commercial offering before 2015–2020. Their operating principles are very different, generally operating at high temperatures (and improved efficiency), requiring new fuels and special coolants.

All current marketed commercial nuclear power reactors use water to remove heat from the reactor core. Most of the nuclear reactors around the world are so-called Light-Water Reactors (PWR, BWR). In addition to light-water reactors, there are heavy-water moderated reactors (CANDU). Other less common reactors in commercial use include graphite moderated and gas cooled tube reactors. Ignalina nuclear power station in Lithuania currently employs the RMBK-1500, a water-cooled and graphite-moderated reactor.

Generation III (Advanced LWR) and III+ (Evolutionary Designs) have a number of characteristic features for future nuclear power plant programs:

- A standardised design for each type to expedite licensing, reduce capital cost and construction time;
- A simpler and more rugged design, making them easier to operate and less vulnerable to operational upsets;
- Higher availability and longer operating life – typically 60 years (cf. 30–40 years for present designs);
- Reduced possibility of core melt accidents by design and additional protection systems;
- Resistance to serious damage that would allow radiological release from external impact and terrorist activity;
- Higher burn up fuel to reduce fuel use and the amount of radioactive waste
- Special "burnable" absorbers to extend fuel life.

The greatest enhancement from Generation II designs is that many incorporate passive or inherent safety features which require fewer or no active controls or urgent operator intervention to avoid accidents in the event of a malfunction. They are not only intrinsically safer, but also have optimised features giving higher availability and better economics than their predecessors.

The possible technical alternatives for nuclear reactors being considered for the new nuclear power plant in Lithuania are all generation III or III+ reactors of the following types:

- pressurized water reactor (PWR);
- boiling water reactor (BWR);
- pressurized heavy water reactor (PHWR).

Specific details of Generation III design alternatives for construction in Lithuania are provided in Section 5.2.

Figure 4.3-1 shows the evolution of nuclear power.

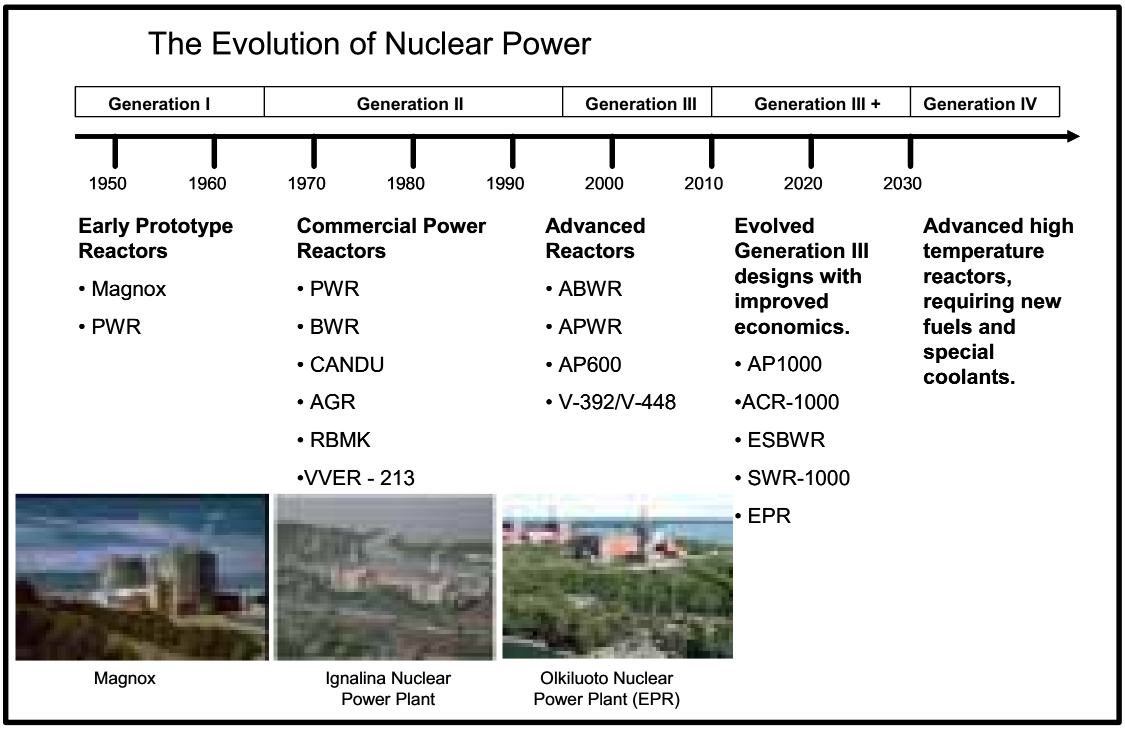

Figure 4.3-1. The evolution of nuclear power.

4.4 NON-IMPLEMENTATION

According to a so called non-implementation, or zero option, no new nuclear power plant unit will be constructed in Lithuania. In this case the supply of energy from diverse, secure, sustainable energy sources which do not emit greenhouse gases and other pollutants will not be secured and the country's energy security will not be ensured.

4.4.1 Electricity demand forecast

Since 2000 the Lithuanian gross domestic product (GDP) has been growing very fast – on average by 7.9 % per year. It is foreseen that the rapid rate of economic growth will persist in the coming two decades. In the National Energy Strategy approved by the Lithuanian Parliament in 2007 (*State Journal, 2007, No. 11-430*) three possible economic development scenarios have been chosen for future forecasts: 1) fast economic growth scenario (the annual rate of 6 % during the period from 2005 to 2025), 2) basic scenario (the growth rate of 4.5 %), and 3) slow economic growth scenario (the annual rate of 4 %). The basic scenario is based on the most likely economic development trends, assuming that the Lithuanian economy will attain the current economic level of the EU states within the next 15 years.

Fast growth of the national economy is one of the most important factors that increases energy consumption, in particular, electricity demand. During the period of 2000–2006 final electricity consumption by end user grew by 5.3 % per year. However, gross electricity consumption increased only by 3 % per year because the power plants' own needs in 2006 were 27 % lower than the 2000 level due to the closure of Unit 1 at Ignalina NPP, and because electricity transmission and distribution losses also decreased during that period.

Although electricity consumption over the period of 2000–2006 showed the most rapid increase compared to the consumption of other energy forms, Lithuania is lagging considerably behind developed European countries in terms of the comparative indicator of final electricity consumption per capita by economic sector (2336 kWh per capita). In 2005, the average electricity consumption per capita in the EU-27 countries was 2.4 times as high as in Lithuania (in Finland 6.6 times, in Germany 2.7 times, even in new member states about 2 times). Therefore, the energy demand forecast was based on the assumption that the modernization of the Lithuanian economy would require the rapid growth of the electricity demand.

An increase in electricity demand will be considerably influenced by the dynamics of macroeconomic indicators (GDP growth, structure of branches of the economy, etc.), rising fuel and energy prices, consumer response to rising income and higher energy prices, energy efficiency enhancement and other factors. With a view to estimate the uncertainty of economic growth and other factors, uncertainty analysis methodology was applied for forecasting. It allows analysing changes in energy consumption in economic sectors, taking into account interrelationship between the factors determining consumption, as well as assessing tendencies of their changes.

To have consistent modelling framework for analysis of the energy sector development, projections of electricity demand (net electricity generation), presented in Figure 4.4-1, take into account final energy consumption, electricity consumption by energy transformation system (including needs of petroleum refinery, oil extraction, heat plants and other energy sector activities) and losses of electricity transmission and distribution. The mathematical MESSAGE model (*Messner et al, 1995, 2000*) which from a set of existing and new technologies selects the optimum mix of generating capacities produces a forecast of electricity consumption for power plants' own use. As is shown in Figure 4.4-1, by the end of planning period electricity generation for the country's internal demand in the fast economic growth scenario will increase 2 times, basic scenario – 1.8 times, and slow economic growth scenario – 1.5 times.

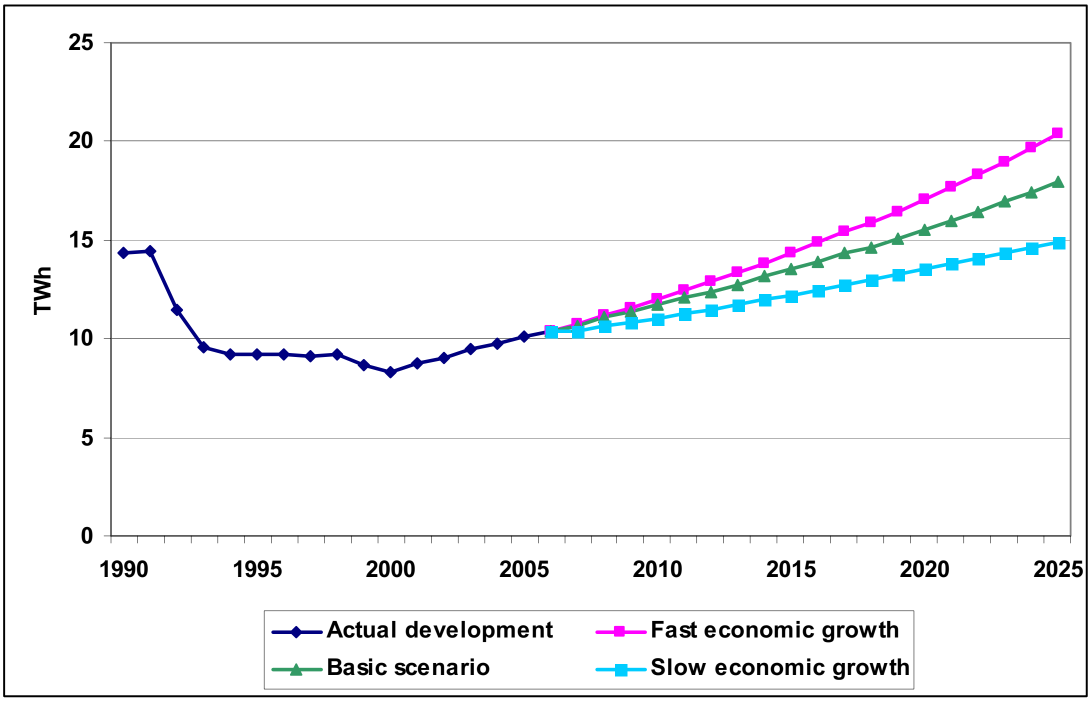

Figure 4.4-1. Electricity demand by scenario.

Disaggregated forecast of electricity demand for the basic scenario by sector is presented in Figure 4.4-2. According to the forecast, the final electricity demand in the branches of economy would reach and exceed the level of 1990 by the year 2017.

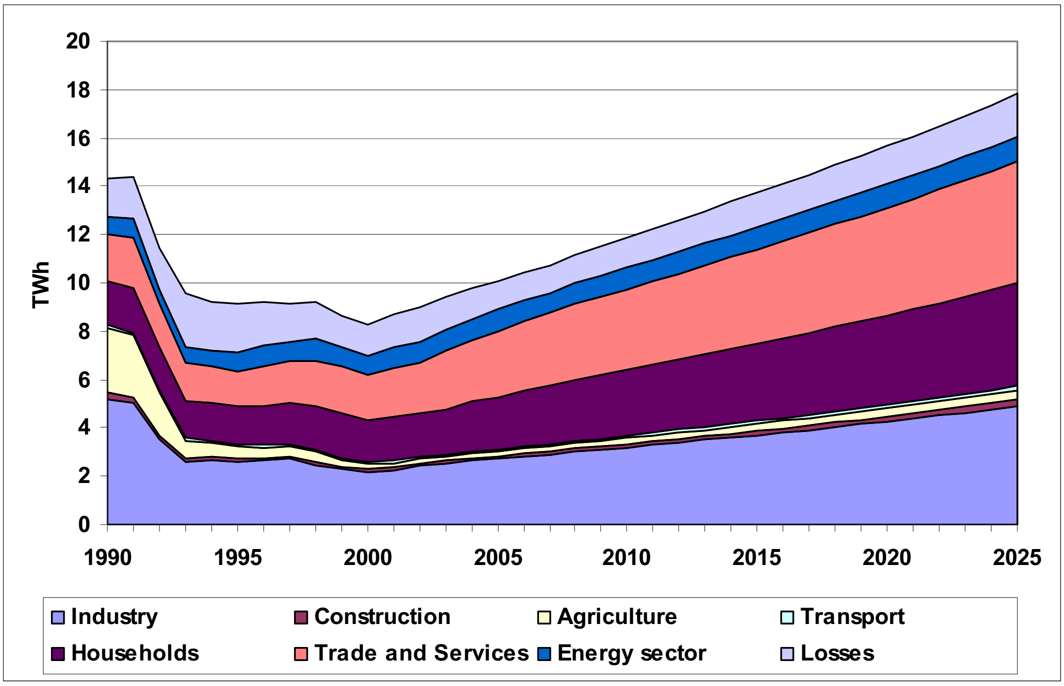

Figure 4.4-2. Electricity demand by sector.

Currently, the Ignalina NPP is dominating in electricity generation – in 2007 its share was 72.6 %. The share of electricity from renewable sources increased up to 4.4 %, and the rest (13 %) was generated by the power plants using natural gas and heavy fuel oil. Lithuania will comply with the EU requirements on the use of renewable energy resources for generating electricity. Renewable energy resources like wind power plants, small hydropower plants and biofuel burning CHP plants being constructed within the next few years will account for over 7 % in the total electricity generation balance in 2010. In 2025 their contribution should increase up to 10 %. Thus, after the closure of the Ignalina NPP more than 90 % of electricity will come from fossil fuels, unless a new nuclear power plant is constructed. In the analysed zero-option, it is assumed that the amount of electricity equal to the production of the new NPP would be partly produced in Lithuania in thermal power plants and part of it would be imported.

Evaluation of the economic effectiveness of utilisation of various energy resources, construction of new energy generating capacities, modernization of existing energy technologies and implementation of appropriate environmental protection measures causes a complex problem, which should be solved by analysing future development of the country's energy sector during a comparatively long period of time. Without such analysis only preliminary assessment could be presented.

Dependence on the energy import from Russia and the risk of energy supply disruptions will increase significantly. The cost of electricity production will increase dramatically – more than three times due to very high prices for gas and oil and comparatively low efficiency of existing generating units at the Lithuanian TPP. In addition, the replacement of nuclear energy by fossil fuel will significantly increase CO_2 emissions.

4.4.2 Environmental impact of zero-option

In a case when future electricity generation is based mostly on fossil fuel, existing units at the Lithuanian TPP should produce more than 50 % of electricity necessary to meet the country's internal demand. In addition, the construction of new CHP plants and combined cycle gas turbine units is required. Natural gas will become the major source of primary energy. As there are targets in the Lithuanian Energy Strategy to increase the use of biomass, also biomass-based electricity production is assumed to be included in the zero-option. Imported electricity is assumed to be produced in thermal power plants using coal and oil as a fuel and in hydro and nuclear power plants as well.

Flue gas and green house gas emissions avoided thanks to the new NPP are estimated and the estimated emissions in the zero-option are presented in Section 7.2.2.2.

4.5 OPTIONS EXCLUDED FROM THE INVESTIGATION

Alternative locations in Lithuania

There are no other realistic options for the location of a new nuclear power plant in Lithuania than the proposed sites close to the existing Ignalina NPP. It is essential for the project to utilise existing land use plans and infrastructure. The suitability of the chosen locations is described more in detail in Section 4.1.

Energy saving

The organisation responsible for the project, Lietuvos Energija AB, does not have means to save energy in Lithuania so that the new nuclear power plant or corresponding amount of electricity would not be needed. Thus energy saving will not be investigated as an alternative to the new NPP.

Alternative ways to produce energy

Other options to generate the electricity would be by using other energy sources such as oil products, coal, natural gas, peat, biofuels, hydropower or wind power. However, the nuclear power plant project organisation, and later project company, has been established for constructing and operating a new nuclear power plant in Lithuania and therefore does not have a mandate or possibilities to construct any other kind of power plants. If another company or organisation should begin to develop such power plants, the environmental impacts of them would be assessed as a part of those projects. The purpose and justification of the nuclear power plant project is described more in detail in Chapter 1.

Thus impacts of alternative forms of electricity production in Lithuania have not been assessed in this EIA process. However, the differences between the impacts from other energy generating sources and nuclear power plants on air quality, the emissions of greenhouse gases and other pollutants caused by producing the corresponding amount of energy with other fuels are demonstrated in Section 7.2.2.