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Energy supply options for Lithuania

A detailed multi-sector integrated energy demand, supply and environmental analysis

IAEA
International Atomic Energy Agency

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FOREWORD

Assistance has been provided to Lithuania by the International Atomic Energy Agency (IAEA) under the Technical Co-operation (TC) project entitled Energy Supply Options for Lithuania: A Detailed Multi-Sector Integrated Energy Demand, Supply and Environmental Analysis (LIT/0/004). The project's main objective is to assist Lithuania in developing strategies for sustainable energy development for Lithuania by comprehensively assessing various future energy development paths taking into consideration the closure of Ignalina nuclear power plant, future technological options and environmental regulations.

A Lithuanian study team was created which includes representatives of the following institutions: Lithuanian Energy Institute (LEI), Ministry of Economy, Ministry of Environment, JSC "Lietuvos Energija" and the Department of Statistics. The study team collected the necessary information and data, prepared the modelling database, performed model runs and analysis of the results and drafted the final project report.

The IAEA's support was essentially in term of the provision of methodologies and models, expert service, and training of the Lithuanian counterpart.

This report documents the work conducted and the principal results obtained. The conclusions and recommendations are put forward for further consideration by the responsible authorities of the country regarding future energy system development.

The IAEA wishes to express its gratitude to the whole Lithuanian team for its efforts and contributions to this study. Special thanks are due to V. Miskinis and A. Galinis (Lithuania Energy Institute) who played the key role in carrying out the study, and M. Strubegger (International Institute of Applied System Analysis) for the assistance in supply system modelling and for training national experts to use the MESSAGE model.

The IAEA officers responsible for this publication were D.T. Bui and A.I. Jalal of the Department of Nuclear Energy.

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SUMMARY

Objective of the Study

The Technical Co-operation (TC) project Energy Supply Options for Lithuania: A Detailed Multi-Sector Integrated Energy Demand, Supply and Environmental Analysis (LIT/0/004) was implemented 2001–2002 by a national team with support from the International Atomic Energy Agency (IAEA). The principal objective of the project was to conduct a comprehensive assessment of Lithuania's future energy supply options taking into consideration the early closure of the Ignalina nuclear power plant (Ignalina NPP). Lithuania, a country in transition to full membership of the European Union, has to comply with the energy acquis (Chapter 14). The "acquis communautaire" (the body of common rights and obligations which bind all the Member States together) must be adopted by all applicant countries. Implementing the acquis requires not only adequate legislation, well functioning institutions (e.g. a regulatory body as required in the electricity and gas directives) or schedules for restructuring the energy sector but also measures to enhance energy supply security, improvement of energy networks, efficiency improvements throughout the energy system and compliance with European environmental standards.

Within the overall context of the transition to EU membership, this study focuses on the future development of the electricity sector and the impacts on energy supply security and environmental performance of a closure of Ignalina NPP by 2009, a pre-condition for accession stipulated by the European Union. The project coincided with the preparation of the new National Energy Strategy for Lithuania and therefore was set up to support the strategy formulation process.

Organization of the Study

A project steering committee was established with senior officials from the Ministry of Economy, the Ministry of Environment, JSC "Lietuvos Energija" and the Department of Statistics. The steering committee provided overall guidance and advice, especially with regard to the study's link to the National Energy Strategy and the decommissioning of Ignalina, the review of the results of project activities. The inter-institutional working group comprised technical experts from the above mentioned organizations with the Lithuanian Energy Institute (LEI) playing the lead role including project co-ordination. The main task of the working group was to perform all relevant technical studies, present results to the steering committee and seek advice from it. The working group also prepared this final report.

The IAEA has developed computer tools suitable for comprehensive assessment analyses such as undertaken in this study. The IAEA has also accumulated substantial experiences in conducting integrated analyses of energy system development through the implementation of numerous TC projects. The IAEA's assistance consisted of the provision of computer equipment, energy models and expert services and training of the Lithuanian national counterpart.

Methodology

The comprehensive assessment of different energy development options in Lithuania consists of two parts: (i) the analysis and projection of energy demand and (ii) the optimization of the energy supply system. In this study an integrated, computer aided approach (Figure 1) was used, which includes:

- Estimating plausible scenarios of future demographic and economic development;
- Providing detailed sectoral energy demand projections by applying the MAED simulation model to the scenarios of demographic development and economic growth;
- Formulating feasible scenarios of energy supply and using the MESSAGE model to optimize future energy, electricity and heat supplies for those supply scenarios taking into consideration all known resources, technologies, environmental constraints, as well as the timing of the closure of the Ignalina NPP;
- Carrying out sensitivity analyses with respect to the fuel prices, the discount rate, the investment costs of NPP and other important parameters.

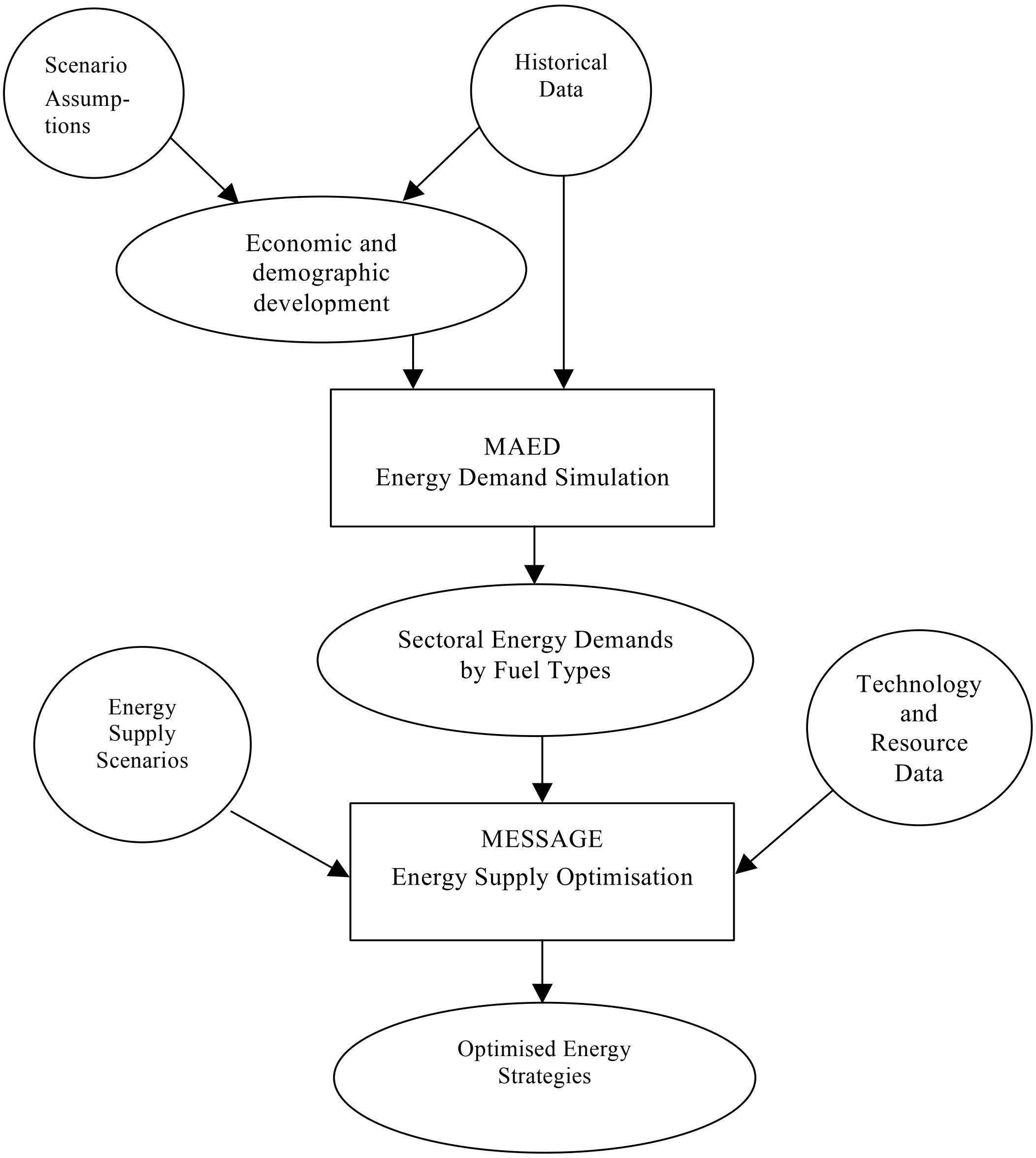


Figure 1. Conceptual Modeling Framework of this Study.

Results

Projected economic growth, structural economic change and the dynamics of sectoral energy intensities are the key drivers of future energy demand. With respect to the economy, three scenarios of GDP growth were considered for the period 2000–2025: (i) the fast economic growth scenario with an average annual GDP growth of 4.6%; (ii) the basic scenario with 3.7% per annum; (iii) and the slow economic growth scenario with 2.6% per annum. The structural changes assumed to take place within the economy for each scenario are presented in Table S.1.

Table 1. GDP Structure by Scenarios (%)

	2000	2005	2010	2015	2020	2025
Slow growth scenario						
Manufacturing	21.48	21.10	21.05	21.00	20.95	20.90
Construction	5.69	6.30	6.25	6.20	6.15	
Agriculture	10.88	11.00	10.90	10.85	10.80	10.75
Mining	0.83	0.50	0.52	0.54	0.56	0.58
Energy	3.33	3.40	3.45	3.50	3.55	3.50
Services	57.78	57.70	57.83	57.91	57.99	58.17
Basic scenario						
Manufacturing	21.48	21.65	21.85	22.05	22.20	22.35
Construction	5.69	6.30	6.40	6.50	6.60	6.70
Agriculture	10.88	10.70	10.40	10.20	9.90	9.70
Mining	0.83	0.82	0.84	0.86	0.88	0.90
Energy	3.33	3.30	3.27	3.24	3.20	3.16
Services	57.78	57.23	57.24	57.15	57.22	57.19
Fast growth scenario						
Manufacturing	21.48	21.75	22.10	22.40	22.70	23.00
Construction	5.69	6.20	6.30	6.40	6.40	6.40
Agriculture	10.88	10.25	9.70	9.20	8.70	8.20
Mining	0.83	0.82	0.84	0.86	0.88	0.90
Energy	3.33	3.30	3.20	3.10	3.00	3.00
Services	57.78	57.70	57.85	58.02	58.30	58.48

Final energy demand, broken down by economic sector and fuel, is shown in Table S.2. Throughout the study period, the Household and Transport sectors have been identified as the two biggest energy users, with each accounting for about 30% of the total energy demand in 2025. However, Industry is the sector with the highest rate of growth. Industrial energy demand will more than double from 2000 to 2025. With the Transport sector being the largest demand sector, demand for motor fuels generally assumes the largest share in total energy demand. As for the Household sector, demands for electricity as well as for district heat increase at above average rates. The energy demand projected by MAED served as input for the energy supply system optimization based on the MESSAGE model. Other inputs to the optimization process included:

- Description of the existing energy supply system and associated infrastructures for oil and oil products, natural gas, other fuels, electricity and heat;
- Techno-economic and environmental characteristics of all energy technologies and processes of the national energy supply system as well as the technology candidates potentially available in the future;
- Energy trade, i.e. oil and oil products, coal, natural gas and electricity;
- Environmental protection requirements stipulated in the EU Directives for sulphur control and Kyoto commitment.

Table 2. Energy Demand by Year, MW/a

	2000	2005	2010	2015	2020	2025
Sectoral breakdown						
Industry	754.9	1065.3	1257.1	1380.3	1531.0	1700.1
Construction	42.2	55.5	68.4	77.7	88.1	100.0
Agriculture	98.1	125.3	148.2	163.0	177.4	195.0
Transport	1051.5	1252.9	1458.0	1621.7	1789.0	1964.9
Household	1348.5	1613.2	1707.4	1804.6	1894.8	1989.5
Services	490.4	546.9	609.4	656.7	707.0	752.3
Total	3785.6	4659.1	5248.4	5704.0	6187.4	6701.7
Fuel breakdown						
Motor fuel	1204.3	1426.5	1648.0	1822.8	2002.2	2192.5
Electricity	532.9	668.4	812.5	930.3	1057.7	1192.9
Fossil fuels for thermal uses	1200.7	1558.5	1696.5	1796.2	1912.1	2037.7
District heat	847.7	1005.6	1091.5	1154.6	1215.4	1278.6
Total	3785.6	4659.1	5248.4	5704.0	6187.4	6701.7

Supply scenarios were designed and corresponding analyses were carried out to address “what … if…” types of questions. The main options are characterized as follows:

Scenario	WHAT would be the future energy supply sector in Lithuania and WHAT would be its associated economic and environmental implications IF the first unit of Ignalina NPP will be closed in 2004 and the Unit 2 will be closed in 2009 and in addition the following conditions apply?
1	No special constraints on other existing and future technologies
2	Construction of new CCGT units at the site of the Lithuanian TPP is not allowed.
3	A new NPP with capacity of 600 MW to be brought on line in 2010.
4	A new NPP with capacity of 600 MW to be brought on line in 2015
5	A new NPP with capacity of 600 MW to be brought on line in 2015. Electricity import during 2010–2015 is not possible.
6	A new NPP with capacity of 600 MW to be brought on line in 2015 and modernization of the Lithuanian TPP will start thereafter

In addition to the main scenarios as listed above, several scenarios were developed in order to assess the sensitivity of the optimal strategies with respect to important parameters, such as: discount rate, fuel prices, investment costs and unit size of a new candidate NPP, and hypothetical possibility of keeping Unit 2 in operation until 2017.

Sensitivity analysis with respect to	WHAT would the optimal supply sector in Lithuania change IF the following conditions apply ?
Operation time of Unit 2 Ignalina	Scenario 1 + Unit 2 of Ignalina to be in operation until 2017
Capital investment of new NPP	Scenario 3 + Investment of 1000 US$/kW versus 1500 US$/kW
Discount rate	Scenario 3 + Investment of 1000 US$/kW versus 1500 US$/kW, with discount rate of 6% and 10% Scenario 1 + discount rate of 6% versus 10%
Unit size of new NPP	Scenario 3 + unit capacity of 1000 MW versus 600 MW
Fuel prices	Scenario 1 + higher fuel prices

The total discounted costs for the least cost development strategy associated with each scenario is shown in Figure 2. An analysis of scenario results distinguishes among three future development paths, namely:

- "Fossil fuel based" development of the electricity sector represented by scenario 1 and scenario 2;
- "Immediate nuclear" development of the electricity sector with an immediate replacement of the Ignalina NPP by a new NPP, represented by scenario 3; and
- "Postponed nuclear" development of the electricity sector with postponed commissioning of a new NPP until 2015, represented by scenarios 4–6.

Scenarios characterized by "fossil fuel based" development entailed the lowest total discounted system costs – about US$ 60–84 million lower than the "postponed nuclear" scenarios; and US$ 160–170 million lower than the "immediate nuclear" scenario. Investment costs for the nuclear scenarios are US$ 600–740 million higher than the "fossil fuel based" scenarios, while the highest O&M costs, including fuel costs, occur in the "fossil fuel based" scenarios, which is about US$ 300 million higher than the "postponed nuclear" scenarios and US$ 600 million higher than the "immediate nuclear" scenario.

Another important finding concerns the level of fuel diversity pertaining to scenarios in this study. For scenario 1, beginning in 2010, over 50% of the total fuel consumption used for electricity and district heat generation will come from natural gas without the possibility of switching to other fuels due to the structure of power plants and environmental limitations.

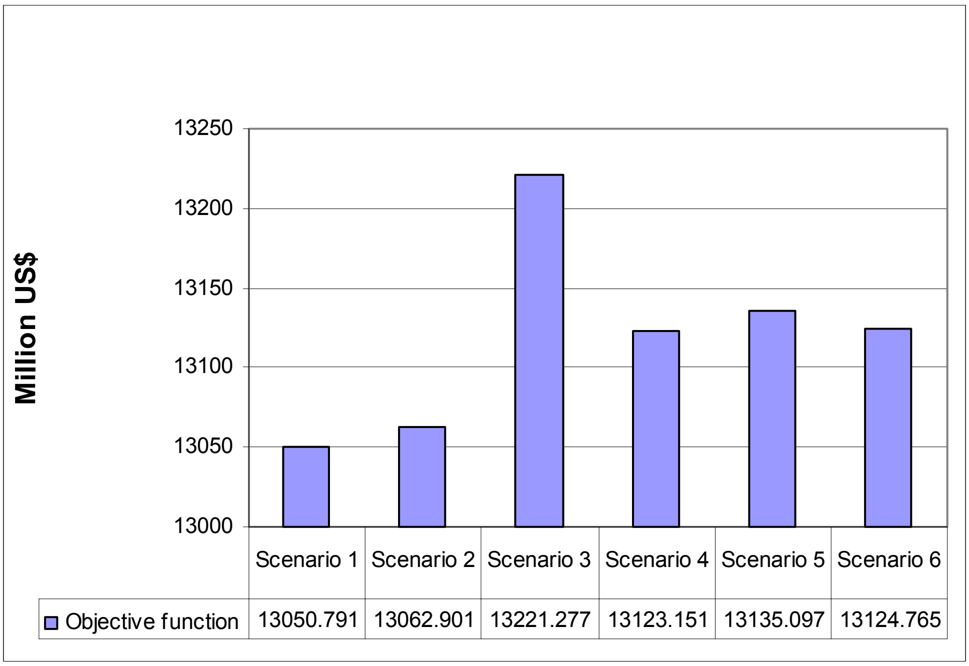


Figure 2. Comparison of Total Discounted Costs by Scenarios.

This situation poses a supply security risk as natural gas is imported from a single source. Scenario 2, where the Ignalina NPP is replaced by the modernization of the Lithuanian TPP, is much less dependent on natural gas supply since the Lithuanian TPP can be adapted to burn natural gas, heavy fuel oil, orimulsion or a combination of these fuels. For nuclear scenarios 3–6, the fuels to be used for electricity and heat generation are more diversified, with nuclear sharing – 25%; gas – 35%; oil and orimulsion – 30% of the total fuel consumption at the end of the study period. However, for these scenarios, power plants are more tightly linked to one or another fuel type in comparison with scenario 2. This means that they have less flexibility in selecting fuel types or suppliers and for negotiation of fuel prices.

For all scenarios the level of CO_2 emissions does not violate the requirement of the Kyoto Protocol throughout the study period. There is an annual margin of 9.7 – 13.8 million tons by 2025. A higher CO_2 reserve margin is naturally related with the nuclear scenarios and without large involvement of the Lithuanian TPP in electricity production. On the other hand, after the decommissioning of the Unit 2 of the Ignalina NPP, emissions of CO_2 increase by 4.0 – 5.5 million tons in the “fossil fuel based” scenarios versus about 1.7 million tons in the nuclear scenarios.

The level of SO_2 emissions is practically stable and independent of the scenarios. This is a result of the compliance with the EU Directive 2001/80/EC, which mandates that all power plants must be equipped with flue gas desulphurization or switch to natural gas. The stabilization of SO_2 emissions was achieved either by the installation of FGD technologies, by increasing dependence on natural gas or by extended use of nuclear energy. The NO_x emissions level is expected to more than double by the end of the study period. However, for all scenarios analyzed, NO_x emissions will remain below the Gothenburg protocol’s requirement, corresponding to 70% of the 1990 emission level.

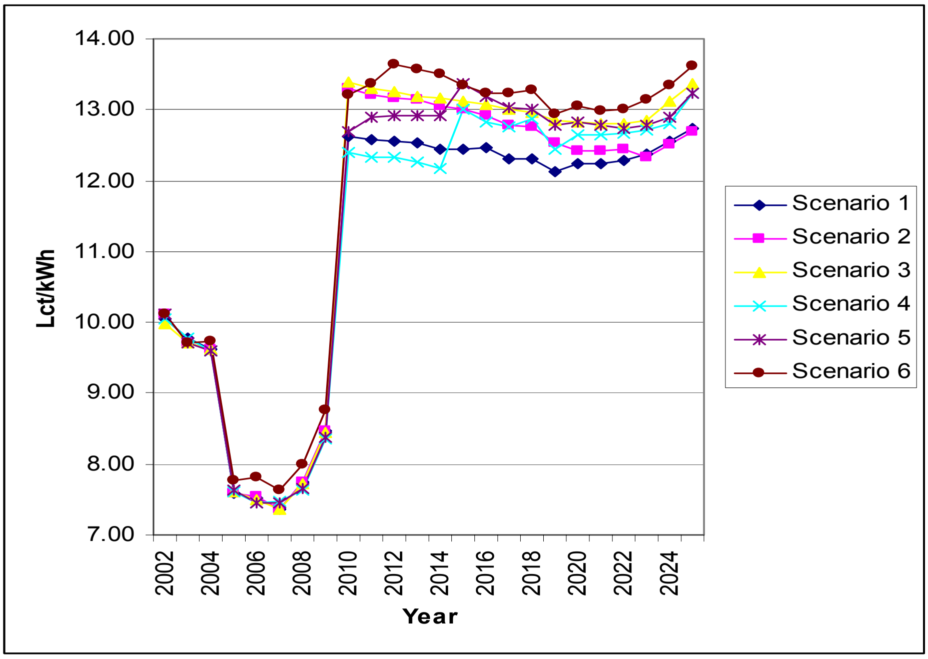


Figure 3. Evolution of Electricity Production Cost by Scenarios.

The evolution of the average electricity production cost is shown in the Figure 3. It is important to note that the closure of Unit 2 of the Ignalina NPP results in an increased cost of electricity production amounting to 2.5 – 3.5 Lct/kW·h above the cost in 2002. After closing Unit 2 of the Ignalina NPP, the average electricity production costs range between 12.1 and 13.7 Lct/kW·h. The lowest electricity production cost is observed in scenario 1, which envisages the construction of new CCGT units at the site of the Lithuanian TPP. The lower production cost in this scenario is possible due to the low investment costs and high efficiency of the new CCGT and CHPs, as well as their high utilization rates resulting from comparatively low O&M costs. Electricity production costs in nuclear scenarios 3 and 6 tend to be higher in comparison with those in fossil fuel scenarios. From 2010 onward, electricity production costs in scenario 3 will be higher than that of scenario 1 by 0.46–0.76 Lct/kW·h. These higher costs can be explained by the higher investments associated with the "immediate nuclear" scenario. However, the cost difference between nuclear and fossil fuel scenarios is not very significant because of the modest size of the new nuclear power plant (600 MW).

From a technical perspective, Unit 2 of the Ignalina NPP can be kept in operation until 2018. The sensitivity analysis of a hypothetical scenario, considering operating Unit 2 up to the end of 2017, shows a savings in total discounted costs of about US$ 390 million compared with closure of Unit 2 in 2009 (e.g. scenarios 1 and 2). This is a result of savings from investment costs, fixed and variable O&M costs, with the highest contribution from the latter. Another aspect concerning the prolongation of operation of Unit 2 is the possibility of accumulating the necessary decommissioning fund. Early closure of Unit 2 requires additional funding of US$ 600–822 million given that a total of about US$ 1000 million is required for the decommissioning of the Ignalina NPP. Extending the operation of Unit 2 would significantly mitigate this problem by enabling the power plant itself to contribute to the decommissioning fund through revenues obtained from the sale of electricity.

The economic competitiveness of nuclear power is another interesting aspect for sensitivity analysis. Using the terminology defined in this study: a higher total discounted cost relative to scenario 1 is considered to be a "loss" and similarly a lower total discounted cost a "gain". It was found that in the case of a 10% discount rate, new NPPs with an investment cost of 1500 US$/kW would entail a "loss" of US$ 170 million, while an investment cost of 1000 US$/kW would result in a lower "loss" (US$ 46 million). The discount rate also played a role – at 6% discount rate 1000 US$/kW would bring a "gain" of US$ 29 million. This is because a lower discount rate favours investments with high up-front payments and corresponding lower operating costs. In order to make the total cost of scenarios 1 and 3 comparable, with a discount rate of 10%, the investment cost for NPPs should not exceed US$ 800/kW, and in the case of a 6% discount rate, the investment cost should be under 1100 US$/kW.

Conclusions

The guiding principle in carrying out the analyses of this study is to provide, to the extent possible, quantitative information on the prospects of different future scenarios of the energy system development in Lithuania. The findings of this study allow the following conclusions to be drawn:

Between 2000 and 2025 final energy demand in Lithuania is expected to grow on average by 2.3% per annum in the basic scenario and by 2.9% in the fast economic growth scenario. At the same time electricity demand will grow faster – by 2.9% per annum in the basic scenario and by 3.7% in the fast economic growth scenario. In the latter case, electricity demand would increase by 2.5 times over the study period and, by 2025, per capita electricity use will be similar to the present average per capita level in the European Union.

In case of the scheduled closure of the Ignalina NPP in 2009, it will not be possible to accumulate the necessary financial means to cover the cost of decommissioning the power plant. Additional funds of about US$ 600–822 million will be required if Unit 1 of the

Ignalina NPP will be closed at the end of 2004 and Unit 2 at the end of 2009. If Unit 2 of the Ignalina NPP would remain in operation until the end of 2017, the power plant itself would be able to produce the necessary financial means for its decommissioning through revenues obtained from the sale of electricity.

In order to meet the growing electricity demand in Lithuania and to compensate for the loss of generating capacity due to closing of the Ignalina NPP, it would be reasonable to use (in order of economic preference): existing CHPs in combined heat and electricity production mode; new CHPs in combined heat and electricity production mode; new CCGT units at the site of the Lithuanian TPP; modernized 300 MW units at the Lithuanian TPP; new CCGT units at the site of the Ignalina NPP; new CCGT units at a new site; new nuclear units. The actual contribution of these candidates will depend on the level of future final energy demand in the country and on national energy policy options related to energy supply security.

Table S.3 shows the electricity generating capacity mix by plant required to meet the internal Lithuanian electricity demand in 2025 (basic demand scenario with constant fuel prices and a 10% discount rate).

Replacing the Ignalina NPP with a new nuclear power plant would cause the highest total discounted costs among all evaluated scenarios. Compared with the fossil fuel scenarios, a new nuclear power plant starting operation right after the closure of Ignalina-2 in 2009 would require additional funds of US$ 158–170 million (assuming basic demand growth scenario, investment costs of 1500 US$/kW for a new nuclear plant, 10% discount rate).

If the commissioning of a new nuclear power plant occurred in 2015, total discounted system costs will be US$ 60–84 million higher than the total system costs of the fossil fuel based scenarios. Delaying the construction of a new NPP effectively lowers the difference in total discounted costs.

Table 3. Power Plant Capacity Utilization in 2015 by Scenarios, MW

	Fossil fuel scenarios	**Nuclear scenario**	**Postponed nuclear scenarios**
Lithuanian TPP	1500	1370	900–1800
Existing CHP	800–820	790	700–790
New CHP	400–450	390	340–370
New CCGT	680–600	600	600–160
New nuclear PP	0	600	600
Hydro & HPSPP	914	914	914
Wind PP	180	180	180
Import	0	0	580–0
Total	**4474-4464**	**4844**	**4814**

The construction of a new nuclear power plant is an economically attractive option in Lithuania if the investment costs are below 820 US$/kW, with a 10% discount rate, or 1100 $/kW for a 6% discount rate. Low discount rates coupled with low investment costs make the replacement of the Ignalina NPP by a new NPP a competitive option in comparison with scenarios that are based on fossil fuel based power plants and constant international oil and gas market prices through 2025.

Average electricity production costs in the Lithuanian power system may decrease after closure of Unit 1 of the Ignalina NPP if the payment of the fixed O&M cost related to that unit can be avoided. After the closure of Unit 2, average electricity production costs increase by 2.5 – 3.5 Lct/kW·h relative to the price in year 2002. The smallest rise of electricity production costs is observed in the case when new CCGT units are constructed at the site of the Lithuanian TPP. The largest increase is associated with the construction of a new nuclear unit of 600 MW. Average electricity production costs after the closure of the Ignalina NPP range between 12.1 and 13.7 Lct/kW·h (for scenario with basic electricity demand, 10% discount rate and constant fuel prices).

Major changes in the heat production structure occur where no previous CHP production capacities exist. Here a fast penetration of new CHPs that replace existing boilers is foreseen. The fastest growth in heat output originates from new CHPs based on biomass and from new small CHPs operating on natural gas. Significant contribution to the heat production arises also from boiler houses converted into CHPs by the installation of steam turbines after steam boilers or additional gas turbines in front of boilers.

1. INTRODUCTION

1.1. Background

The policy for reforms in all sectors of the economy has been stated by the Lithuanian Parliament and Government since the first days of the regained independence in 1990. However, the transition process from a centrally planned economy into a market oriented one after the collapse of the former Soviet Union (FSU) proved to be very difficult. Three essential factors are political will, time and financial resources.

Lithuania has a comparatively modern energy sector. However, its institutional and technical structures, inherited from the past, are not compatible with the typical requirements for a small country. Existing overcapacities in the Lithuanian energy system could be very useful if economies in neighbouring countries are growing. However, Lithuania and its neighbours with transitional economies from former Eastern Block countries (i.e. Latvia, Estonia and Belarus) have experienced deep economic recession. In addition, all sectors of the Lithuanian economy (consumers of energy resources) are characterized by intensive energy use as a result of:

- Very low energy prices that existed for the past several decades;
- Inadequate or non-existent metering and control of energy production and consumption;
- Lack of incentives for energy efficiency.

It is also clear that large financial resources are required for the modernization of the energy sector. The country needs help from the international donors and the banking system. The energy sector in Lithuania requires special attention, because:

- Success of the transformation process depends very much on energy efficiency and security of energy supply;
- Integration of the energy systems with those of the Western countries could play a very important role in the whole integration process of Lithuania into the European Union.

Since 1990, Lithuania has experienced changes in the management and in the infrastructure of economy and of the energy sector. For instance, the Energy Law, the legal framework for a new energy structure, was adopted in 1995 and updated in 2002. Various studies related to future development of the energy sector have been prepared. Some positive changes in collection of data necessary for energy planning have resulted along with experience. Nevertheless this study of the Lithuanian energy sector development using methodology based on principles of market economy is extremely important.

This study, Energy Supply Options for Lithuania — A Detailed Multi-Sector Integrated Energy Demand, Supply and Environmental Analysis, sets out to determine future final and primary energy demand in major sectors of the national economy taking into consideration the conditions of the country in transition with special attention to the requirements of the accession into the European Union. The study is conducted by the Lithuanian Energy Institute and the Ministry of Economy under the IAEA's Technical Co-operation project LIT/0/004. The present report describes the study conducted in the framework of the overall programme for preparation of the National Energy Strategy for Lithuania. It was fulfilled in co-operation with experts from the Ministry of Economy, the Joint Stock Company "Lietuvos Energija" and other institutions.

1.2. Purpose and Scope of the Study

In line with other IAEA technical co-operation projects, this study has been undertaken as a joint effort of the Lithuanian Republic and the IAEA. Each side assumed clear and well established responsibilities:

- The Lithuanian team had full responsibility for preparation of the study, including data collection, analysis and preparation of necessary information, execution of the computer runs, interpretation and improvement of results and finally for preparation of the draft report of the study;
- The IAEA experts provided guidance and coordination of the study as well as expertise of the initial data and results; another important task of the IAEA experts was to provide on-the-job training on the use of the MAED and MESSAGE models, to transfer knowledge and experience to the counterparts and the necessary methodologies and computer planning tools to Lithuania.

This division of tasks and responsibilities was set up so that at the end of the study energy planners and experts in Lithuania would have acquired sufficient experience in the use of methodologies and tools provided by the IAEA and could utilize them independently for execution of future energy planning studies.

1.3. Objectives of the Study

The study has the following major objectives:

- To implement systematic energy planning procedures in Lithuania;
- To prepare a comprehensive modelling system for analysis of energy production and energy consumption sectors;
- To perform an analysis of competitiveness of nuclear power in comparison with other sources of electricity generation;
- To perform a detailed analysis of the Lithuanian energy sector development and related environmental issues;
- To increase the number of specialists, able to use modern tools for energy planning.

Within this TC project Lithuania has received two complete personal computer configurations, which have been dedicated to the energy planning studies and analyses.

1.4. Organization of the Study

The implementation of the MAED and MESSAGE model for the study in Lithuania was carried out by experts from the Lithuanian Energy Institute (LEI) and the Ministry of Economy. Other participants involved in this study are from the Joint Stock Company "Lietuvos Energija", the Department of Statistics and the Kaunas University of Technology. Their contribution is related to the analysis of initial data necessary for runs of the models and assessment of future development of social, economical and technological indicators and parameters.

LEI provided overall coordination of the national institutions and liaised with IAEA and its experts. LEI was also responsible for execution of the energy modelling using the MAED model (for energy demand projection) and MESSAGE model (for energy supply analysis) as well as for the preparation of the project report. Within the project team, there were two levels of responsibilities: the steering group and the Working Group (Table 1.1).

Table1.1. Members of the Steering Group and the Working Group

Name	**Institution**	**Position**
A. Steering Group		
1. Mr. Faustas Juska	Ministry of Economy	Head of department
2. Mr. Jurgis Vilemas	Lithuanian Energy Institute	Director
3. Mr. Virgilijus Zukauskas	JSC "Lietuvos energija"	Head of department
4. Mr. Birute Teskeviciene	Ministry of Economy	Head of department
5. Mr. Vytautas Krusinskas	Ministry of Environment	Head of department
6. Mr. Arvydas Andreikenas	Department of Statistics	Head of department
B. Working Group		
1. Mr. Vaclovas Miskinis	Lithuanian Energy Institute	Head of laboratory
2. Mr. Arvydas Galinis	Lithuanian Energy Institute	Senior research associate
3. Mrs. Inga Konstantinaviciute	Lithuanian Energy Institute	Research associate
4. Mr. Egidijus Norvaisa	Lithuanian Energy Institute	Post-graduate student
5. Mrs. Janina Danaitiene	Ministry of Economy	Senior expert
6. Mr. Mindaugas Ziukas	Ministry of Economy	Senior expert
7. Mr. Rimas Rutkauskas	JSC "Lietuvos energija"	Engineer
8. Mrs. Natasa Golovanova	Department of Statistics	Senior expert

The steering group was responsible for providing general guidelines for this study. The working group carried out the analytical work and was responsible for the preparation of the draft final report in close co-operation with the IAEA experts.

1.5. Methodological Description

1.5.1. MAED Model

For Lithuania, like many countries with an economy in transition and characterized by drastic changes in economic activities and thus energy consumption, the use of time-series methods for extrapolating past trends of energy consumption into a future trend cannot be applied. In those countries, when projecting future energy demand it is necessary to analyze the evolution of many factors that determine energy consumption. Some of these factors reflect the state of the economy and GDP growth, as well as its structural changes, the dynamics of production in economic sectors, and changes in living conditions, etc. Other factors assess the implementation of new technologies, the effect of substituting one energy form with another, and the penetration of more efficient equipment. In the principle, these factors may complement or counteract each other in determining future energy demand.

Taking into account the particular condition of countries in transition in relation to energy demand evolution, the Model for Analysis of Energy Demand (MAED) [1], a model based on the techno-sectoral and scenario approach can be the best tool to be applied in this study. The methodology of energy demand forecasting employed in MAED is based on the establishment of interrelationships of economic development and structural changes, technological advancement and lifestyle with the demand for different energy forms in the long term future. The MAED model allows for the differentiation between energy demand for specific uses and substitutable energy demands; thus the user can analyze the competition between energy carriers. Further, the MAED allows the evolution of technological parameters of equipment and appliances at final consumers to be taken into account.

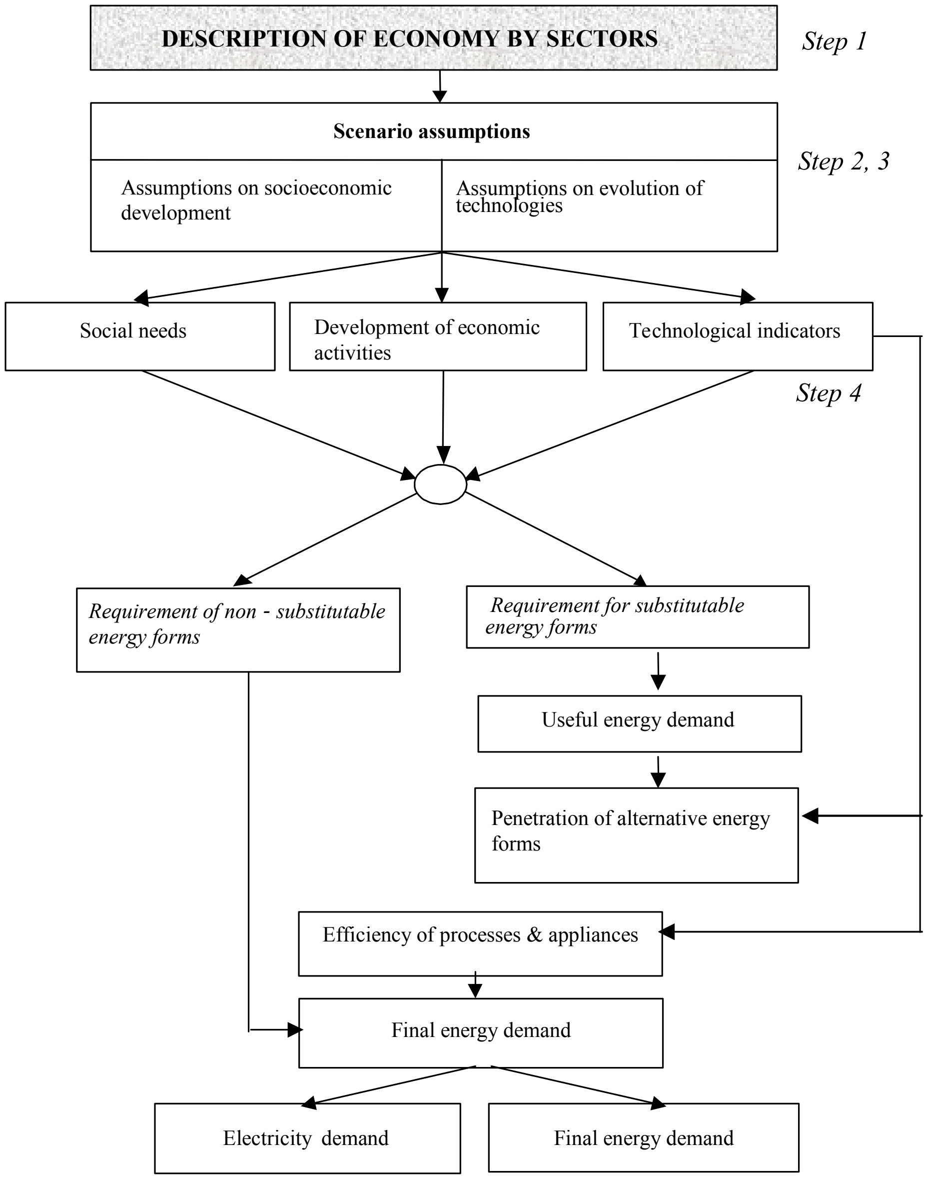


Figure 1.1. Aggregated Scheme of the MAED Model.

The analysis and projection of future energy and electricity demand using MAED involves four main steps (Fig. 1.1). In the first step of energy demand modelling, the total final energy consumption is disaggregated into consumption by economic sectors e.g. industrial sector, transport sector, household and service sector. The energy consumption in the industrial sector is further subdivided into consumptions by manufacturing, construction and agriculture. For each sector, energy consumption is further categorized into specific energies (non-substitutable) and substitutable energies.

Following this categorization, for each end use category a set of important factors influencing energy demand can be identified in the second step. These factors, so-called determinants are the following: GDP growth rates and changes of GDP structure, growth of population and its distribution in the country, changes in living standards, growth of population mobility, freight and passenger transportation, and market penetration of competing energy forms. In the third step — scenario writing — a set of scenarios, each consistently reflecting the future evolution of the energy determinants, is prepared.

The fourth step involves the establishment of the relationships (in quantitative and qualitative terms) between the level of energy demand and the social, economic and technological factors identified above for each end use category. Based on these relationships, final energy and electricity demands would be calculated.

1.5.2. The MESSAGE Model

The analysis of the Lithuanian energy supply system is carried out using the MESSAGE model [2]. In MESSAGE, the whole energy supply system is represented as an oriented network of technologies and activities, starting from extraction or supply of primary energy, passing through energy conversion processes (e.g. electricity generation), to transmission and distribution to meet the given demand for final energy in the industry, transportation, household and service sectors. In this oriented energy network the links represent technologies or transportation and allocation processes of energy whilst the nodes represent energy forms (e.g. electricity, oil and gas). Both existing technologies and candidate technologies for future system expansion are included in the network. Technologies are represented by a set of parameters such as investment costs, fixed and variable costs, energy conversion efficiencies, historical capacities, availability factors, emission factors and others.

The mathematical method used in the MESSAGE model is linear programming, which means that all technical and economic relations describing the energy system are expressed in terms of linear functions. The optimization criterion of the MESSAGE model is the minimization of the present value of the cumulated costs of the energy system throughout the planning period [2]. The planning period is user-defined. In this study, a medium term time scope of 25 years is chosen. Moreover, it is important to note that in this study, the cost optimization refers to real energy production and transformation costs of the Lithuanian energy system rather than to energy prices (with the exception of energy import).

The decision variables in the model optimization are energy flows and capacities of technologies. The model variables are determined subject to a system of constraints, representing structural and technological properties of the energy system, existing stock of equipment, projected energy demand, energy policies and environmental protection policies etc.

As a result of the optimization of using the MESSAGE model a least-cost intertemporal mix of energy supply technologies can be found. By analyzing the results, answers to the "what… if…?" type of questions can be proposed. Strategies for future energy supply structure can be formulated, and different emission control strategies can be compared with respect to their emission reduction efficiencies and their impact on structure and economic performance of the energy system.

2. COUNTRY PROFILE

Lithuania is the largest of the three Baltic States. It shares borders with Latvia, Belarus, Poland, the Kaliningrad region of the Russian Federation and the coastline (Fig. 2.1). The total area of Lithuania is 65 300 square kilometres with a population of 3.5 million.

For half a century Lithuania was fully integrated into the Former Soviet Union (FSU). As a Republic of the FSU, Lithuania operated within a centrally planned economy where all Republics developed their economies to meet the requirements of the common economy of the FSU. On 11 March 1990, Lithuania announced its independence from the Former Soviet Union. This historical decision was made by the Lithuanian Parliament (the Highest Council of the Republic of Lithuania). Following the collapse of the FSU, economic recession in the former FSU Republics was much deeper than in other Central and East European countries. As such, the difficulties associated with transition to a free market economy in Lithuania have been more severe than for other countries of Eastern Europe.

In October 1992 Lithuania approved a new constitution by referendum. A parliamentary system was introduced with President as the head of state, who is elected for a five-year period by direct voting. The Lithuanian Seimas (Parliament) comprises 141 members elected for a four-year period. The Prime Minister is appointed or relieved of his/her post by the President with the consent of the Seimas.

During the 1995 reform, 44 local districts were joined into 10 counties, each being governed by a county governor appointed by the Government. Local self-government is formed according to the Lithuanian administrative territorial division. There are 56 municipalities. The highest self-government institutions are municipality councils elected by direct voting. The main functions of local authorities are to oversee the development of the municipal economy, social security and public health services and education.

Lithuania is now experiencing rapid internal and external changes. One of the main domestic policy objectives is the establishment of an independent economic system and the introduction of a free market mechanism instead of a centrally planned economy. One of the major foreign policy goals is the integration into the European Union (EU), NATO and other Western organizations. In November 2002 Lithuania was invited to join NATO, and in December 2002 to become a member of the EU. In general the country is ready to continue the harmonization of legal, economical and technical standards and practices prevalent in the EU. In line with integration into the EU it is very important to use methodologies based on principles of a market economy to study future conditions and development of the Lithuanian energy sector.

2.1. Geography, Location and Climate

Geographically, Lithuania is situated in the centre of Europe. The point indicating this centre is 20 km to the north of Vilnius, the capital of Lithuania. However, from a geopolitical point of view the country is considered to be part of Eastern Europe. The total length of its land borders is 1747 km. Compared to other Baltic States, Lithuania has the shortest border with the Baltic Sea coast (99 km).

Figure 2.1 Geographical Location of Lithuania.

Lithuania is considered as a country of plains. However, because of its rich variety of scenery, stimulating contrasts can be found within short distances. There are two elevated regions: the Aukstaiciai Highlands and the Zemaiciai Highlands, and three plains: the Pajuris Lowland, the Central Plain and the Eastern Lowland. The mean absolute surface altitude is 100 m above sea level; the highest point (294 m) is in the east of the country. Geology in Lithuania was considerably influenced by the last European glacial epoch. Therefore, Lithuania is rich in mineral and sedimentary rocks, such as, anhydride, dolomite, limestone, clay, sand, gravel and gypsum as well as chalk, oil, mineral water, etc.

Lithuania has 758 rivers that are longer than 10 km. The longest one is the Nemunas, with a length of 937 km. There are 2834 lakes that are larger than 0.5 ha. The biggest one is Lake Druksiai (4479 ha, 33.3 m deep). Forests cover 31.2% of the country's territory; pine (36%), fir (23%) and birch (20%) stands prevail in Lithuania. Wetlands cover about 7% of the total area.

In Lithuania, a coastal area marine climate prevails in the west and central part. The climate gradually becomes continental moving from eastward. Due to the influence of west winds, summers are moderately warm, 80% air humidity predominates. During the wintertime, permanent snow cover is formed. Average temperature in January is – 4.9°C and in July it is +17.2°C. Average annual precipitation varies from 540 to 930 mm.

2.2. Past and Projected Population

The population of Lithuania has grown from 2.8 million at the beginning of the last century to 3.5 million at present. Different nationalities live in Lithuania: Lithuanians (83.5 percent), Russians, Polish, Belorussians, Ukrainians, Tartars, Jews and people of other nationalities (Fig. 2.2). Approximately 67 percent of the population live in urban areas and 33 percent live in rural areas.

The capital of Lithuania is Vilnius; its population is nearly 550 000. According to the Constitution of Lithuania, the Lithuanian language is the official state language. By origin and language, Lithuanians belong to the Baltic group of the Indo-European family of nations. Best of all current Indo-European languages, the Lithuanian language retained the old sound system and most of the specific morphological features. Standard Lithuanian started to form in the middle of the 16th century. In 1547 Mazvydas published the first Lithuanian book in Karaliaucius.

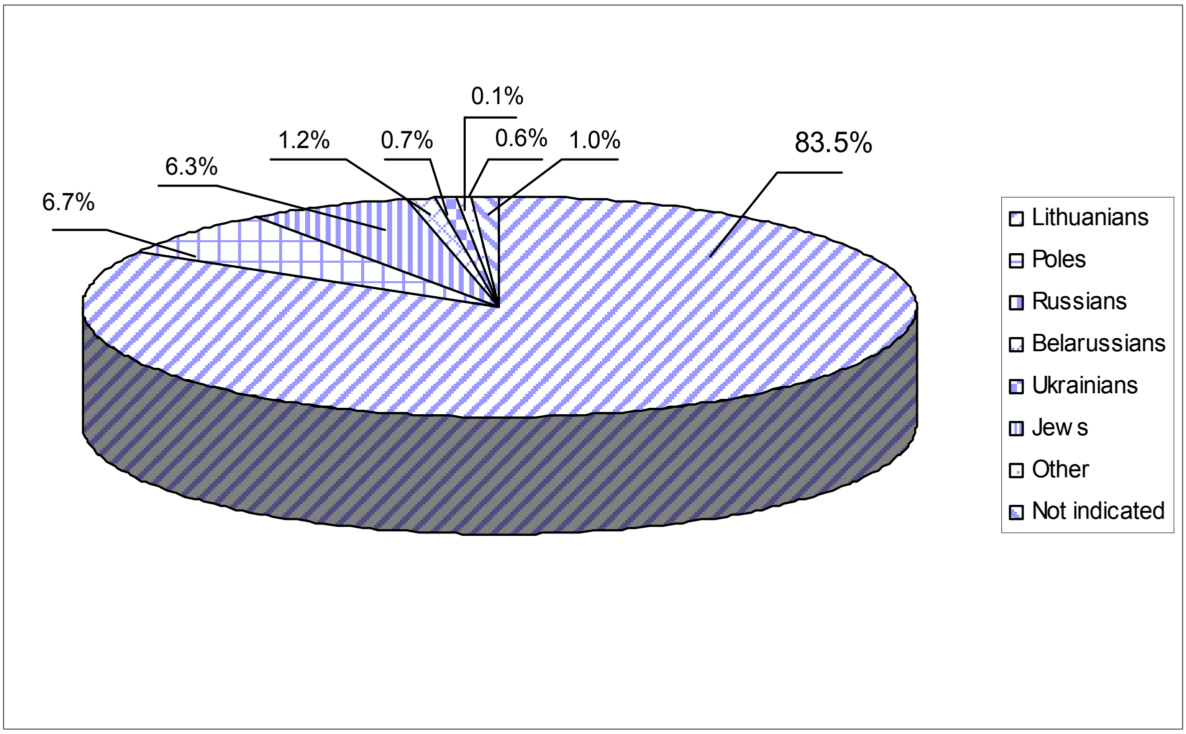


Figure 2.2 Structure of Population in Lithuania [4].

The majority of Lithuania's Polish inhabitants reside along the southeastern border between Lithuania and Belarus. Most of the current local inhabitants are descendants of ethnic Lithuanians who were settled in the 19th and 20th centuries. Approximately 50 percent of the Poles live in rural areas. The majority of them speak Polish, as well as a dialect of the Belorussian language. A portion of them has adopted Russian as their primary language. The majority of Lithuania's Russians live in urban areas.

By religion, the majority of Lithuanian residents are Roman Catholics. Moreover, Evangelical Lutherans, Evangelical Reformats, Orthodox, Old Believers, Catholics of eastern rituals, Muslims, Judaic believers, Kharaims are traditional religious communities.

According to the 2001 Census results prepared by the Lithuanian Department of Statistics, the population in Lithuania has decreased by 190 800 since the 1989 Census. Natural increase made up 33 700 people and negative net migration was 224 500 (Table 2.1).

Table 2.1. Development of Population, million [5, 6]

Year	Total	Urban	Rural
1970	3.14	1.58	1.56
1975	3.30	1.86	1.44
1980	3.41	2.10	1.30
1985	3.56	2.35	1.21
1989	3.67	2.48	1.19
1990	3.69	2.51	1.18
1995	3.64	2.46	1.18
2000	3.51	2.37	1.14
2005	3.45	2.31	1.14
2010	3.43	2.30	1.13
2015	3.42	2.29	1.13
2020	3.42	2.29	1.13
2025	3.44	2.30	1.14

2.3. Macroeconomic Situation

During the fifty-year period beginning in 1940, conditions of economy development in Lithuania as one small republic of the FSU were greatly different in comparison to economic conditions in Western Europe. The economy inherited from the past could be characterized by: 1) a high degree of integration within the common system of exchange of goods and energy resources of a large country; 2) dependency on imports of many raw materials and on supply of oil and natural gas mostly from the Russian Federation; 3) specialization in the production of goods for a comparatively closed area within the FSU and the integration of industries; 4) a high share of energy intensive industries and low productivity agriculture serving a large region of the FSU; and 5) low prices of energy resources together with low energy efficiency. These conditions led to deep economic recession in Lithuania when the economy was being transformed to a free market economy.

After the collapse of the FSU all countries that had had centrally planned economies experienced a large reduction in economic activities. However, market oriented economic reforms since the sixties in Central and Eastern European countries remedied in some way their economic decline. Based on the indicators prepared by the International Energy Agency, Gross Domestic Product (GDP) dropped in Slovakia, Romania, Hungary, Slovenia, Czech

Republic and Poland to 79% - 93% of the 1990 level [7]. Reductions of the economic activity in Croatia and Bulgaria were much larger — correspondingly to 65.6% and 73.2% of the 1990 level. In addition, the period of economic slump was comparatively short in these countries. However, in countries of the Commonwealth of Independent States (CIS) processes of transition have been more dramatic and the economic recession was much more severe — GDP dropped in Georgia to 28.8%, in Republic of Moldova — to 33.9%, in Ukraine — to 41.0%, in Belarus — to 65.3 %, in the Russian Federation — to 73.2 % of their respective 1990 levels (Fig. 2.3).

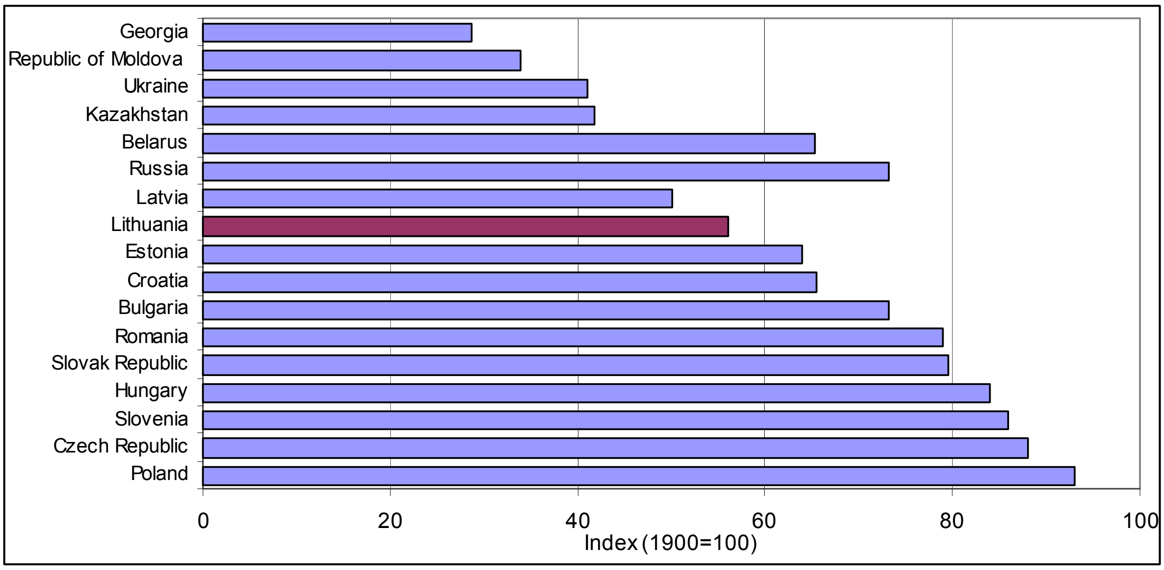


Figure 2.3. Level of Economic Decline in the Former Centrally Planned Economies [7]

The economic slump in Lithuania was less severe than in the majority of CIS countries: at the end of 1994, Lithuanian GDP dropped to 56.1% of the 1990 level [8]. GDP in Lithuania began to increase in 1995 by 3.3% (Fig. 2.4) and continued to increase by 4.7% in 1996, 7.3% in 1997, and 5.1% in 1998. As a consequence of the financial and economic crisis in the Russian Federation, GDP in Lithuania decreased by 3.9% in 1999. However, an analysis of the basic macroeconomic indicators confirms that the Lithuanian economy was able to get out of this crisis and has been recovering. In 2000, GDP climbed by 3.8% and in 2001, according to the provisional estimate, went up by 5.9%. Average GDP growth rate during the period 1995–2001 was 3.7%.

Despite many difficulties during the transition period in Lithuania, steady progress in strengthening the performance of market-supporting institutions and undertaking necessary reforms confirms the possibility of strong and long term economic recovery. This progress could be characterized by several transition indicators, such as a growing share of private sector in the total GDP, an accelerating pace of privatization, price liberalization, the removal of restrictions and tariff barriers on trade and foreign exchange, progress on the creation of competition policy, commercialization and regulation of telecommunications, restructuring of the energy sector, the establishment of bank solvency and liberalization of interest rates, the emergence of non-bank financial institutions, etc.

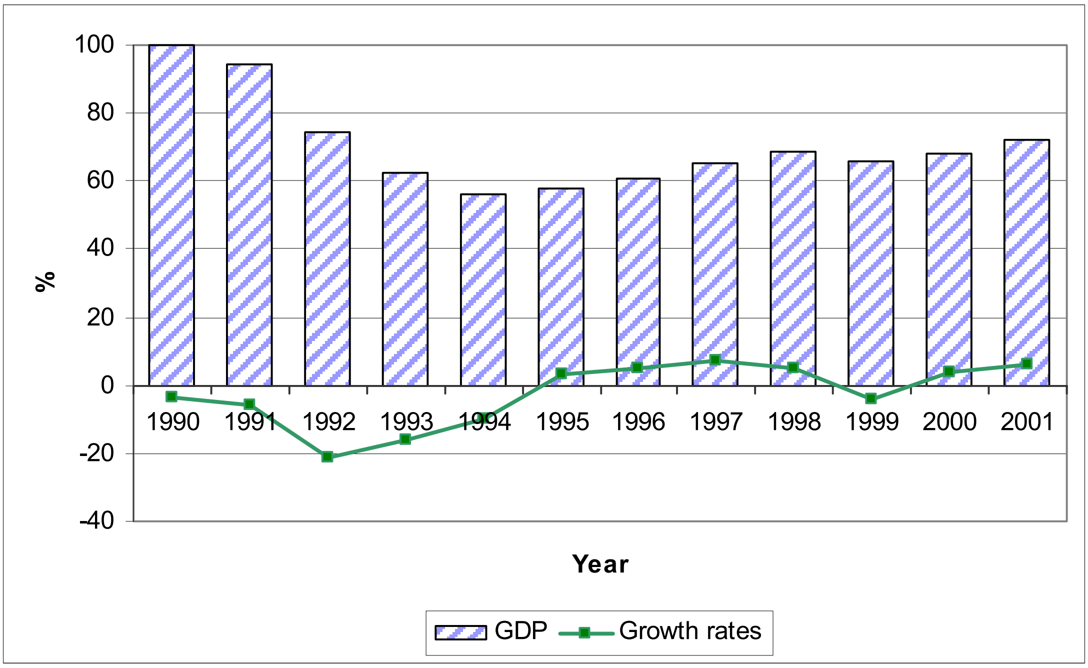


Figure 2.4. Annual Changes in Lithuanian GDP [8].

According to an assessment by the European Bank for Reconstruction and Development (EBRD), Lithuania has achieved significant progress in several important areas of necessary reforms taking into account the four main elements of a market economy – markets and trade, enterprises, infrastructure and financial institutions. The measurement scale for the indicators used for comparing various countries ranges from 1 to 4+, where 1 represents little or no changes from centrally planned economies and 4+ represents the standards and performance of an industrialized market economy. Lithuania was given the highest rate (4+) in two areas: small-scale privatization and the trade and foreign exchange system [9]. In December 2000, the country joined the World Trade Organization and Lithuanian exporters now have the possibility to enter new markets. This will strengthen domestic competition.

Large-scale privatization is also close to completion; substantial progress has been achieved in the commercialization and regulation of the telecommunications sector. A large degree of decentralization and commercialization has taken place in the operation of water and wastewater utilities. According to the assessment of the EBRD, progress of Lithuania in these three areas is measured by the rate 3+. The lowest rate of 2+ is given to the pace of restructuring of the railway and road transport, which is due to the moderate degree of decentralization and only minimal involvement of the private sector in this sector.

Since February 2002, the Lithuanian currency - the Litas (LTL) - has been re-pegged from the US$ to the Euro (3.4528 LTL = 1 EUR). This step was made after seven months of preparation, allowing enough time for the population and enterprises to adjust to the currency composition. At the beginning of transition, however, monetary policy and a stable exchange rate of the national currency with the dollar were important means for the reduction of inflation, especially given the fact that the major part of the external trade was with the CIS. The share of trade with the EU and EU candidate countries has steadily increased in recent years to almost 75% of total export. Therefore the decision of the Lithuanian Central Bank is well founded and it should be helpful to ensure macroeconomic stability.

One of the most important indicators showing the attractiveness of the Lithuanian economy and its openness to developed countries is the growth of foreign investment. Foreign direct investments, according to the international accounting methodology, include:

- A share of enterprise capital which is acquired by a foreign direct investor;
- Reinvested profit, i.e. a share of profit belonging to a direct investor that has not been distributed as dividends but has remained in the enterprise's business;
- Short term and long term loans granted by a direct investor, except the ones borrowed on behalf of the state and under government guarantee;
- Other capital of an enterprise.

At the beginning of 2002, foreign direct investment reached almost 2.7 billion US$ [10]. Until the mid 1990s, the contribution of foreign investors to the development of the Lithuanian economy was very low. Since 1996 it has been growing very quickly — over a 6-year period it has increased almost eightfold (Fig. 2.5).

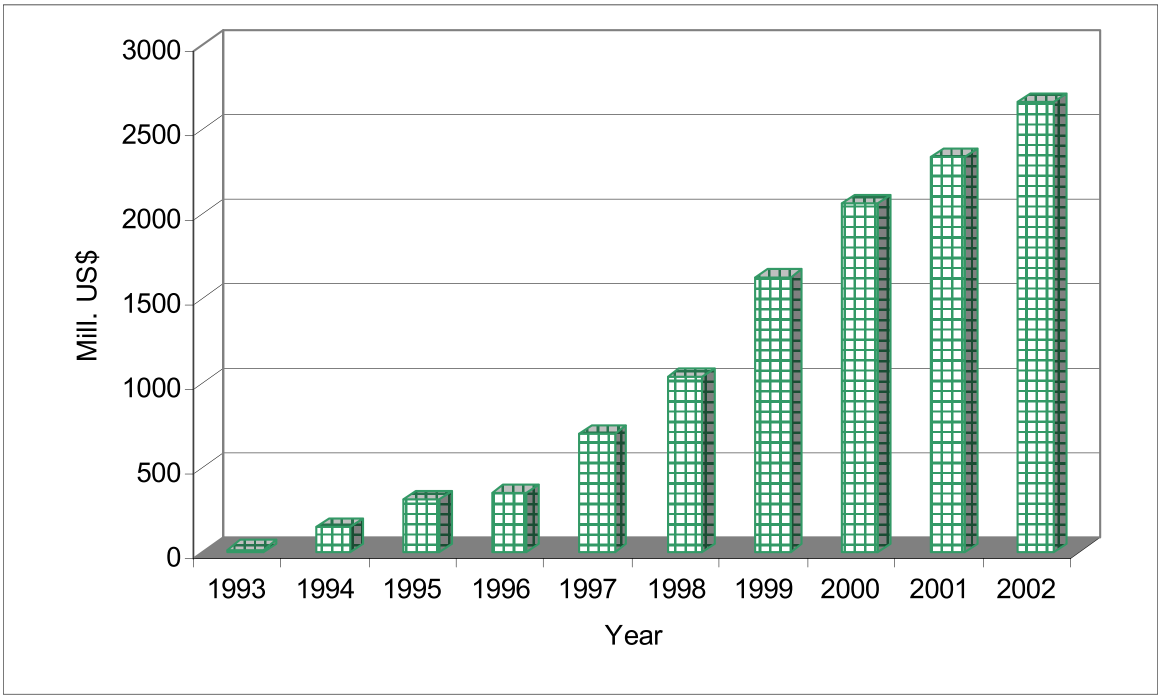
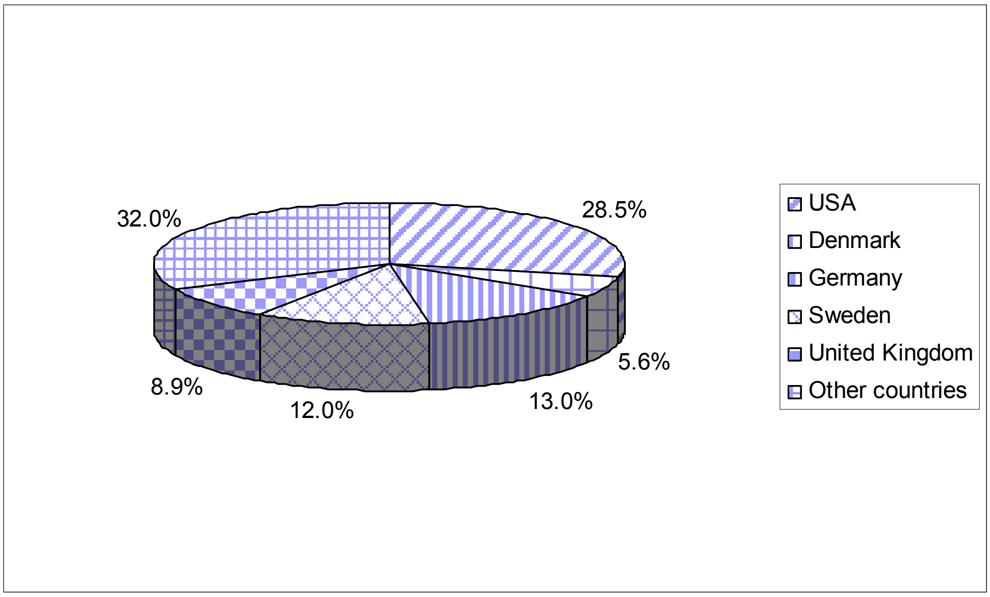
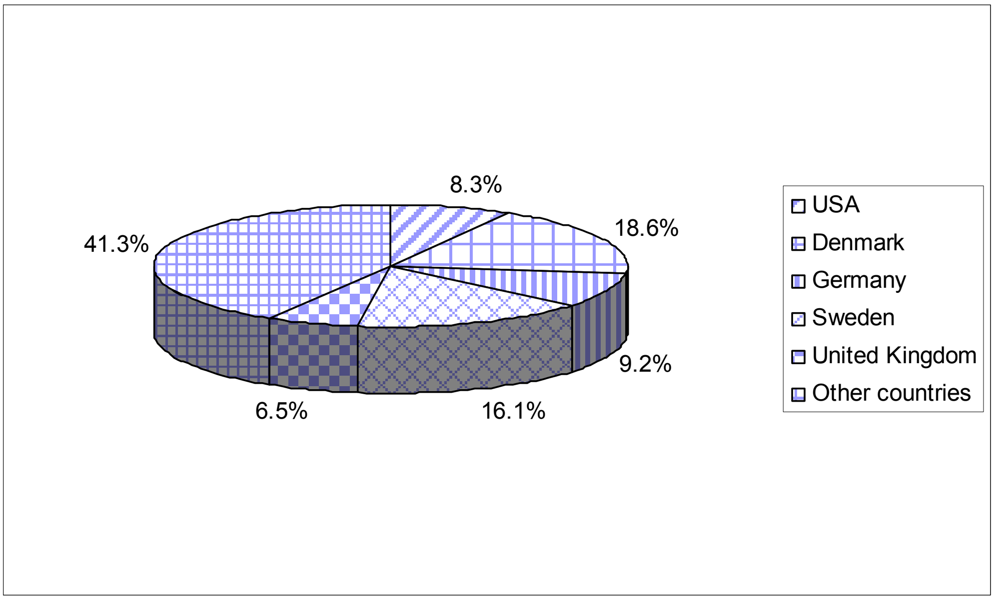


Figure 2.5. Foreign Direct Investment in Lithuania [10].

During the period 1993–1997 more than 70% of total foreign investments had gone to the manufacturing sector and wholesale and retail trades. Later on this share in the total structure of foreign direct investments decreased steadily. In January 2002, foreign investors had invested in various sectors of the economy. The four largest areas for foreign direct investments were: manufacturing (25.6%); wholesale and retail trade (20.4%); financial intermediation (19.9%); and transport, storage and communication (18.7%). The share of the energy sector in the total foreign investments was comparatively low (about 3%) due to the delayed privatization of the energy sector infrastructure.



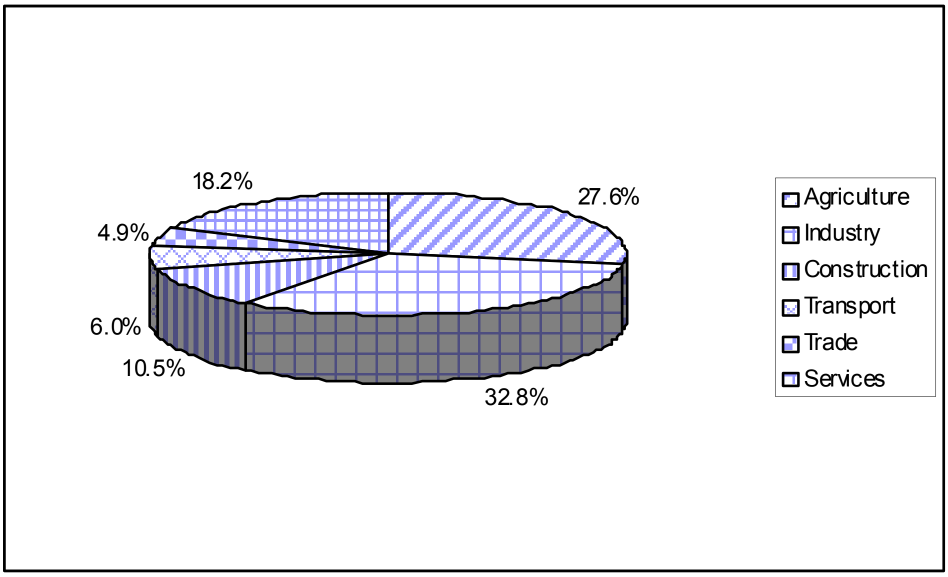
a) 1997



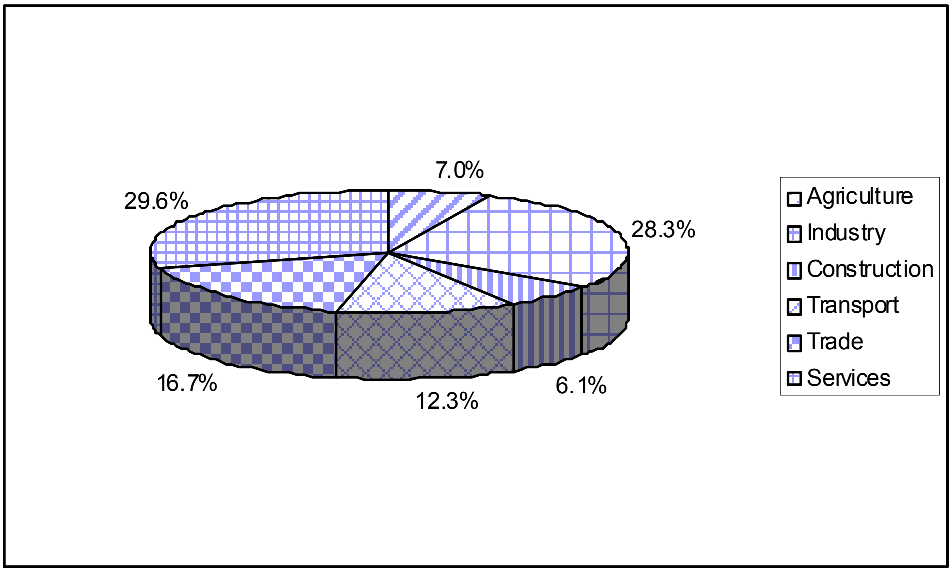
b) 2002

Figure 2.6. Major Investor Countries [10].

The process of globalization and cooperation with many countries is illustrated by the growing interest of investors in the Lithuanian economy. Fig. 2.6 shows a significant change in the structure of the foreign investments in Lithuania by main countries. In 1997, the USA dominated the foreign investments in Lithuania with a total amount of US$ 200 million. In 2002, with the same level of investment in absolute value (US$ 220 million), the share of the USA decreased to 8%. Conversely, the total amount of investment from Denmark increased from US$ 39 million in 1997 to almost US$ 500 million in 2002. Its share in the total foreign direct investments increased from 6% to 19%, and Denmark is now the top foreign investor in Lithuania. Similarly the total investments from Sweden increased five-fold during this period and Sweden is now the second largest investor in Lithuania with US$ 430 million.



1990



b) 2001

Figure 2.7. Structure of GDP [8].

In 1990 the largest sector of the national economy was industry (32.8 % of GDP) followed by agriculture (27.6 % of GDP) (Fig. 2.7). According to some experts, in 1990 the share of GDP was even higher for industry and respectively lower for agriculture. However, in 2001 the combined share of these two sectors was nearly cut in half, while the share of the trade and services sectors increased significantly.

The largest increase occurred in the trade sector where its share of total GDP increased from 4.9% in 1990 to 16.7% in 2001. The reason for the increase is that until 1990 trade was state-owned and centrally planned, while in 1990 trade became the first sector of the Lithuanian economy in which restructuring of properties took place and the number of trade enterprises increased considerably. At present the trade sector plays an important role in stimulating the development of the economy.

2.4. Energy Resources

2.4.1. Primary Energy Supply

Primary energy supply is dominated by imports from the Russian Federation — all crude oil, natural gas and nuclear fuel is imported from this country. There is a concern about the political and economic consequences of this dependence.

Natural gas has been used in Lithuania since 1961 when the gas pipeline from Dashava (Ukraine) reached Lithuania. After 35 years of service, this pipeline is worn out and is closed at the Belarussian border. Gas is imported to Lithuania by another pipeline from Belarus, which was commissioned in 1975. It connected the Lithuanian gas network to the "Northern Lights" pipeline transporting natural gas from Siberian gas fields. In the north of Lithuania the gas network is connected to the Latvian gas system. However, pipelines connecting the two countries are closed at present. They could be reopened in case of an emergency. In the normal course of events this pipeline will transport gas after the building of a gas metering station at the border. In the west of the country the Lithuanian network is connected with the gas system of the Kaliningrad region of the Russian Federation.

Natural gas is also supplied to Lithuania by a pipeline, of diameter 1200 mm, from Minsk. Given the existing two transmission pipelines to Latvia, there is a good opportunity in the near future to import natural gas from the Latvian gas network, via Incukalns and Dobele underground storages, which are the largest in Eastern Europe. The pipelines to Latvia will most likely remain closed until a gas metering station is installed at the border. Nevertheless for upgrading the reliability of gas supply to the country, the two different suppliers are highly desirable.

Taking into consideration the existing technical means of gas supply in Lithuania and existing environmental protection requirements, natural gas is considered to be the most progressive kind of fossil fuel. For the near future, use of natural gas in Lithuania is not limited by supply. However, as natural gas will likely be supplied to Lithuania from a single source (the Russian Federation) during the next 5–10 years, the following steps are necessary to assure the reliability and safety of supply [11]:

- To expand and upgrade the gas transmission networks and ensure that conditions applied for transit of energy resources in Lithuania are in line with the European Energy Charter, legal acts of the European Union and their practical implementation;
- To install the missing gas metering stations on the cross-border gas pipelines;
- To continue the investigation and prepare a study for the construction of a storage facility, to be followed, subject to a feasibility study, by the construction of an underground gas storage in Lithuania;
- To consider, together with the other Baltic States, the possibility of connecting with the gas pipelines of Poland and Finland.

The share of petroleum products in the balance of the country's primary energy resources is quite significant: in 2000, the consumption of oil products by all sectors of economy amounted to 2.2 million tons. This constituted about 31% of the total amount of the consumed primary energy resources. The main supplier of petroleum products in the country is the Mazeikiai State Refinery "Nafta", the only one in the Baltic States region. The refinery went into operation in 1980 and at the time it was one of the most modern refineries in Eastern

Europe. Prior to Lithuanian independence the refinery operation was stable and its total capacity was about 12 million tons of crude oil per year. At present its capacity is 7–8 million tons, and in 2001 almost 7 million tons of crude oil was processed. In the future the refinery should be upgraded to produce petroleum products that are in demand in Europe.

Crude oil is imported from the Russian Federation via a line from the main Russian pipeline “Druzba”. Crude oil comes almost entirely from the Tyumen oil fields through a double pipeline link of 720 mm diameter via Novopolotsk in Belarus to the Birzai (Lithuania) pumping station. From there one pipeline runs to the Mazeikiai Refinery, and the other to the Ventspils port in Latvia. The maximum import throughput of this pipeline is 16 million tons per year.

There are two import and export facilities in Lithuania — Klaipeda oil terminal and Butinge oil terminal. The Klaipeda oil terminal was built in 1959 and recently modernized. It can be used for export and import of heavy fuel oil, diesel fuel, bitumen and lubricants. Butinge oil terminal is constructed for export or import of crude oil. Its capacity is 8 and 6 million tons of crude oil for export and import respectively. At present Lithuania possesses all technical possibilities for importing crude oil and petroleum products and has achieved diversification in supplier countries. In this way Lithuania has substantially expanded its supply capacities of petroleum products and is technically protected against possible disruptions in the supply from any single country.

Indigenous oil resources are not very plentiful; however, domestic oil production can continue for several decades at the current oil extraction level of 0.3-0.5 million tons per year. For this reason the Lithuanian oil sector will be increasingly dependent on imported oil. Although the share of petroleum products used for production of other types of energy will shrink to 20–25% by the end of the study period, petroleum products will remain a reserve fuel for thermal power plants and large district heating systems and, upon installation of flue gas cleaning equipment these products will compete with natural gas.

Coal could be supplied from various places of the Russian Federation and also from Poland. Lithuania imports coal by railway, and it does not have seaport facilities, largely limiting the number of supply sources. Coal is not currently used in power generation. Before 1990, its share was comparatively high (about 20%) in the household sector. In recent years the share of coal in the balance of primary energy decreased from 3.7% in 1990 to 0.9% in 2001. At present its role in the household sector is also very low — about 1%. About 58% of total coal, supplied to Lithuania in 2001, was consumed by small consumers in the services sector, 26% in the household sector and 11% in boiler houses.

2.4.2. Indigenous and Renewable Energy Resources

Lithuania has very limited primary energy resources; however, their share of the total primary energy balance increased more than four times during the period 1990–2001 to about 8.5% by wood, peat, and hydro (13.8% including domestic oil production). Although energy production from wood, peat and hydro increased slightly over the past several years, the significant drop in total primary energy consumption resulted in these energy sources making a greater contribution to the overall energy consumption in the country.

Historical consumption of indigenous energy resources in Lithuania is shown in Fig. 2.8. The country has realized a steady growth in domestic oil extraction — from 12 000 tons in 1990 to 316 000 tons in 2000 [12].

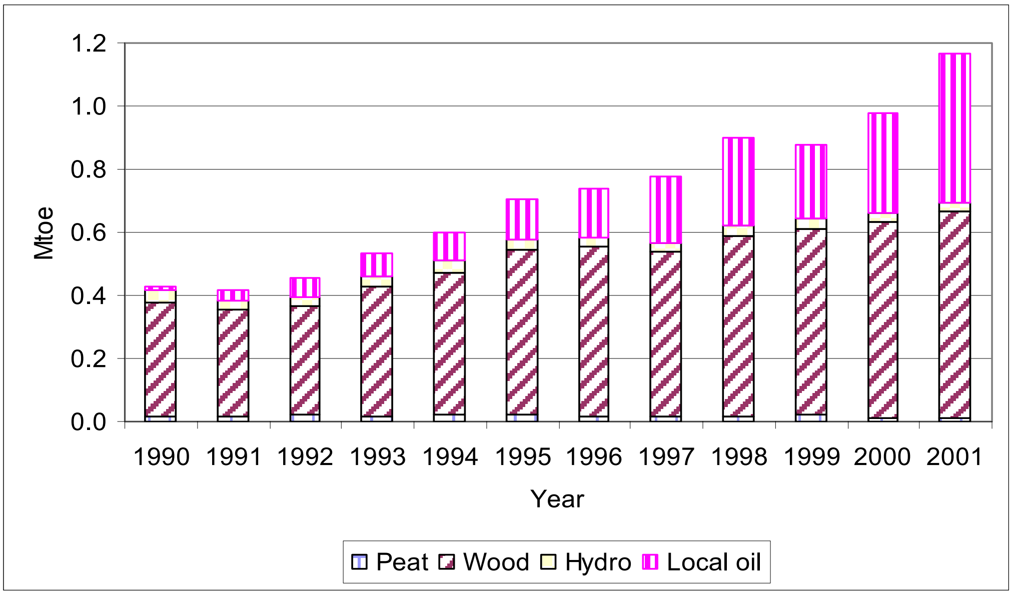


Figure 2.8. Consumption of Indigenous Resources in Lithuania

With some 60 million tons of recoverable reserves of onshore oil and 25 million tons of offshore reserves, potential domestic oil resources are rather significant for the country's economy. According to various sources, in the near future, domestic oil production in Lithuania may reach 500 000 tons per annum.

Given the high dependence of Lithuania on imported energy resources, a greater proportion of indigenous energy supplies in the country's energy balance would be very desirable. A project funded by the PHARE Programme of the Commission of the European Communities was initiated in 1994 with the goal of identifying the most economically and environmentally attractive indigenous energy resources and determining how best to promote the expanded use of these resources.

A rough estimate of the technically harnessable energy potential from indigenous and renewable resources developed under the PHARE project suggests that up to 15% of the primary energy demand in Lithuania could be met by wood, peat, hydro and other local resources. Taking into account the anticipated level of domestic oil extraction this target of 15% could be achieved. However, without oil this long term target is perhaps rather ambitious, given the costs and the changes that would have to take place to achieve this goal. Peat is an indigenous resource with one of the largest theoretical energy potentials in Lithuania that also has the most straightforward method of resource collection and use. Although the estimated total potential is 270 million tons of peat, during the last several years only 70–80 thousand tons were used annually. At present peat is primarily used as a fuel in the household sector. About 20% of peat is used in heat plants and in boiler houses of peat enterprises.

The future potential for energy production from wood is estimated to be 700–900 thousand tons of oil equivalent. At present about 95% of the energy production from wood is used for final energy in the household and services sectors, with a comparatively small portion used in district heat systems. Various sources estimate that about 300 000 tons of heavy fuel oil could be replaced by firewood and wood industry waste. This could be an attractive option for reducing GHG emissions by modernizing existing oil-fired heat plants and installing new wood chip boilers based on West European technology.

The potential for energy production from straw is closely related to Lithuanian agricultural policy. An expected grain yield of 3 million tons per year gives an estimated total straw potential of 4.5 million tons per year. If only 10% of the estimated total amount of straw is available for energy production it could satisfy some 2–3% of the total primary energy demand in the country.

Municipal waste generated in the largest cities constitutes a realistic potential energy source. The amount of municipal waste generated in these cities is estimated to be more than 80 000 tons annually which corresponds to a potential energy production of 50 000 toe per year. At present such wastes are usually disposed of in municipal landfills. Disposal at landfills leads to a large number of environmental problems, particularly as some landfills lack adequate control and protection measures. Improvements of existing municipal waste management systems include the prospect of developing some form of energy recovery from the combustible portion of municipal wastes.

Reliable sources of biogas in Lithuania, include those from: agriculture (manure of poultry and farm animals), food processing (organic wastes) and municipal wastewater treatment plants (with their methane tanks for anaerobic digestion). Biogas from farms of joint stock companies is considered to be about 300 million m^3 per year.

The natural conditions in Lithuania are not, in general, favourable for hydro power construction, as there are no deep valleys where high dams can be built. Moreover, the volume of flow in the rivers fluctuates considerably over the course of the year. The combined energy potential on large and medium rivers is only approximately 4.5 TW(h). There are, however, many smaller existing water storages throughout the country that could accept small hydropower installations with reduced civil works requirements. Taking into consideration the situation in fossil fuel market, the construction of a cascade of hydro power plants on the Neris River and the middle track of the Nemunas River may be justified. However, environmental, land ownership, monument protection and other requirements will restrict the possibility of construction of these hydro power plants.

In the Western part of Lithuania geothermal water resources were found. However, the identified resources are characterized by high salinity, relatively low temperature and large investment costs needed to use the geothermal water, which must be compared with the otherwise attractive aspects of using this resource. Scientists of the Geological Service of Lithuania have estimated the technically harness-able energy potential to be some 8 TW(h) per annum, but only 10% of this is available for energy production.

On the basis of radiation measurements, the annual solar energy potential in Lithuania has been estimated at 1 MW(h) per m^2. This potential is comparable with areas of similar altitude in northern Germany and Denmark. Therefore solar energy could be applied for water preparation, passive space heating, etc. Although installation of photovoltaic collectors is technically feasible in Lithuania, high costs limit the current use of this technology. Increased use of solar energy may be feasible in the longer term.

The region with the highest wind energy potential is the coastal area, where the average wind speed is 5 m/s at 10 m height. As regions with wind speeds less than 4 m/s are not recommended for wind projects most of non-coastal Lithuania is not suitable for wind energy sites.

In order to follow guidelines of the European Union, reduce the dependency on imported fuels and create new working places, Lithuania plans to take the following actions to stimulate increased utilization of indigenous resources [11]:

- Programmes for the consumption of indigenous energy resources will be drawn up and regularly updated;
- Extensive use of indigenous energy resources will be encouraged through organizational, economic and financial measures;
- Support will be given to enterprises in order to increase production and installation of equipment for processing and use of indigenous resources;
- Projects for the use of wind, water and solar energy as well as for the consumption of other renewable and waste energy resources will be implemented, and the experience gained in the construction and operation of the relevant facilities will be accumulated and summarized. The state will back the implementation of these projects and provide conditions for the EU structural and other support funds to be used for achieving the above goals;
- Conditions will be provided for developing the production of biofuels (denatured dehydrated ethyl alcohol, oils of biological origin, ethyl and ethyl ester). The existing legal acts and regulations promoting production and use of the above biofuels will be amended and revised on a regular basis;
- Efforts will be directed toward increasing the share of renewable energy in the primary energy balance to 12%, by 2010, and ensuring that the share remains close to meeting the requirements of EU directives.

The most recent expectations about utilization of indigenous energy resources are presented in Table 2.2.

Table 2.2. Forecast of Utilization of Indigenous and Renewable Energy Resources, in ktoe/year [13]

	2000	**2020**
Wood and wood waste	615.3	970
Peat	11.2	46
Straw	2.5	15
Biogas	1.7	18
Wind energy	0	40
Solar energy	0.03	0.9
Geothermal energy	0	23
Biofuel	0	175
Hydro power plants	29.2	40
Total	*659.9*	*1330*

2.5. Energy Planning Organization

Lithuania inherited an energy sector with a legal and institutional framework characterized by centralized management by state owned enterprises with no clear separation between political and commercial parts of the system. During 1990 to 1996, these enterprises were supervised by the Ministry of Energy and, since 1997, by the Ministry of Economy. The country's transition towards a free market economy and restructuring of the legal and institutional system in the energy sector was initiated in the first days of the regained independence.

Institutions involved with planning in the energy sector can be divided into four groups: the Parliament, the Government, the Ministry of Economy and other institutions. The Parliament (Seimas) is the highest body of state power in Lithuania. The Government is the highest level of energy policy executing institutions. The Ministry of Economy has primary responsibility for issues concerning the supply of energy including matters pertaining to energy exchanges with other countries. Several other ministries such as the Ministry of Finance, the Ministry of Environment, the Ministry of Communication and the Ministry of Agriculture are responsible for specific aspects (e.g. financial, legal, environmental) concerning energy supply and consumption.

Strategic development of the energy sector is based on economic development scenarios. These scenarios are developed at the Ministry of Economy and the Ministry of Finance with support of recruited experts from other institutions (including experts from Western countries). Short term projections are revised every year.

Departments of the Ministry of Economy, with support from the Lithuanian Energy Agency, address matters pertaining to energy sector planning, management and regulation, along with development and implementation of the National Energy Strategy. These bodies are responsible for: preparation of standards and statements linked to energy regulation, preparation of projects for privatization, decentralization and commercialization of enterprises, management of research studies, planning of energy production and consumption, regulation of international co-operation in the energy sector, etc.

The Lithuanian Energy Institute provides technical and analytical support for drafting of the National Energy Strategy. Studies conducted by the Institute include an assessment of changes and development of different sub-sectors of the energy sector, analysis of trends in energy consumption and forecasts of their future development, elaboration of policy in energy trade, and security of energy supply. Other institutions involved in energy planning include: the Kaunas University of Technology, the Vilnius Technical University, the Joint Stock Company "Lietuvos energija", the Ignalina Nuclear Power Plant, the Join Stock Company "Lietuvos dujos" and others. In addition, the State Energy Pricing and Control Commission and the Power Inspectorate provide input for energy planning, energy pricing and energy activities.

The National Energy Strategy provides guidelines for development of the main energy sub-sectors (electricity, heat, oil, gas and other) for the next twenty years. According to the Lithuanian Energy Law, passed by the Parliament in 1995 and updated in 2002, the National Energy Strategy must be revised every 5 years. Preparation of the Strategy is managed by the Ministry of Economy. The Strategy is developed at the Lithuanian Energy Institute with participation of experts from other institutions.

The Ministry of Economy provides oversight for the execution of projects by reviewing interim and draft reports and organizing workshops. For the most important projects, the Ministry creates special commissions to supervise and review results. The public is informed of the main conclusions of the study using journals and mass media (including special energy newspapers and journals).

The Ministry of Economy presents the energy strategy and other plans of the energy sector development to the Government. The Government, after discussions, presents proposals to the Parliament. Strategic energy development directions approved by the Parliament become laws.

2.6. Energy Policy Issues

The future energy sector of Lithuania will constitute an integral part of the advanced economy in a modern society that will ensure reliable and secure energy supply to all economic sectors at economically justified prices, taking into account actual costs and operational efficiency. It will be environmentally friendly, create favourable conditions for further progress of the country, be integrated into the Western and Eastern energy systems and be competitive in an open international energy market. It will consist of well-balanced energy sectors enabling further development of the society and economic growth.

Taking into account the key factors that shape the energy policy, the following strategic objectives of the Lithuanian energy sector have been set in the National Energy Strategy, which was approved by the Seimas in October 2002 [11]:

- To ensure a reliable and secure energy supply at least cost and with minimum environmental pollution, as well as constantly enhancing the operational efficiency of the energy sector;
- To liberalize electricity and natural gas sectors by opening the market in accordance with the requirements of EU directives;
- To privatize energy enterprises subject to privatization in the natural gas transmission and distribution and power sector, as well as to continue privatization of oil refining and transportation enterprises;
- Within the terms agreed with the European Union, to develop and start performing a set of measures facilitating the implementation of the European Union environmental directives in the energy sector, as well as to ensure compliance with nuclear safety requirements;
- To ensure that 90-day stocks of crude oil and petroleum products are built up by 2010 according to the agreed schedule;
- To prepare for the decommissioning of the reactors of the Ignalina NPP, the disposal of radioactive waste and the long term storage of spent nuclear fuel;
- To integrate the Lithuanian energy systems into the energy systems of the European Union within the next 10 years;
- To further develop regional co-operation and collaboration with a view to creating a common Baltic electricity market within the next five years;
- To pursue an active policy of integration into the Western and Central European electricity markets and ensure that conditions conforming to the Energy Charter, EU legislation and practices are applied to the transit of energy resources through Lithuania;
- To increase the efficiency of district heating systems;

- To achieve that the share of the electricity generated in the combined heat and power operation mode would account for at least 35% in the electricity generation balance at the end of the period;
- To strive for a share of renewable energy resources of up to 12% in the total primary energy balance by 2010;
- To improve energy sector management; i.e. strengthen institutions in the sector, improve the skills and knowledge of specialists of those institutions.

Seeking to implement the established strategic objectives of the energy sector, it is necessary to strengthen institutions involved in the management, control and regulation of energy, to modify current laws regulating energy management, and to define measures for their implementation that are based on a comprehensive analysis of reasonable development scenarios for the country's economy and energy system. When improving the energy sector management, the following is required:

- Grant state institutions greater autonomy in deciding on the strategic issues of energy planning, development and regulation;
- Restructure energy enterprises to conform with the requirements of EU directives;
- Develop management incentives based on economic methods and pricing;
- Establish competitive environment for energy enterprises or create an adequate regulatory framework for monopolies.

There is also a need to change the management principles and forms of ownership in the energy sector, to introduce universal standards of energy accounting and to foster the emergence of new technologies. In addition, the introduction of entirely new systems of information, control and regulation will require specialists with appropriate professional qualifications.

Lithuania has acceded to international environmental conventions including the National Environmental Strategy approved by Seimas in 1996, the Strategy for Approximation in the Environment Sector and the National Strategy for the Implementation of the United Nations Framework Convention on Climate Change accepted by Resolution of the Lithuanian Government in 1996, and requirements of the EU environmental directives.

The main environmental directions for the energy sector in the near future are as follows:

- All combustion plants will have to reconsider by 2008 the structure of the fuel used and to prepare for fulfilling new requirements;
- The largest Lithuanian power plants will have to install flue gas cleaning equipment;
- Priority in fuel consumption will be given to indigenous and renewable energy resources, having regard to the environmental and economic aspects of the use of these resources;
- The Government shall prepare the required legal acts and measures ensuring stable long term supply of indigenous and renewable resources to energy generating enterprises and other consumers;
- Improvement of radioactive waste management and reconstruction of radioactive waste storage facilities in conformity with international requirements;
- Ensuring pollutant emission monitoring in major thermal power plants and boiler houses;

- Implementation of oil products desulphurization technologies in the Mazeikiai Oil Refinery;
- Wider application of economic measures promoting pollution reduction and implementation of environmentally friendly technologies;
- Further development and improvement of the environmental taxation system by introducing pollution trading systems, green certificates systems and other measures;
- Priority environmental investment in the energy sector should be made in the atmosphere sector first of all in order to fulfill the EU requirements and other international obligations in the field of atmospheric pollution, taking into consideration the consequences of the Ignalina NPP decommissioning.

3. ENERGY DEMAND ANALYSIS AND PROJECTION

3.1. Evolution of Primary Energy Consumption

The development of total primary energy consumption in million tons of oil equivalent (Mtoe) is shown in Fig. 3.1 [12, 14]. During the period of transition nuclear represented a large share of the total energy consumption, ranging from 25.3% in 1994 to 37.5% in 1996. In 2001 the nuclear share was 35.0%. The role of nuclear fuel is very important for two reasons: 1) nuclear being the lowest cost imported fuel for Lithuania helped to relieve some burden of balance of payments and therefore softened social problems; and 2) nuclear fuel helped to increase the security of primary energy supply, especially in the power sector.

Oil products are also very important fuels in Lithuania. However, their share in the primary energy balance has decreased steadily — from 42.4% in 1994 to 30.5% in 2001. This is related mostly to a reduction in the consumption of heavy fuel oil for producing electricity and district heat. The share of natural gas, the most attractive fuel over the long term, has increased from 21.8% in 1994 to 25.4% in 2001. The role of coal has decreased throughout the period — from 3.7% in 1990 to 0.9% in 2001.

During the transition period several factors contributed to lower levels of primary energy consumption, including: declining economic activity, reduced demand for exported electricity and oil products, and development of internal consumption. Due to existing overcapacities for production of electricity and oil products in Lithuania, changes in primary energy demand are largely influenced by energy consumption in the power sector and Mazeikiai refinery. As a result, lower primary energy demand in 1999–2000 was related to lower levels of final energy consumption and reduced demand for electricity exports.

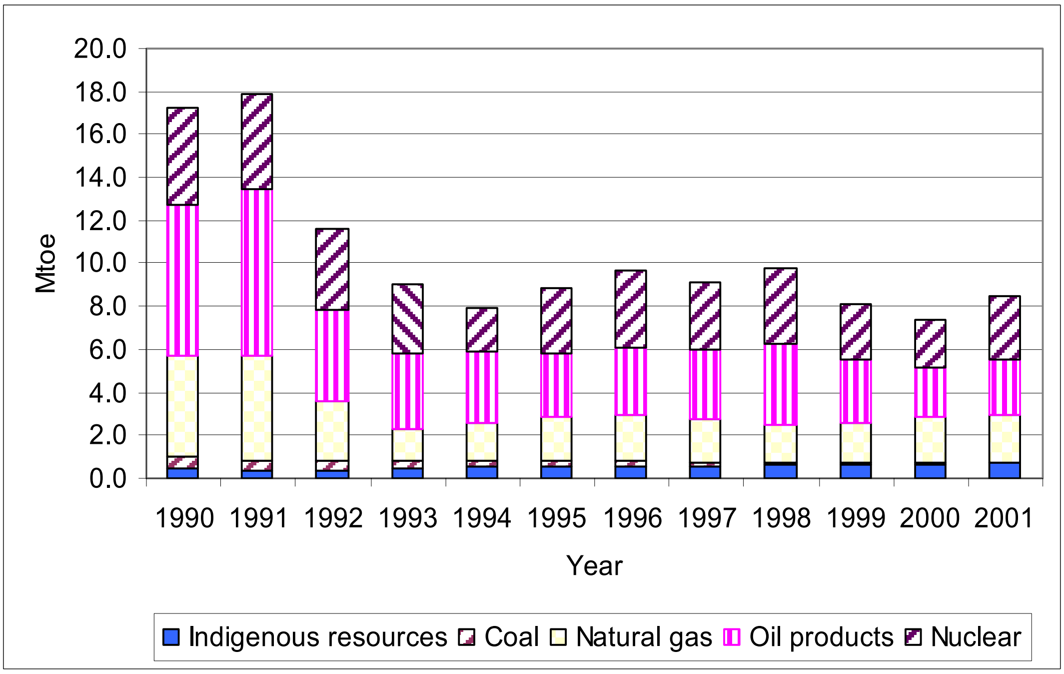


Figure 3.1. Primary Energy Consumption in Lithuania.

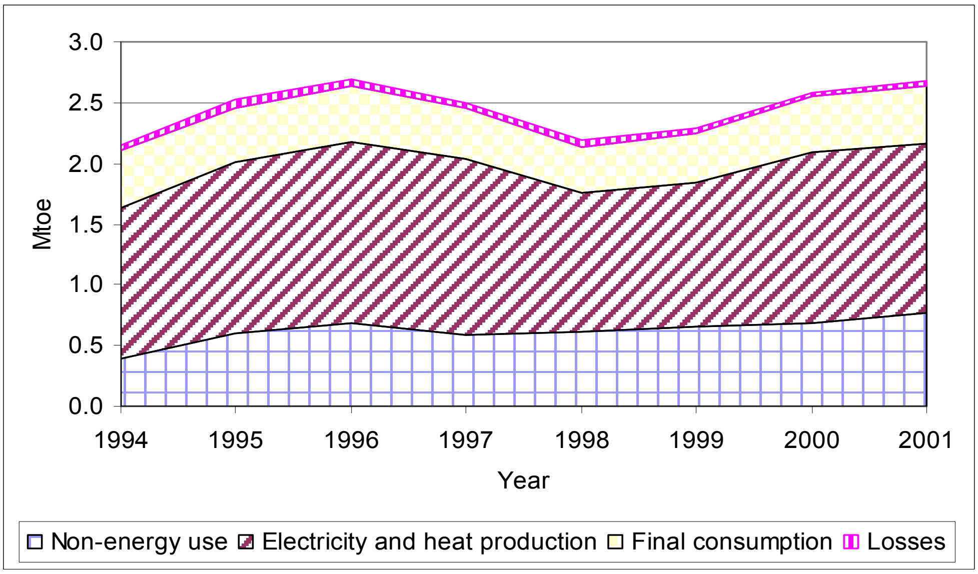


Figure 3.2. Dynamics of Natural Gas Consumption in Lithuania.

After a significant reduction in consumption of natural gas at the beginning of the transition period (total consumption of this fuel in 1993 was 3.3 times less than in 1991), its use has fluctuated around 2 Mtoe (Fig. 3.2). These changes were mainly related to the development of prices for heavy fuel oil and natural gas. Volumes of natural gas consumption for production of mineral fertilizers in 2001 were 1.9 times higher than in 1994.

The evolution of consumption of oil products in Lithuania during the transition period is shown in Fig. 3.3. The category "other oil products" represents the consumption of kerosene, petroleum coke, refinery gas, bitumen, etc. During 1990–1992 a portion of oil consumption was related to military use (mainly transportation and housing of troops) of the FSU.

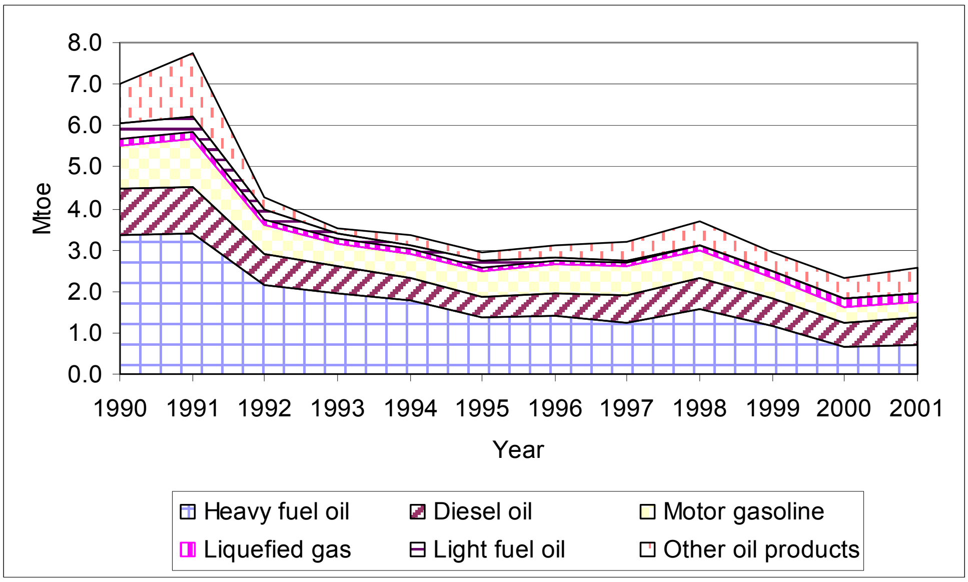


Figure 3.3. Consumption of Oil Products in Lithuania.

Due to increasing prices, the consumption of light fuel oil, which was a rather important fuel in the household sector until 1992, has decreased sharply. According to the official energy balance the consumption of fuels (diesel oil, motor gasoline and liquefied gas) for passenger and freight transportation has also dropped significantly, i.e. a drop of 25% from 1998 to 2000. This decline can be attributed to more efficient energy use combined with an increase in unreported sales of motor fuels.

3.2. Final Energy Consumption

Total final energy consumption in Lithuania decreased from 8.7 Mtoe in 1990 to 3.8 Mtoe in 2000. In fact, from 1991 to 2000, energy consumption decreased in all sectors of the national economy (Fig. 3.4)**.** However, this trend reversed in 2001 with a slight increase of final energy consumption to 3.9 Mtoe.

An analysis of final energy demand by sector shows a sharp decrease in the shares of agriculture, construction and industry. In 2000 final energy consumption in these sectors dropped to 11%, 23% and 25% of the 1990 value respectively. At the same time the share of the trade and services sector decreased slightly. Energy demand in the household and transport sectors decreased to 73% and 72% of the 1990 value respectively. Consequently, their shares increased significantly — from 21% and 17% in 1990 to 35.3% and 29.6% in 2001 (Fig. 3.5).

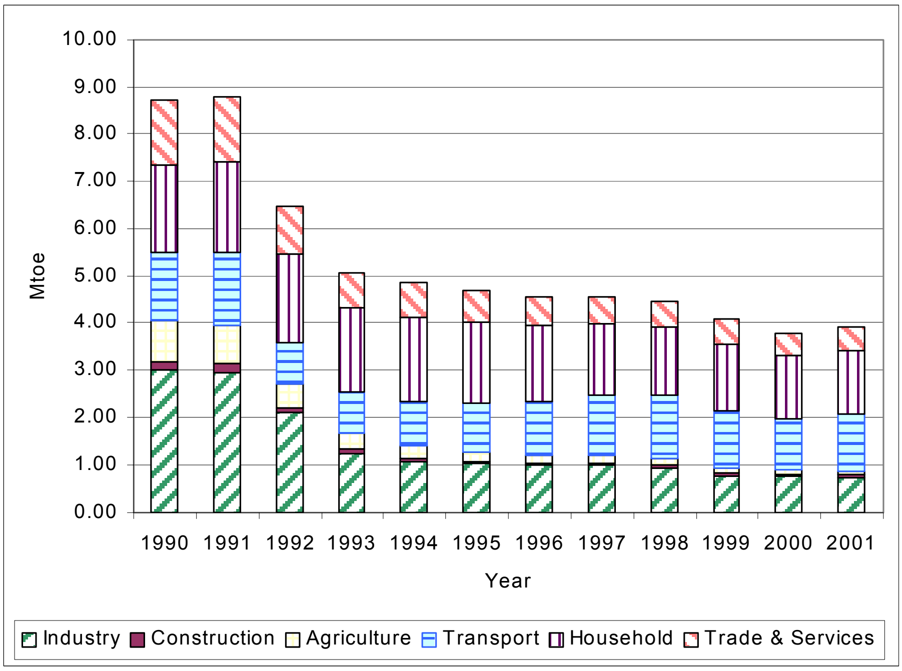


Figure 3.4. Final Energy Consumption in Lithuania.

When analyzing final consumption of different energy carriers (electricity, heat and fuel) one notices that electricity consumption decreased from 12 TWh in 1990 to 6.2 TWh in 2000, then increased in 2001 to 6.4 TWh. District heat consumption decreased more than 3 times during the transition period, then began to rebound from 9.9 TWh in 2000 to 10.1 TWh in 2001. Final consumption of fossil fuels decreased from 4.6 Mtoe in 1990 to 2.4 Mtoe in 2000, then increased to 2.5 Mtoe in 2001. As a result of these changes in energy consumption, the share of electricity consumption in the structure of final energy increased from 11.8% in 1990 to 14.2% in 2001 (Fig. 3.6).

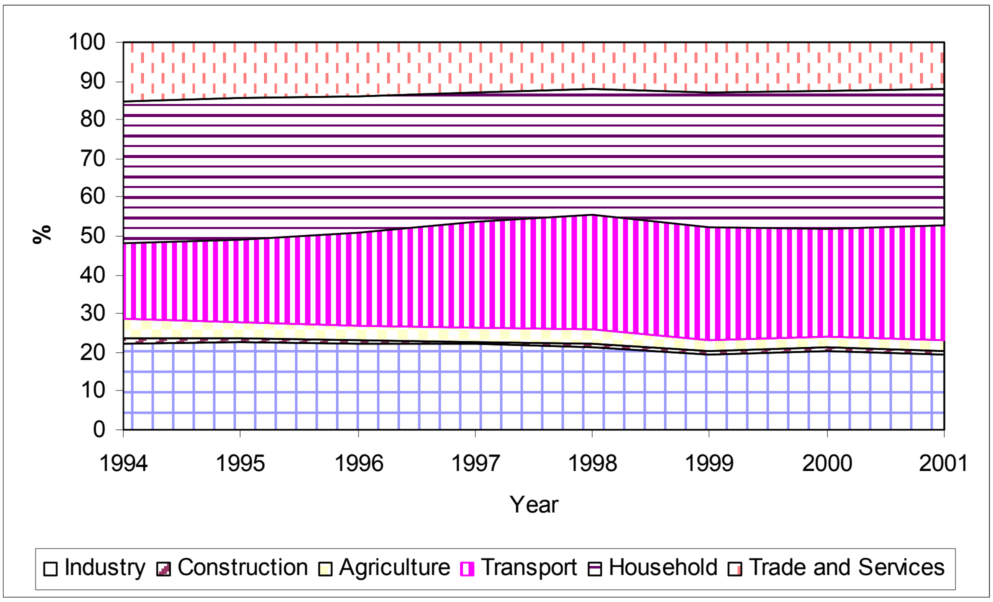


Figure 3.5. Structure of Final Energy Consumption in Lithuania.

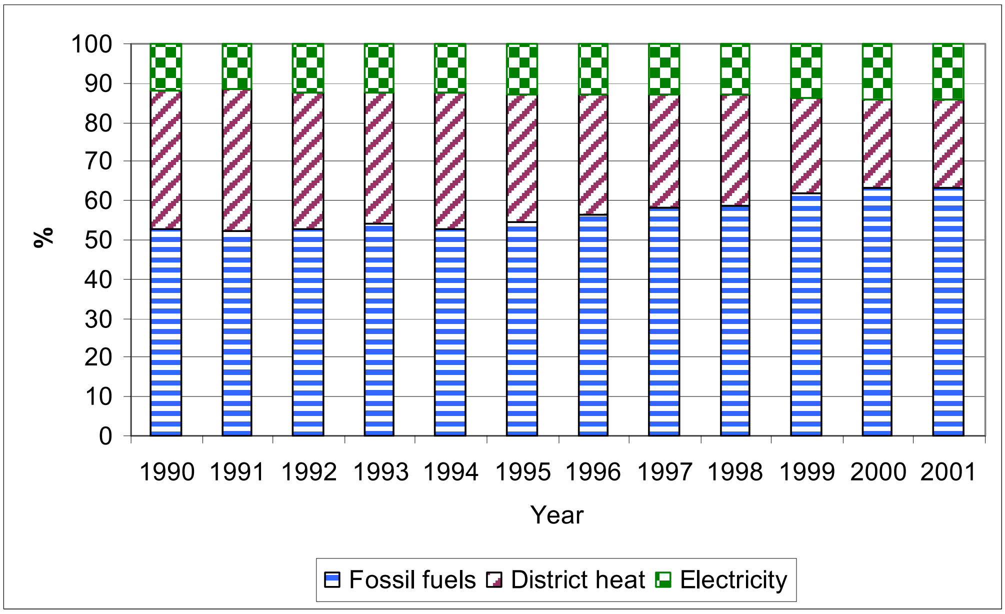


Figure 3.6. Structure of Final Energy Consumption in Lithuania (by Energy Forms).

One of the legacies of central planning is the inefficient use of energy in transition countries. High energy intensity in these countries is caused by several factors, including: the existence of very low energy prices; old and inefficient technologies; low thermal performance of dwellings and public buildings; higher percentage of old automobiles; inadequate metering and control of energy consumption, etc. Therefore enhanced energy efficiency is one of the most important strategic objectives of Lithuanian energy sector development [15]. At the beginning of the transition period, energy intensity in Lithuania increased because of a decline in economic activity in all sectors of the economy and the significant share of the household and transport sectors in the total final energy demand. However, since 1994, energy intensity in Lithuania has been decreasing, and in 2000 it was 35% lower than the 1990 level.

In 1993, Western experts estimated that by 2000 final energy intensity in Lithuania could be reduced by 32% of the 1990 level in the case of rapid reforms in the economy, but only by 18% in the case of slow reforms [16]. Thus, the actual reduction in energy intensity by 35% in the past decade is one of the most important positive changes for the Lithuanian economy.

The evolutions of sectoral energy intensities in various branches of the Lithuanian economy are shown in Fig. 3.7. The dynamics of energy intensity reflect significant changes in energy consumption per value added, especially in the agriculture, construction and services sectors. In the agriculture sector, changes in the structure of activities and energy consumption resulted in a nearly 4 times reduction in energy intensity from 1991 to 2001. During the same period, energy intensity in the construction and services sectors decreased some 3.5 times and in manufacturing by a factor of 2 as a result of a decrease in activities of energy-intensive industries and the implementation of new technologies in modernized enterprises.

Energy consumption in households decreased very slowly from 1990 to 1995, during which time the energy intensity in this sector was increasing. However, energy intensity in households began to decrease in 1995 to the extent that by 2001 the value was slightly lower than the 1991 level, while energy consumption had declined by 72%. This reduction in energy consumption is a result of the implementation of energy saving measures and a lower comfort level, especially in low-income households.

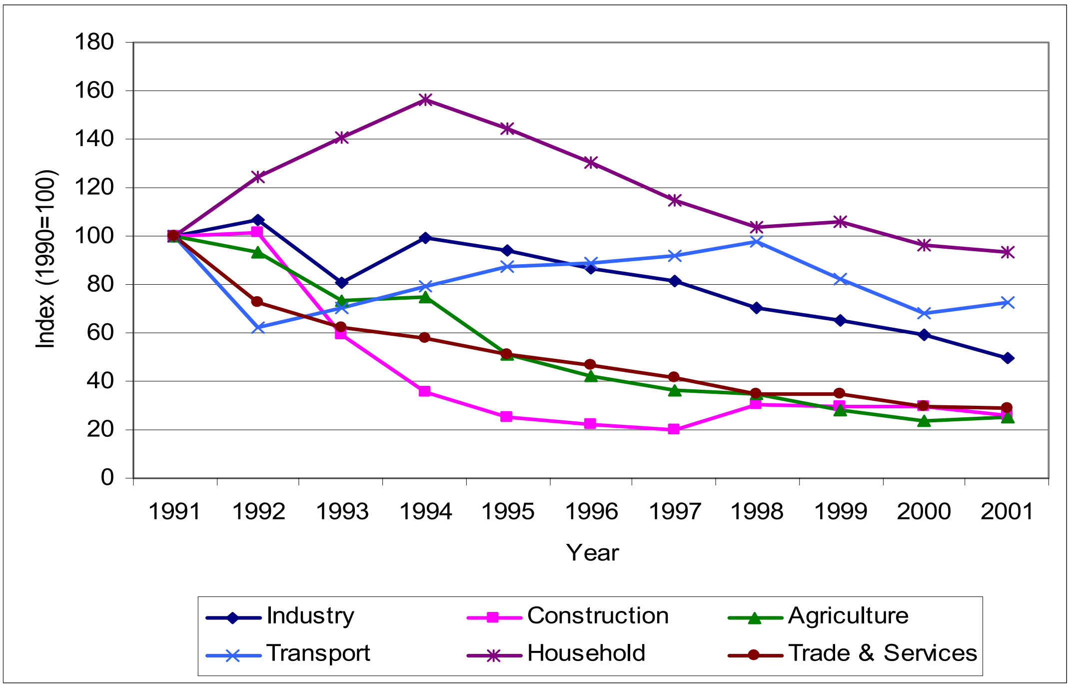


Figure 3.7. Changes of Energy Intensity in Different Branches of the Lithuanian Economy.

The energy savings potential in Lithuania can be assessed in comparison with the relative energy consumption of other countries using several indicators, such as primary energy intensity, final energy intensity, energy consumption per capita, etc. The most commonly used indicator is that of primary energy intensity. This indicator is defined as the ratio of total primary energy consumption per unit of GDP adjusted for exchange rates. It is used in many studies prepared by the International Energy Agency (IEA), the European Commission [17–21] and various statistical publications. For example, according to a published source [20], in 1999 the average energy intensity for countries of Central and Eastern Europe was 3–5 times higher than for countries of the EU.

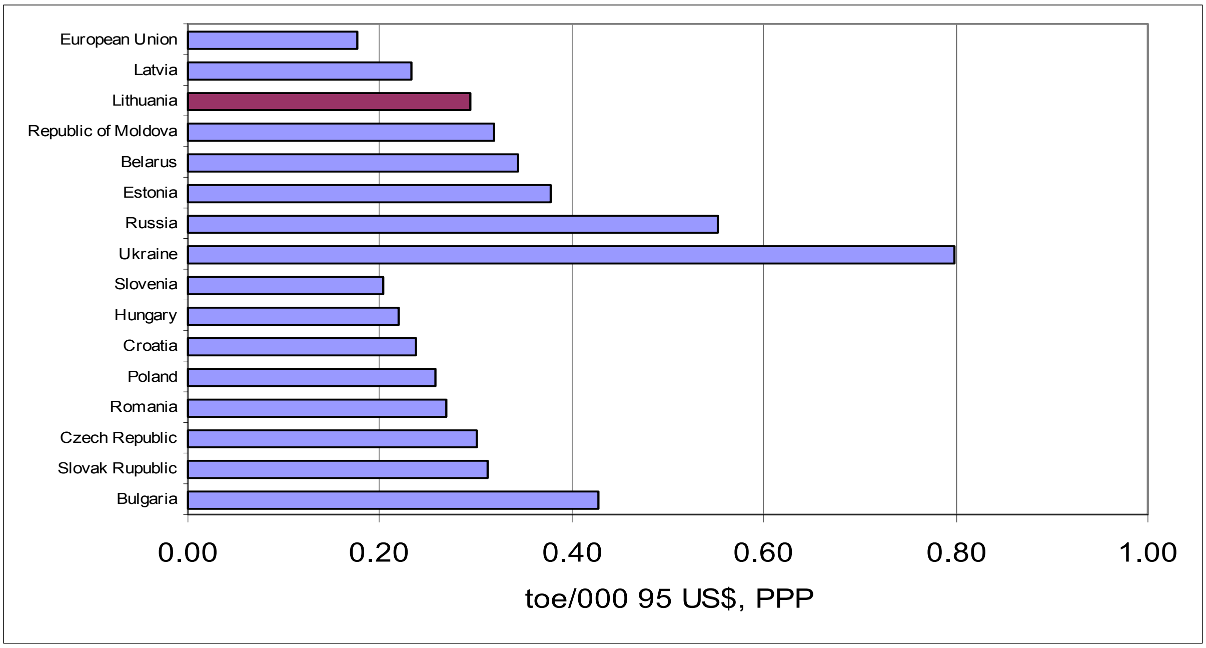


Figure 3.8. Primary Energy Intensity for Former Centrally Planned Economies in 2000 [17].

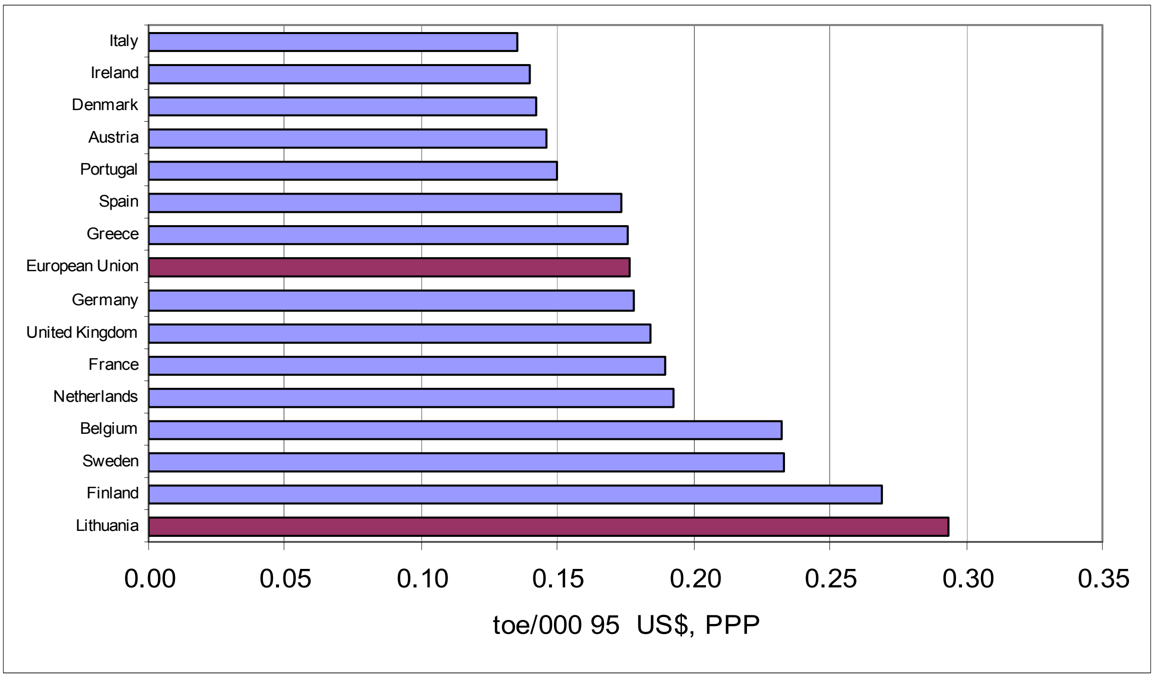


Figure 3.9. Primary Energy Intensity for Countries of the EU in 2000 [18].

In former centrally planned economies, low levels of GDP largely caused by price distortions and differences in evaluation methods contribute to high values of energy intensity. For this reason, Purchasing Power Parity (PPP) is often used in place of GDP. Using the PPP method, the average energy intensity for countries of Central and Eastern Europe is only 1.5–3 times higher than the average of EU countries (Fig. 3.8**)**. As shown in Figure 3.9, primary energy intensity in Lithuania was 1.7 times higher than the EU average and was similar in value to several EU countries (e.g. 9% higher than Finland, and 26% higher than Sweden).

When comparing indicators of primary energy intensity for various countries it is important to note that differences are not only attributable to energy efficiency and GDP. Structural differences of energy systems (e.g. differences in generation mix, non-energy consumption, transmission and distribution losses, and final energy consumption) play an important role and vary greatly among different countries. For example, according to the IEA methodology, electricity generation from hydro power plants requires three times less primary energy per unit of output than nuclear power. Thus, primary energy intensity is very much dependent on the structure of electricity generating capacities. Another structural characteristic of the Lithuanian energy sector is that electricity generation and oil processing capacity, constructed through 1990, considerably exceeds the requirements of the country. For this reason, the level of primary energy consumption in the country is very much dependent on the level of exports of electricity and oil products. Lastly, final energy, i.e. that part of primary energy and secondary energy resources, which is used by final consumers, is the real basis for production of various goods and for the delivery of services. Indicators of primary energy intensity fail to capture the benefits of improved energy efficiency in the demand sectors.

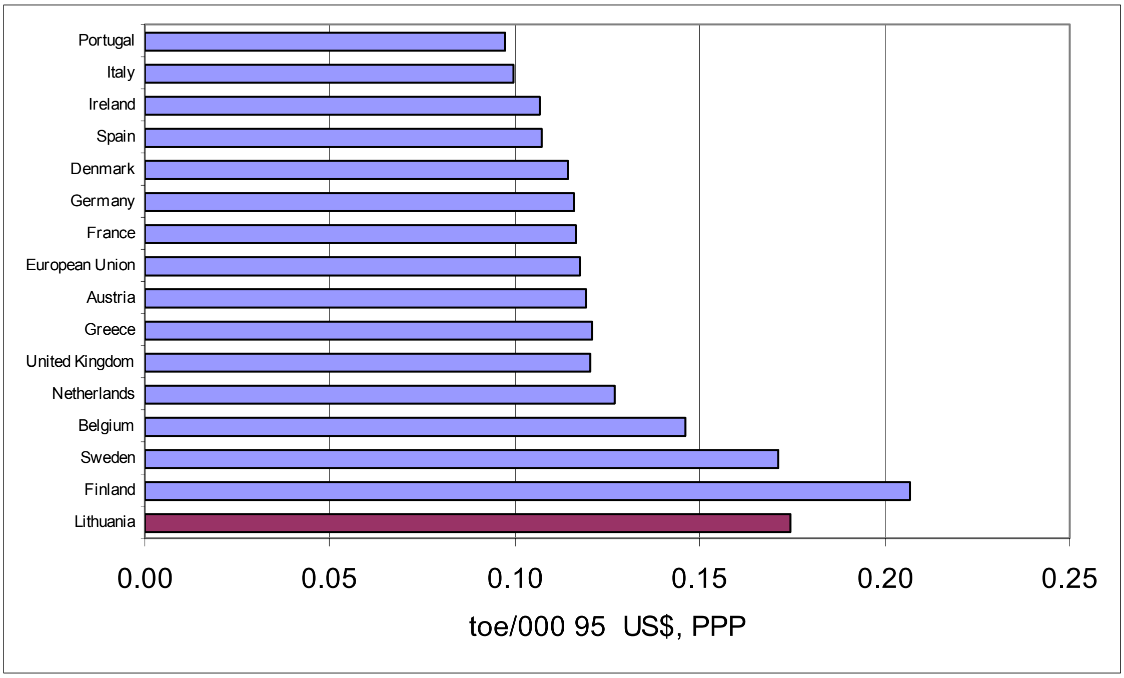


Figure 3.10. Final Energy Intensity in Countries of the EU in 1999 [18].

For the above mentioned reasons, using a ratio of final energy consumption and GDP (based on PPP) provides a more accurate indicator of energy saving potential for countries with transitional economies. As shown in Fig. 3.10, in 1999 final energy intensity in Lithuania was about 1.5 times higher than the average for EU countries; however, it was 15% lower than in Finland. Final energy intensity in Lithuania is about 1.7 times higher than in countries with comparatively low energy consumption for heating purposes — Portugal, Italy and Spain [18]. The value of final energy intensity in Lithuania is expected to continue improving through enhanced energy efficiency, along with increased contribution of the energy sector in the production of value-added products and services in the country's economy and increased opportunities for exports of electricity and oil products.

Measures to improve energy efficiency in Lithuania include implementation of advanced technologies in manufacturing, modernization of the district heating systems, improvement of thermal insulation of residential houses and public buildings, increased share of modern vehicles, etc.

A detailed assessment of energy saving potential in Lithuania was performed in support of the National Energy Efficiency Programme approved by the Government of Lithuania in 1996 and updated in 2001 [21]. The energy saving potential determined for various sectors of the economy and associated required investments are shown in Table 3.1. As can be seen, from 20% to 50% of energy currently consumed in various sectors could be saved through the introduction of energy saving measures.

Table 3.1. Evaluation of the Total Energy Saving Potential in Lithuania

Sector of economy or area of energy consumption	**Consumed in 1999, TWh**	**Annual total saving potential, TWh**	**Investment Requirements, billion LTL**
Household and Services sector [(1)]	32.8	10.3	2.34
Industry	9.7	2.3	0.45
Transport	13.7	1.8	0.60
Agriculture	1.3	0.6	0.23
Total	57.5	15.0	3.62

[(1)] Considered heat consumption, based on the assumptions given in the National Energy Efficiency Programme [21].

The largest energy saving potential exists in the household, trade and service sectors. However, some energy saving measures in those sectors require significant investment and have a long payback period. For example, insulation of the houses and public buildings (perfect insulation and full modernization of the heating systems) would save up to 45% of the thermal energy used for space heating. But this measure requires investments over 20 billion LTL and the payback period could reach more than 20 years. Therefore, at present only more realistic measures that need lower investments and have a shorter payback period (up to 5 years) are considered for implementation. One measure of this type is a partial modernization of heating systems. This measure has a payback period of 1 to 3 years, and could save about 3.9 TWh of heat per annum.

The transport sector ranks second in term of its share in the total final energy consumption. The main share of energy is consumed by engines, which are used for road transport. Significant energy saving potential could be realized in the transport sector through a system of measures implemented at the national, sectoral and company levels. The main areas for fuel savings are the following: 1) structural change of vehicle stock with priority given to diesel automobiles, 2) increasing share of public transport in towns, and 3) improving quality of roads.

Since 1990, final energy consumption in industry decreased by nearly three times. At present its share is about 21% of the total final energy. The main energy saving potential in the industry sector is through implementation of new, less energy intensive technologies. As Lithuanian industrial technologies require on average 20–50% more energy per unit of output than Western ones, implementation of new technologies would allow for savings of about one third of the energy consumed in this sector.

3.3. Socio-Economic Development

Three possible scenarios of the economic development were chosen in the preparation of the updated National Energy Strategy approved by the Lithuanian Parliament in 2002, namely: 1) the fast economic growth scenario (7% per annum till the year 2010 and 3% in the period 2011–2020), 2) the basic or moderate economic growth scenario (4.7% per annum till the year 2010 and 3% in the period 2011–2020), and 3) the slow economic growth scenario (2% per annum till the year 2010 and 3% in the period 2011–2020) [11].

The slow economic growth scenario defines a lower bound for economic development, which could be anticipated in the case of an unfavourable domestic and international environment. For example, in the case of a very slow pace in restructuring of the economy, low level of domestic and foreign investment, unexpected political and economic crises, etc. According to this scenario the average annual growth rate of GDP for the period till 2020 is 2.7%.

The fast economic growth scenario defines an upper bound for economic development. This scenario is prepared from an optimistic perspective based on the assumption that GDP would grow at an average rate of 5.0% per annum. Such a high growth rate may be realized with the expectations that: a) the Lithuanian industry will be restored and developed at a rapid pace; b) the overall policy of economic development will be very favorable to large scale investment intended for modernization of the Lithuanian economy and acquisition of new technologies; c) technical assistance from the European Union will be large and efficiently used. If such a scenario would become a reality the Lithuanian economy would reach its 1990 level by the year 2008. In this case, over the longer term, the Lithuanian economy would approach the level of European Union countries.

The basic scenario corresponds to an approximate average of the upper and lower bound scenarios. It is based on the economic development trends, which have been provided in the forecasts of macroeconomic indicators for the years 2002–2005 prepared by the Ministry of Finance. These forecasts were extended till the year 2010 assuming an annual growth in GDP of 4.7%. After the year 2010, i.e. after the first stage of the economy's restoration, the average GDP growth will be 3.0% per annum. According to the basic scenario the average annual growth rate of the economy over the planning period will amount to 4%.

As a consequence of the economic crisis of 1999 actual development of GDP is similar to the forecast that was expected according to the slow economic growth scenario. However, according to recent forecasts of the Ministry of Economy it is very likely that actual tendencies and rates of economic growth until the year 2004 would be reflective of the basic scenario.

The prospects for long term development of the Lithuanian economy are still uncertain and development of GDP could be influenced by many factors. In the case of fast and efficient accession of Lithuania into the European Union the main principle could be assumed that GDP per capita in the longer term (for example till 2020) will approach the EU average for this indicator. According to expectations of economic growth by the world's regions presented in [22] it is assumed that the economic growth rate of Western Europe will be 2.4% in the period 2000–2010 and 2.0% in the period 2011–2020. It is expected that economies in countries of the Former Soviet Union will grow with an average of 5.8% during the period 2000–2020. Therefore it is likely that GDP growth rates in Lithuania could be 5% or higher until the year 2010.

Seeking to encompass a large range of possible long term developments paths the current study considers the same three scenarios chosen for the National Energy Strategy and extrapolates these scenarios until 2025. The resulting scenario assumptions can be summarized as follows:

- Fast economic growth scenario – reflecting GDP growth of 7% per year until 2010 and 3% during the period 2011–2025 for an average annual growth rate of 4.6% over the study period of 2000–2025;
- Basic or moderate economic growth scenario – reflecting GDP growth factors provided by the Ministry of Finance until 2005, growth of 4.7% per year until 2010, and 3% during 2011–2025 for an average annual growth rate of 3.7% over the study period; and
- Slow economic growth scenario – reflecting 2% per annum until the year 2010 and 3% during the period 2011–2025 for an average rate of 2.6% per annum over the study period.

These three scenarios are presented in Fig. 3.11.

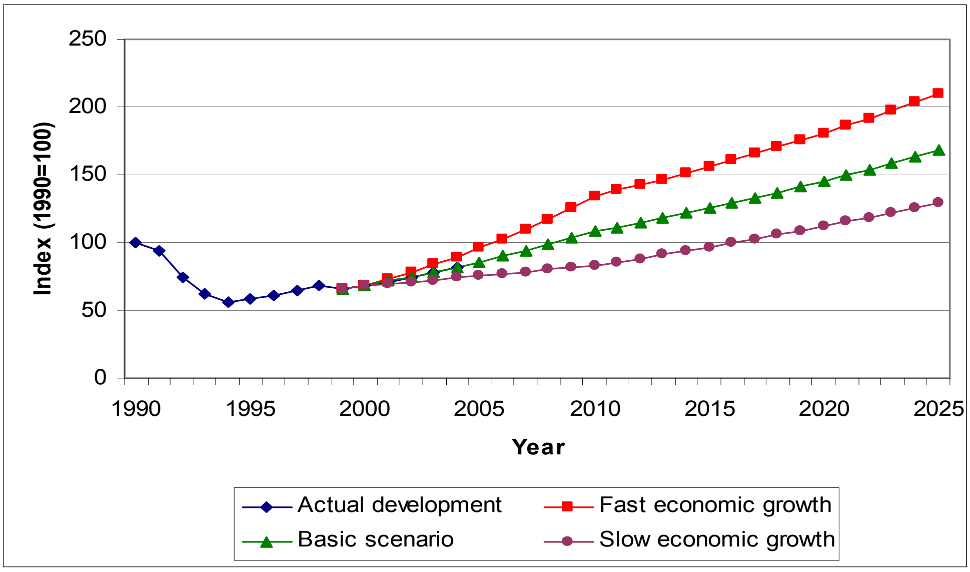


Figure 3.11. GDP Growth Scenarios.

3.4. Main Assumptions for Selected Scenarios

The MAED model requires the determination of the future development of the most important indicators affecting energy demand in branches of the national economy, such as:

- Total population and its distribution in the country;
- Changes of the living standards;
- GDP growth rates and changes of GDP structure;
- Improvement of energy efficiency;
- Volumes of freight and passenger transportation;
- Market penetration of competing energy forms, etc.

Development of the Lithuanian economy will depend on its integration into the EU and other Western economic organizations. The main factors influencing future economic development are the following:

- Relationships with West and East;
- Growth of imported fuel prices;
- Participation of the foreign capital in the reconstruction of industries and service sector;
- Environment for technological innovations;
- Recovery of economy in the neighbouring countries;
- Volumes of financial assistance from the EU, Group 7 and other states as well as international financial institutions related to closure of the Ignalina NPP, etc.

All three scenarios of this study are consistent with the primary objectives of social and economic policy of Lithuania, in particular: growth of economy and improvement of living standards, stability of prices for goods and services, stimulation of export and reduction of growth of foreign debts. However, higher GDP growth is a primary precondition to assure expectations on population growth, increase size of dwellings, growth of population mobility, growth of floor area in the service sector, etc. The main indicators used for description of scenarios are presented below.

3.4.1. Population

Population in Lithuania was increasing for several decades, but the growth rate was comparatively low – 1.3% per annum in the sixties, 0.9%/a in seventies and 0.8%/a in eighties. Since 1992 population has decreased by an average of 0.6%. During the last decade, because of the political and economical changes, the total population in Lithuania decreased by 224000 and in 2002 the total population stood at 3.48 million inhabitants, similar to the level at the beginning of the eighties. The main parameters regarding the future development of population in the country: active labour force, size of dwellings, as well as its distribution in urban and rural area are presented in Table 3.2.

Table 3.2. Main Demographic Parameters of the Basic Scenario

	2000	**2005**	**2010**	**2015**	**2020**	**2025**
Total population, million	3.51	3.45	3.43	3.42	3.42	3.44
Growth rate, % p.a.	-0.69	-0.34	-0.12	-0.06	0.04	0.09
Active labour force, million	1.64	1.65	1.65	1.66	1.67	1.68
Urban population, million	2.37	2.31	2.30	2.29	2.29	2.30
Growth rate, % p.a.	-0.84	-0.51	-0.09	-0.09	0.0	0.09
Share, %	67.6	67.2	67.1	67.0	66.9	66.9
Rural population, million	1.14	1.13	1.13	1.13	1.13	1.14
Growth rate, % p.a.	-1.22	-0.07	-0.09	0.0	0.11	0.09
Share, %	32.4	32.8	32.9	33.0	33.1	33.1
Persons per dwelling	2.72	2.58	2.43	2.33	2.22	2.11
Number of dwellings, million	1.29	1.34	1.41	1.47	1.54	1.63

The recent forecast envisages further reduction of population. In the case of the fast economic growth scenario and basic scenario, the population will continue to decrease until 2015 after which time the population will begin to grow and reach 3.44 million by 2025. In the slow economic growth scenario the population will continue decreasing until the end of the planning period and in 2025 will be 3.30 million. The most important changes are related to living standards: in the fast economic growth scenario the number of persons per dwelling will decrease to 1.95 and number of dwellings will increase to 1.76 million. For the slow economic growth scenario these figures will be 2.35 and 1.41 million respectively.

3.4.2. Economic Growth

Seeking to encompass a large range of possible long term development paths it is assumed that average GDP growth rates during the period 2000–2025 will be: 4.6% in the case of the fast economic growth scenario, 3.7% for the basic scenario, and 2.6% in the case of the slow economic growth scenario. Projected GDP growth in constant 1995 prices for the basic scenario is presented in Table 3.3, changes of GDP structure for all analyzed scenarios are presented in Table 3.4, and a comparison of GDP for various branches of the economy in 2025 is presented in Table 3.5. As would be expected, the greatest changes in the structure of GDP occur under the assumptions of the fast economic growth scenario.

Table 3.3. GDP and Value Added in the Basic Scenario

	2000	**2005**	**2010**	**2015**	**2020**	**2025**
Total GDP, billion LTL	28.39	35.75	44.98	54.14	60.45	70.08
GDP growth rate, %	3.9	4.7	4.7	3.0	3.0	3.0
Manufacturing, billion LTL	6.29	7.74	9.83	11.50	13.42	15.66
Construction, billion LTL	1.57	2.25	2.88	3.39	3.99	4.70
Agriculture, billion LTL	3.16	3.83	4.68	5.32	5.98	6.80
Mining, billion LTL	0.23	0.29	0.38	0.45	0.53	0.63
Energy, billion LTL	0.64	1.18	1.47	1.69	1.93	2.21
Services, billion LTL	16.50	20.46	25.75	29.80	34.59	40.08

Table 3.4. Changes of GDP Structure by Scenarios, %

	2000	**2005**	**2010**	**2015**	**2020**	**2025**
Slow growth scenario						
Manufacturing	21.48	21.10	21.05	21.00	20.95	20.90
Construction	5.69	6.30	6.25	6.20	6.15	6.10
Agriculture	10.88	11.00	10.90	10.85	10.80	10.75
Mining	0.83	0.50	0.52	0.54	0.56	0.58
Energy	3.33	3.40	3.45	3.50	3.55	3.50
Services	57.78	57.70	57.83	57.91	57.99	58.17
Basic scenario						
Manufacturing	21.48	21.65	21.85	22.05	22.20	22.35
Construction	5.69	6.30	6.40	6.50	6.60	6.70
Agriculture	10.88	10.70	10.40	10.20	9.90	9.70
Mining	0.83	0.82	0.84	0.86	0.88	0.90
Energy	3.33	3.30	3.27	3.24	3.20	3.16
Services	57.78	57.23	57.24	57.15	57.22	57.19
Fast growth scenario						
Manufacturing	21.48	21.75	22.10	22.40	22.70	23.00
Construction	5.69	6.20	6.30	6.40	6.40	6.40
Agriculture	10.88	10.25	9.70	9.20	8.70	8.20
Mining	0.83	0.82	0.84	0.86	0.88	0.90
Energy	3.33	3.30	3.20	3.10	3.00	3.00
Services	57.78	57.70	57.85	58.02	58.30	58.48

Table 3.5. Comparison of GDP and its Structure in 2025

	GDP, billion LTL			GDP structure, %		
	Slow growth scenario	**Basic scenario**	**Fast growth scenario**	**Slow growth scenario**	**Basic scenario**	**Fast growth scenario**
Manufacturing	11.28	15.66	20.03	20.90	22.35	23.00
Construction	3.29	4.70	5.57	6.10	6.70	6.40
Agriculture	5.80	6.80	7.14	10.75	9.70	8.20
Mining	0.31	0.63	0.80	0.58	0.90	0.90
Energy	1.89	2.21	2.61	3.50	3.16	3.00
Services	31.39	40.08	50.93	58.17	57.19	58.48

3.4.3. Energy Intensity Evolution

Future energy intensities in industrial branches for the basic scenario are presented in Table 3.6. A similar decrease of energy intensities is assumed for the fast growth scenario. The potential for implementing modern technologies is the lowest in the slow growth scenario where energy intensities would decrease by 10–20%. As the reduction of energy consumption in manufacturing is a primary objective, it is assumed that final energy intensity in this sector would be reduced by more than 30% in the fast economic growth scenario, by 25% in the basic scenario and by 20% in the slow economic growth scenario.

Table 3.6. Final Energy Intensity in Industrial Branches of Economy, kWh/LTL

	2000	**2005**	**2010**	**2015**	**2020**	**2025**
Agriculture						
Motor fuels	0.160	0.156	0.151	0.146	0.142	0.138
Electricity for specific uses	0.069	0.067	0.066	0.065	0.063	0.062
Thermal uses	0.140	0.134	0.129	0.124	0.119	0.114
Construction						
Motor fuels	0.130	0.126	0.122	0.118	0.115	0.111
Electricity for specific uses	0.064	0.062	0.060	0.058	0.056	0.055
Thermal uses	0.069	0.065	0.062	0.059	0.056	0.053
Mining						
Motor fuels	0.049	0.047	0.046	0.044	0.043	0.042
Electricity for specific uses	0.210	0.204	0.197	0.192	0.186	0.180
Thermal uses	0.294	0.280	0.266	0.252	0.240	0.228
Manufacturing						
Motor fuels	0.031	0.029	0.028	0.026	0.025	0.023
Electricity for specific uses	0.330	0.321	0.312	0.304	0.295	0.287
Thermal uses	1.206	1.149	1.095	1.045	0.997	0.952

3.4.4. Freight and Passenger Transportation

The important changes in the transport sector are related to the increase of total activity and mobility of the population (Table 3.7).

Table 3.7. Development of Freight and Passenger Transportation

	2000	2025		
		Slow growth scenario	**Basic growth scenario**	**Fast growth scenario**
Freight, billion tkm	17.5	28.4	34.5	40.2
Passenger intercity, billion pkm	15.7	27.1	30.4	35.4
Passenger intracity, billion pkm	5.5	8.0	10.5	11.7

It was assumed also that in the slow economic growth scenario the activity of trucks, cars and buses would be comparatively low and energy intensities for freight and passenger transportation will be 5–10% higher at the end of the planning period.

3.4.5. Specific Energy Consumption in the Household Sector

There are various factors influencing energy consumption in the household sector: size of dwellings, improvement of the insulation of buildings, structure of buildings because of increased share of single family houses, energy prices, improvement of quality of life, etc. These factors have different impacts on the level of energy consumption in the household sector. Some factors (such as increased size of dwellings and improvement of life quality) stimulate growth of energy consumption. Other factors, especially improvement of the insulation of buildings and growth of energy prices, stipulate a decrease in energy demand. It is assumed that the future average size of existing buildings will increase slightly as older and smaller dwellings are demolished. The size of new single family houses will decrease because during the last few years the size of such houses was too large. It is assumed that the size of dwellings with room heating will increase as a consequence of improved quality. Development of energy consumption per dwelling is presented in Table 3.8**.**

Table 3.8. Energy Intensities in the Household Sector (Basic Scenario), kWh/dwelling/year

	2000	2005	2010	2015	2020	2025
Space heating in houses constructed before base year:						
Single family houses	13312	13057	12801	12544	12285	12026
Apartments	6755	6643	6531	6418	6304	6190
Dwellings with room heating	7157	7029	6901	6772	6642	6512
Space heating in houses constructed after base year:						
Single family houses	22234	21723	21216	20716	20221	19732
Apartments	10536	10450	10362	10273	10181	10088
Dwellings with room heating	6315	6714	7108	7500	7887	8270
Water heating	1968	1976	1988	1996	2000	2001
Cooking	1104	1100	1090	1080	1070	1060
Air conditioning	265	281	298	319	341	362
Electrical appliances	1230	1490	1770	2005	2225	2435

It is assumed that the specific energy consumption per dwelling for space heating will be similar for all scenarios. However, as can be seen in Table 3.9, indicators related to quality of living standards differ significantly across the various scenarios. At present, electricity consumption per capita in households is only about 500 kWh, and a comparatively large share (more than 40%) of this volume is used for lighting. Therefore it is assumed that in all scenarios electricity penetration will increase for space heating, preparation of hot water and cooking. The faster the growth of the national economy, the higher will be the electricity penetration into the various processes and the greater will be the amount of electricity consumed for electric appliances.

Table 3.9. Indicators of Energy Consumption in the Household Sector

	2000	2025		
		Slow growth scenario	**Basic scenario**	**Fast growth scenario**
Hot water per capita, kWh/year	703	680	825	950
Electricity consumption for appliances, kWh/dwelling	1230	2105	2435	2770
Electricity penetration into:				
Space heating, %	0.6	1.3	2.5	2.9
Water heating, %	2.5	6.5	8.7	11.5
Cooking, %	6.7	12.1	14.8	19.0

3.4.6. Indicators of Energy Consumption in the Service Sector

Energy consumption in the service sector is dependent on the increase of total floor area and changes of specific energy consumption per m^2. Assumptions about development of the main factors influencing energy demand are presented in Table 3.10. The main assumption is that higher contribution of the service sector into total GDP stimulates faster growth of the country's economy. Better quality of services, based on modern technologies, requires more specific use of electricity.

3.5. Energy Demand Projections

Future final energy demand for Lithuania was projected based on an accurate determination of energy consumption for various branches of the economy in the reference year (2000), identification of the relationships between factors influencing such consumption, and presumptions of the development of influencing factors till 2025. Based on these assumptions the MAED model was utilized to develop a forecast of final energy demand. The resulting future final energy demand is presented in Table 3.11 and Fig. 3.12. Disaggregated results for the basic scenario by sectors and by main energy forms are presented in Fig. 3.13 – 3.14.

Table 3.10. Indicators of Energy Consumption in Service Sector

	2000	2025		
		Slow growth scenario	**Basic scenario**	**Fast growth scenario**
Energy consumption for space and water heating in buildings, kWh/ m^2/year				
Constructed before base year	170	165	165	165
Constructed after base year	165	160	160	160
Specific use of electricity, kWh/ m^2/year				
Constructed before base year	75.7	83.2	87.7	91.2
Constructed after base year	80.0	87.5	90.5	92.5
Floor area per employee, m^2/employee	24.5	32.6	35.7	41.2
Total floor area, million m^2	21.4	29.1	32.7	37.4

Table 3.11. Total Final Energy Demand

Years	**Scenario**		
	Slow growth, basic efficiency	**Basic scenario, high efficiency**	**Fast growth, high efficiency**
Energy demand, Mtoe			
1990	8.72	8.72	8.72
1995	4.67	4.67	4.67
2000	3.78	3.78	3.78
2005	4.17	4.66	4.92
2010	4.39	5.25	5.87
2015	4.72	5.70	6.45
2020	5.07	6.19	7.07
2025	5.45	6.70	7.74
Indices (1990=100)			
1990	100	100	100
1995	53.5	53.5	53.5
2000	43.4	43.4	43.4
2005	47.9	53.4	56.5
2010	50.3	60.2	67.4
2015	54.1	65.4	74.0
2020	58.2	71.0	81.1
2025	62.5	76.9	88.7

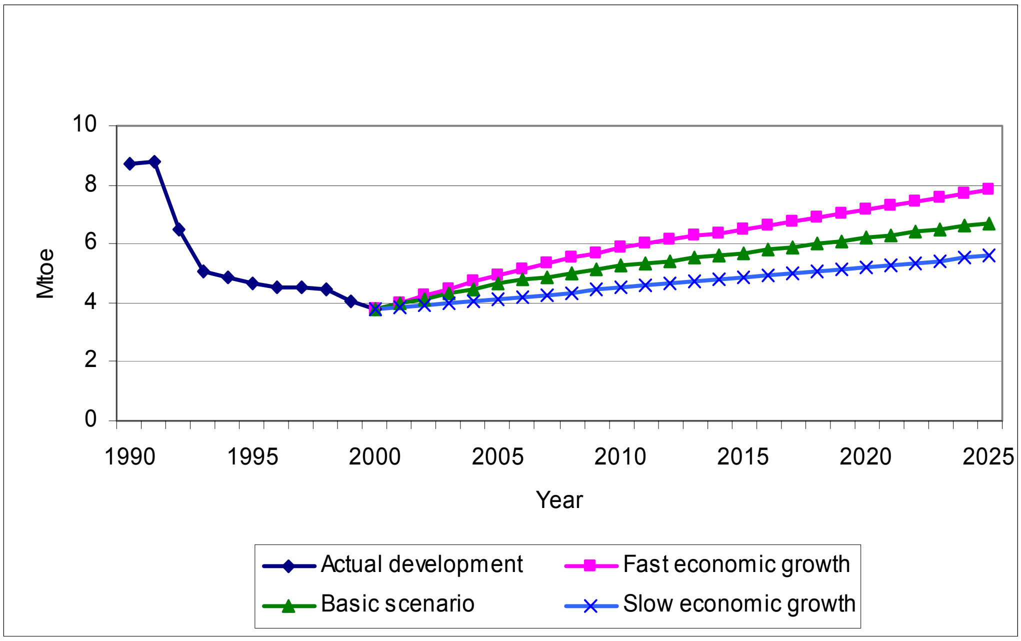


Figure 3.12. Final Energy Demand Scenarios.

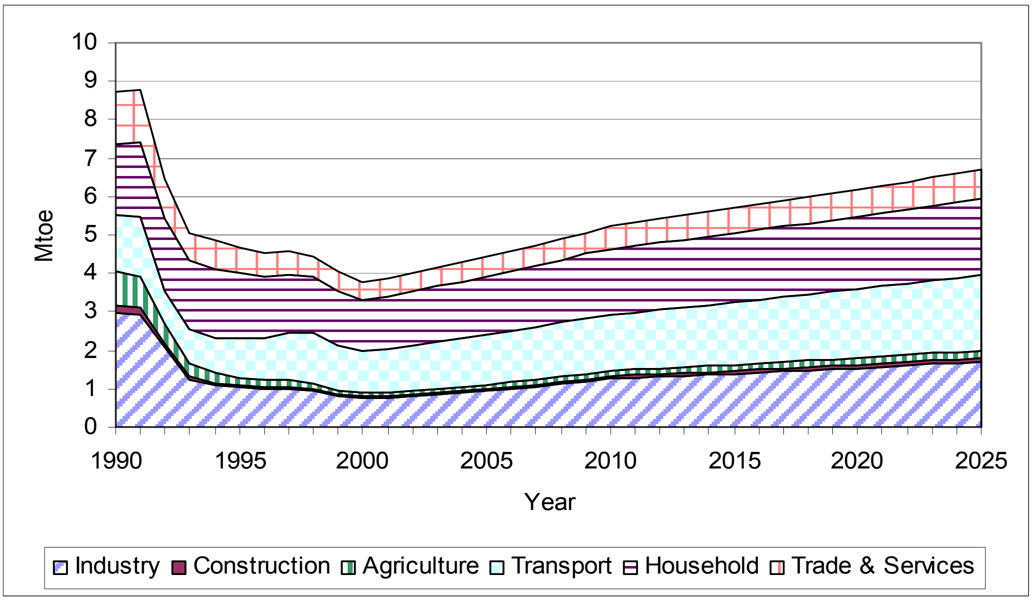


Figure 3.13. Final Energy Demand by Sector of the Economy.

In this study, the MAED and MESSAGE models were used in an integrated manner to provide a consistent modelling framework for analysis of energy sector development. Projections of final electricity demand from MAED were used as input information for the MESSAGE model, which performs an analysis of overall energy sector development. The MESSAGE model produces a more accurate forecast of electricity consumption within the energy sector because the model accounts for electricity consumption by energy transformation systems (i.e. including needs of petroleum refinery, oil extraction, heat plants and other energy sector activities).

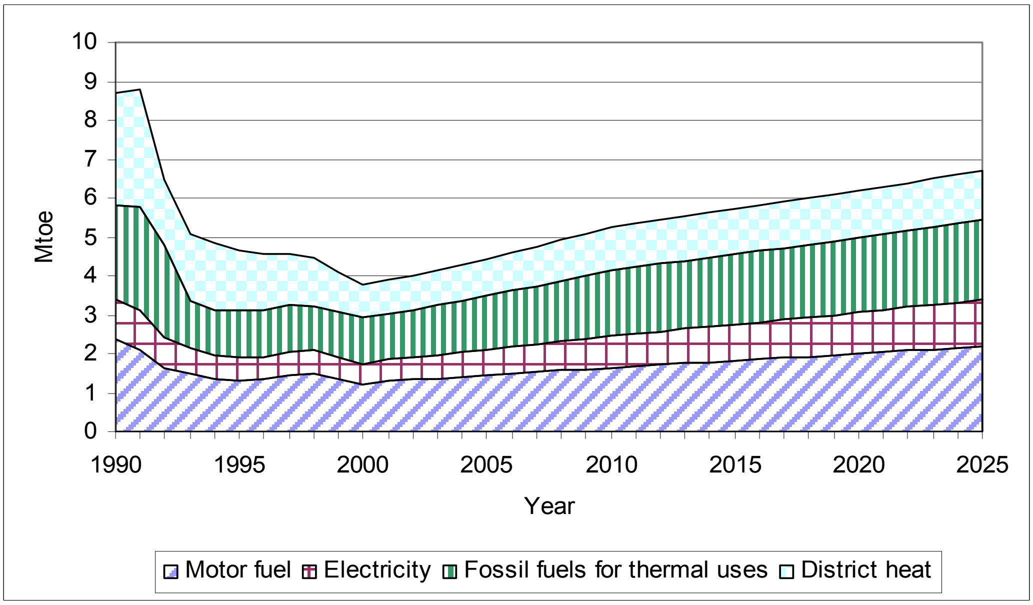


Figure 3.14. Final Energy Demand by Energy Forms.

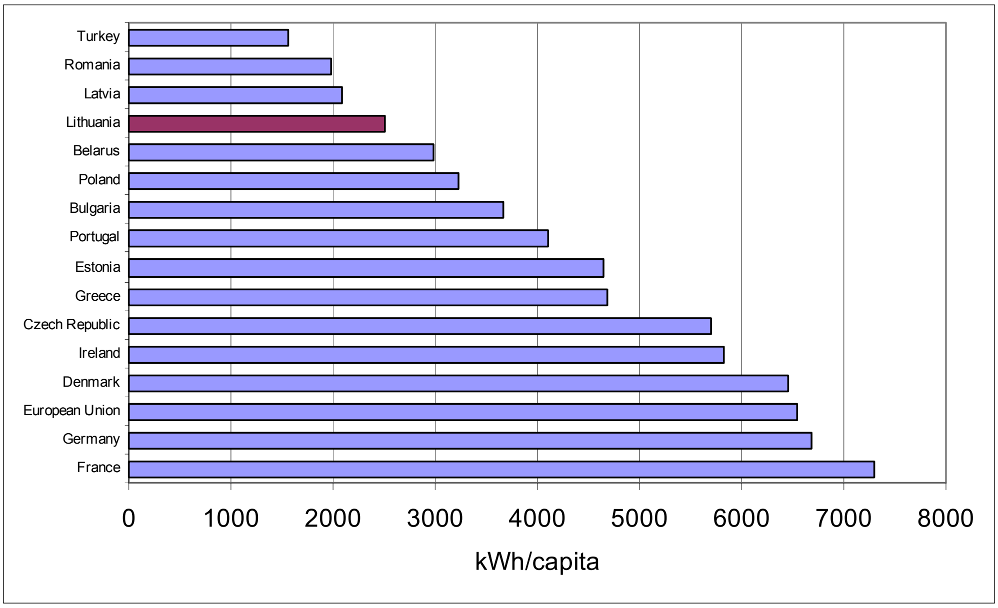


Figure 3.15. Electricity Consumption per Capita in 2000 [23].

For the period 1990–2000, electricity consumption had the slowest decrease among the various energy forms. However, Lithuania lags considerably behind the developed European countries and is behind the majority of its neighbouring countries in terms of electricity consumption per capita (Fig. 3.15). In many countries electricity consumption per capita is several times higher than in Lithuania: in Finland 6.1 times, in France 2.9 times, in countries of the European Union (on average) 2.6 times, in Ireland 2.3 times, in Estonia 1.8 times.

Another indicator, which could be used for comparison of electricity consumption in various countries, is the share of electricity in the final energy. During transition period the share of electricity in the final energy consumption in Lithuania increased from 11.9% in 1990 to 14.1% in 2000. However, at present this indicator in many EU countries is much higher than in Lithuania, e.g. in Norway by 3.5 times, in Sweden by 2.2 times, in France by 1.5 times.

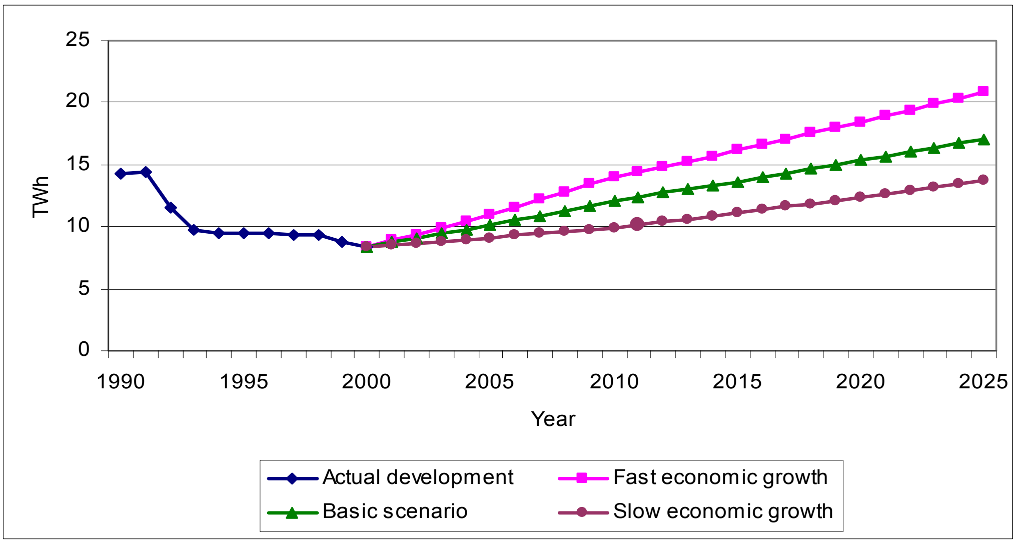


Figure 3.16. Electricity Demand by Scenarios.

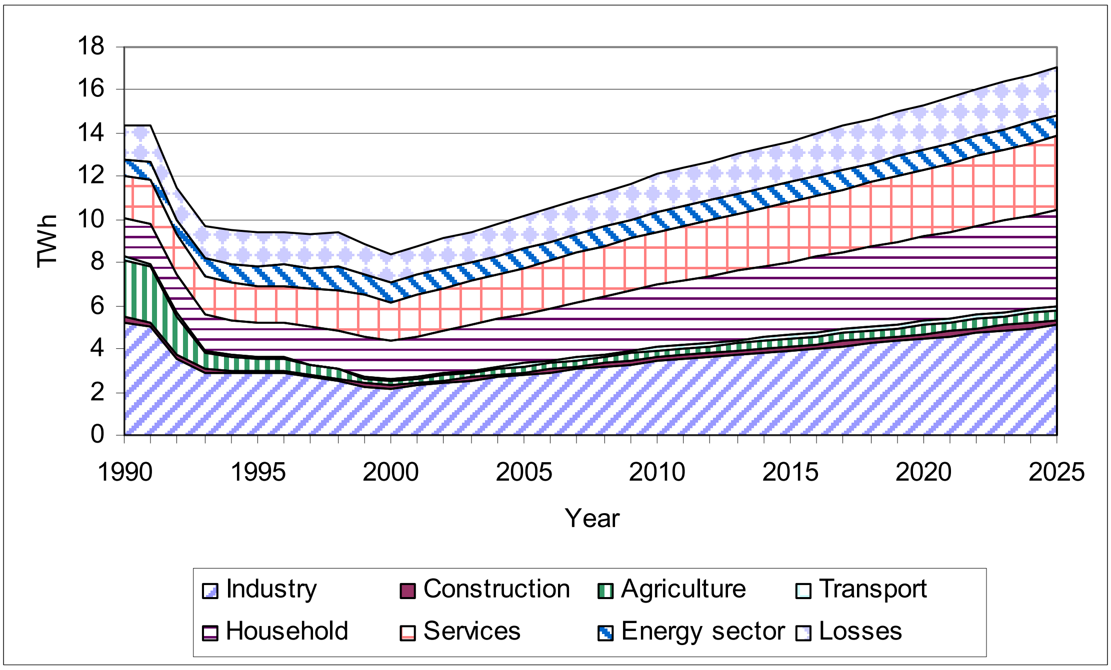


Figure 3.17. Electricity Demand by Sector (Basic Scenario).

The average share of electricity in the final energy for EU countries is 19.1%, which is almost 1.4 times higher than in Lithuania. Therefore this study assumed further growth of electricity penetration in all branches of the Lithuanian economy.

As is shown in Fig. 3.16, by the end of the planning period net electricity production could increase up to 2.5 times (in the fast economic growth scenario). The slow economic growth scenario is the only case in which total internal electricity demand (excluding own use of power plants) does not exceed the 1990 level by the end of the study period. For the fast economic growth scenario the level of electricity consumption per capita in Lithuania will be similar to that of Denmark in 2000 or similar to the present average of EU countries. For the basic scenario by 2025 Lithuania would be able to reach the present level of electricity consumption per capita in Czech Republic and Ireland. In the case of slow economic growth scenario this indicator would be higher than the present level in Bulgaria and Hungary but will not exceed the present level in Estonia.

Electricity demand by sector of the economy for the basic scenario is presented in Fig. 3.17. A comparison of the base year consumption and energy demand projections for the three scenarios are presented by sector in Table 3.12 and by energy form in Table 3.13. To be consistent, figures in those tables represent final energy consumption and do not include direct consumption of fossil fuels for non-energy purposes.

Table 3.12. Final Energy Demand by Sector, ktoe

	2000	2005	2010	2015	2020	2025
Slow growth scenario						
Industry	754.9	792.5	842.8	941.2	1051.8	1175.5
Construction	42.2	49.3	52.6	58.9	66.0	73.9
Agriculture	98.1	113.8	121.3	136.3	153.1	172.0
Transport	1051.5	1130.6	1225.9	1360.2	1496.4	1637.5
Household	1348.5	1564.1	1586.4	1622.6	1662.1	1702.7
Services	490.4	523.9	560.1	601.6	645.2	689.9
Total	3785.6	4174.2	4389.0	4720.7	5074.7	5451.4
Basic scenario						
Industry	754.9	1065.3	1257.1	1380.3	1531.0	1700.1
Construction	42.2	55.5	68.4	77.7	88.1	100.0
Agriculture	98.1	125.3	148.2	163.0	177.4	195.0
Transport	1051.5	1252.9	1458.0	1621.7	1789.0	1964.9
Household	1348.5	1613.2	1707.4	1804.6	1894.8	1989.5
Services	490.4	546.9	609.4	656.7	707.0	752.3
Total	3785.6	4659.1	5248.4	5704.0	6187.4	6701.7
Fast growth scenario						
Industry	754.9	1172.9	1535.7	1692.2	1883.5	2097.8
Construction	42.2	58.4	80.2	91.1	101.7	113.7
Agriculture	98.1	137.4	177.9	190.4	203.3	216.4
Transport	1051.5	1329.9	1646.4	1843.1	2046.4	2266.8
Household	1348.5	1646.7	1763.1	1883.4	2013.6	2154.9
Services	490.4	577.9	671.5	751.0	823.1	886.9
Total	3785.6	4923.2	5874.9	6451.3	7071.8	7736.6

Table 3.13. Final Energy Demand by Energy Form, ktoe

	2000	2005	2010	2015	2020	2025
Slow growth scenario						
Motor fuel	1204.3	1292.4	1389.4	1531.2	1676.1	1827.3
Electricity	532.9	596.3	657.4	743.3	839.4	942.8
Fossil fuels for thermal uses	1200.7	1316.1	1352.5	1419.5	1493.0	1573.0
District heat	847.7	969.3	989.8	1026.7	1066.2	1108.3
Total	3785.6	4174.2	4389.0	4720.7	5074.7	5451.4
Basic scenario						
Motor fuel	1204.3	1426.5	1648.0	1822.8	2002.2	2192.5
Electricity	532.9	668.4	812.5	930.3	1057.7	1192.9
Fossil fuels for thermal uses	1200.7	1558.5	1696.5	1796.2	1912.1	2037.7
District heat	847.7	1005.6	1091.5	1154.6	1215.4	1278.6
Total	3785.6	4659.1	5248.4	5704.0	6187.4	6701.7
Fast growth scenario						
Motor fuel	1204.3	1515.0	1864.1	2073.1	2289.6	2524.8
Electricity	532.9	729.1	959.6	1123.6	1299.3	1487.5
Fossil fuels for thermal uses	1200.7	1618.2	1851.7	1971.4	2113.9	2266.9
District heat	847.7	1060.8	1199.6	1283.2	1369.0	1457.5
Total	3785.6	4923.2	5874.9	6451.3	7071.8	7736.6

Total demand of fossil fuels for thermal uses, including their consumption for non-energy purposes (such as use of natural gas for production of fertilizers, consumption of bitumen for construction, etc.), is presented by energy form in Table 3.14. The forecast of final consumption of primary energy by sector is used as an input to the MESSAGE model. The complete set of detailed information about energy demand (by fuels, their shares and territory of the country for district heat) necessary as an input to the MESSAGE model is presented in the Appendix I.

Table 3.14. Demand of Fossil Fuels by Energy Form, ktoe

	2000	**2005**	**2010**	**2015**	**2020**	**2025**
Slow growth scenario						
Coal	81.0	82.1	82.1	83.1	83.4	83.2
Peat	9.0	12.0	14.3	16.5	18.8	20.7
Wood	591.2	675.9	688.1	708.6	729.7	752.6
Natural gas	917.4	961.1	993.1	1045.3	1106.1	1174.5
Fuel oil	293.0	285.5	285.3	289.8	292.9	295.0
Total	1891.6	2016.4	2063.0	2143.2	2230.8	2325.9
Basic scenario						
Coal	81.0	91.7	96.2	97.2	98.2	98.1
Peat	9.0	13.0	16.2	19.1	22.3	25.0
Wood	591.2	712.8	754.3	798.1	840.7	886.7
Natural gas	917.4	1096.3	1190.2	1260.1	1347.4	1445.7
Fuel oil	293.0	351.4	364.1	361.9	360.9	358.3
Total	1891.6	2265.2	2421.1	2536.4	2669.6	2813.8
Fast growth scenario						
Coal	81.0	95.9	105.3	108.7	111.1	112.0
Peat	9.0	13.2	16.8	20.0	23.5	26.7
Wood	591.2	710.5	754.9	791.5	832.2	875.0
Natural gas	917.4	1142.5	1310.5	1408.3	1527.6	1662.0
Fuel oil	293.0	368.3	403.5	401.1	399.2	394.9
Total	1891.6	2330.3	2591.0	2729.6	2893.6	3070.5

4. ENERGY SUPPLY ANALYSIS AND PLANNING

4.1. Characteristics of Existing Supply System

4.1.1. Current Energy Infrastructure

Lithuania depends heavily on the import of energy. Only about 13.8% of primary energy requirements are covered by domestic resources. The remaining part of primary fuels is imported from neighbouring countries, mainly from the republics of the former Soviet Union. Main energy flows in 2000 are shown in Fig. 4.1. It can be seen from Fig. 4.1 that oil and oil products are the main source of energy in Lithuania (51.6% of the total of primary energy requirements). Nuclear energy accounts for about 21% of total primary energy requirements, followed by natural gas — about 20% [14]. Wood, coal, peat and other fuels made up the remaining part of the total primary energy requirements in 2001.

4.1.2. Oil Supply System

4.1.2.1. General Structure of the Oil System

The Lithuanian oil system includes all processes and activities beginning from crude oil extraction and ending by sale of oil products to final consumers. The main infrastructure of the oil system comprises the Mazeikiai Refinery, the Birzai pipeline and the Butinge oil terminal, currently owned by JSC Mazeikiu Nafta; the Klaipeda oil terminal; and oil extraction facilities and facilities for transportation and distribution of oil products.

4.1.2.2. Crude Oil Production

On the basis of scientific data, the land area of Lithuania contains 46 million tons of recoverable oil; the shelf of the Baltic Sea belonging to Lithuania contains in addition 30–60 million tons of oil [24]. Currently crude oil is produced only from oil fields located in the western part of the country — in the Kretinga-Plunge-Gargzdai region. Fields located in the Southwest of Lithuania are a potential oil extraction area in the future. At present 33 wells are in operation in Lithuania. All of them belong to four companies of the Geonafta group. In 1964 the Oil Exploration Expedition was established; this was reorganized into the Gargzdai State Oil Geology Enterprise in 1991 and into JSC Geonafta in 1995.

Up to 1993 only JSC Geonafta carried out searching, exploration and production of oilfields. It discovered all 15 oilfields and 21 potential oil-bearing structures currently known in Lithuania. And at present it is the only company in Lithuania drilling deep wells, performing seismic survey and other services related to oil exploration and production.

In 1993–1995 the joint ventures with foreign companies, JSC Genciu Nafta and JSC Minijos Nafta, were established for oil exploration and production in which Geonafta owns 50% of shares in each of them. In 2001 Geonafta purchased 50% of the shares of JSC Manifoldas engaged in oil exploration and production. Thus JSC Geonafta takes part in the activities and management of these companies carrying out petroleum works in Lithuania. At present Geonafta is carrying out oil production in the oil fields of Kretinga, Nausodis and Girkaliai, for which the original recoverable reserves are 1324 thousand cubic meters of oil [24]. In October 2000 Geonafta was privatized by means of an international tender by JSC Naftos Gavyba.

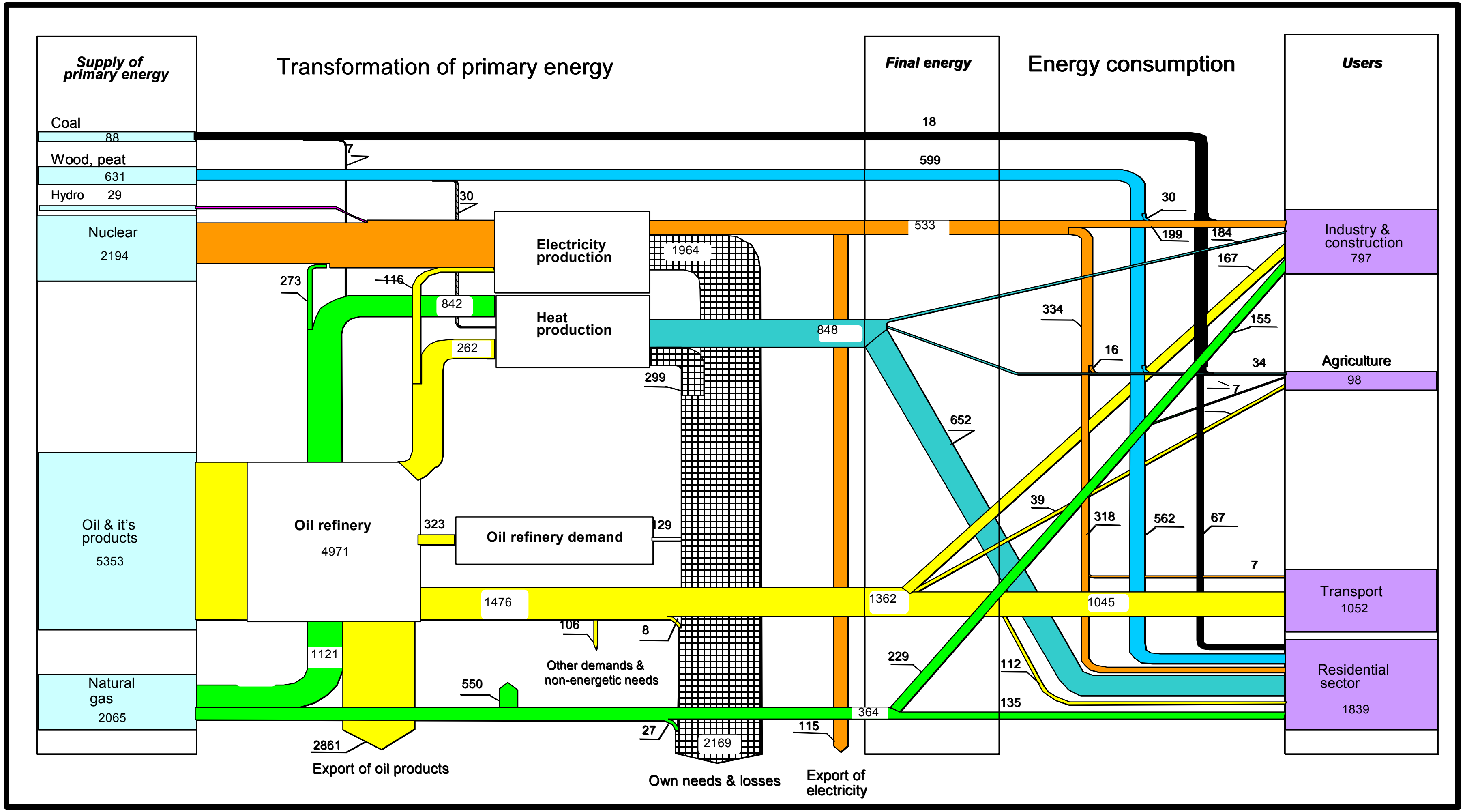


Figure 4.1. Diagram of Main Fuel and Energy Flows in 2000, ktoe.

Oil production in recent years has been constantly increasing. In 2000, 316 400 tons (316.4 ktons) [14] of oil were produced. Oil production reached 474 ktons in 2001 [12] and is estimated to reach 500 ktons in the future.

Having a high quality, Lithuanian crude oil is mainly exported. However, each year Mazeikiai Refinery processes about 200 ktons of Lithuanian crude oil [25]. The dynamics of Lithuanian crude oil extraction, as well as export, are presented in Table 4.1.

Table 4.1. Extraction and Export of Crude Oil, ktoe [14]

Year	1996	1997	1998	1999	2000
Extraction	155.4	212.3	277.5	232.5	316.4
Export	122.9	193.3	264.8	228.3	310.8
Import	3667.6	5018.1	6297	4409.3	4683.6

4.1.2.3. Import-Export of Crude Oil

Crude oil is mainly imported from Russia via the pipeline that runs from the Western Siberia oil fields via Novopolotsk (Belarus) to Birzai (Lithuania), and onwards to the Mazeikiai Refinery. The construction of a crude oil transportation pipeline through the territory of Lithuania was started in 1966 and the first pipeline — the Polotsk-Birzai-Ventspils in Latvia (with a diameter of 720 mm, 87 kilometers within Lithuanian territory, with a capacity of 13–14 million tons (Mtons) of crude per year) — was constructed in 1968. This pipeline serves the Ventspils export terminal in Latvia. In 1970 the intermediate crude pumping station, located not far from Birzai, was brought into operation. The product pipeline Ilukste-Birzai-Ventspils was brought into operation in 1971 (530 mm in diameter, 87 kilometers in length within Lithuanian territory, capacity of 4 Mtons of oil products per year). It serves for import of diesel oil from Russian refineries via Venspils terminal. The Polotsk-Birzai-Mazeikiai pipeline was completed in 1979. The Mazeikiai Refinery is also connected to the Birzai pump station via pipeline with a capacity of 16.2 Mt per year [25]. The load dynamics of the complete pipeline system in Lithuania are presented in Fig. 4.2.

With the commissioning on July 21, 1999 of the crude oil export-import terminal at Butinge, Lithuania acquired an alternative source of crude oil supply. The Butinge terminal is capable of accommodating tankers of up to 150 000 DWT with a draft of up to 15.5 meters. Loading rates run from 5300 m^3 to 5700 m^3 per hour. The Butinge terminal is an ice-free port with capabilities for the import of oil from the West and the export from the East. The Butinge terminal is connected to the Mazeikiai Refinery by a 22-inch pipeline, 92.5 kilometers in length. This provides the Butinge Terminal with a remarkable opportunity to import light or medium oil from the West and to export Russian and CIS oil. The Butinge Terminal has an annual throughput of 8 Mtons of exported oil and between 5 Mtons and 6.1 Mtons of imported oil. In 1999 the terminal operated at about 45 percent of its capacity. A total of 3.1 Mtons of oil was loaded for export and 0.4 Mtons of crude oil was offloaded from import.

YUKOS was the Butinge terminal’s main customer in 1999, accounting for approximately 80 percent of total crude oil exports during that year. In September of 2000, YUKOS signed a 5-year agreement for the export of 4 Mt per year through the Butinge terminal. Dynamics of oil import-export dynamics in 2000 is shown in Fig. 4.3. In order to construct the Butinge oil terminal a company, Butinges Nafta, was established as a public company in 1995. It was merged into JSC Mazeikiu Nafta at the end of 1998, and became the company Butinge Terminal.

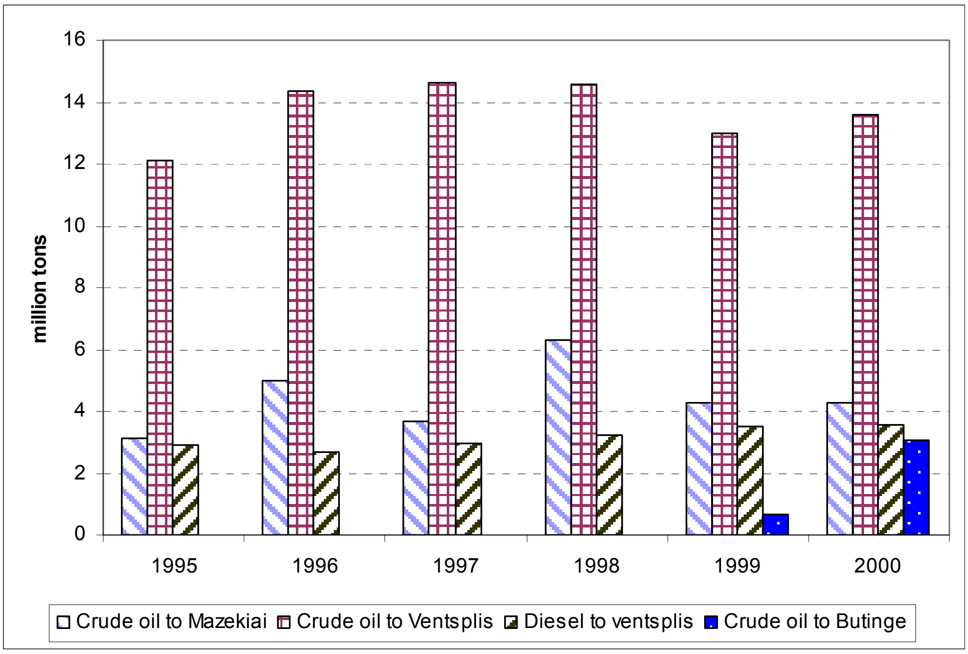


Figure 4.2. The Throughput of Pipeline System in 1995–2000 [26].

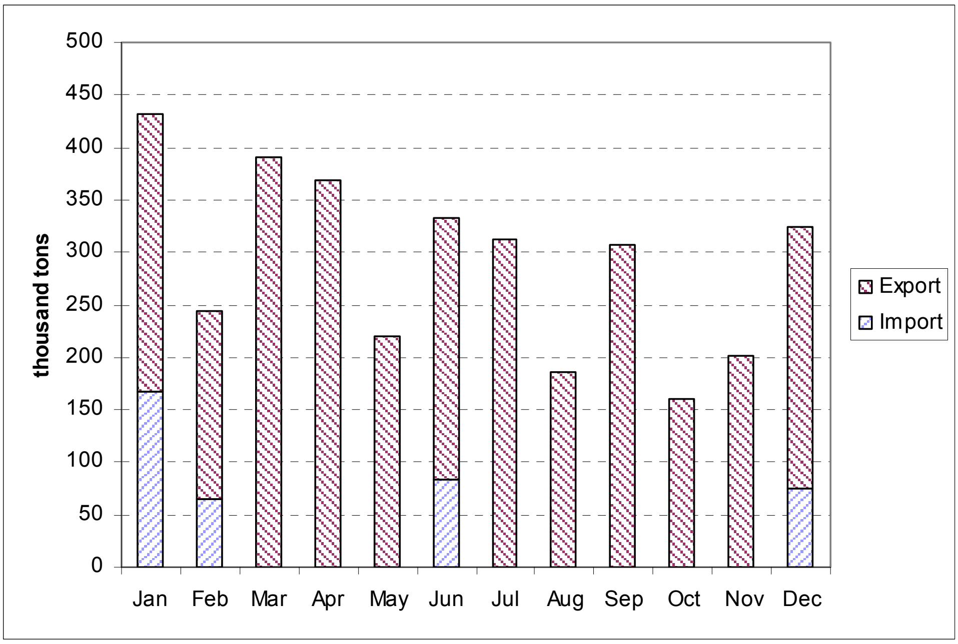


Figure 4.3. Dynamics of Crude Oil Import-Export via Butinge Oil Terminal in 2000 [26].

4.1.2.4. Refining of Crude Oil

Mazeikiai Refinery is the largest enterprise of the JSC Mazeikiu Nafta, which was founded on December 1, 1998, after the merger of the Mazeikiai Oil Refinery, the Butinge Oil Terminal and Birzai Oil. The Mazeikiai Refinery is situated some 18 kilometers to the Northwest of the town of Mazeikiai, and around 90 kilometers from each of the terminals at Klaipeda, Butinge and Ventspils (Latvia). The first part of refinery began operation in 1980, the second part in 1984. The design capacity of the Mazeikiai Refinery is 15 Mt of crude oil per year [25]. In order to utilize refinery capacities as much as possible, feedstock such as gas condensate, atmospheric residues and middle distillates are also processed. The capacities of the major units of the refinery are as follows:

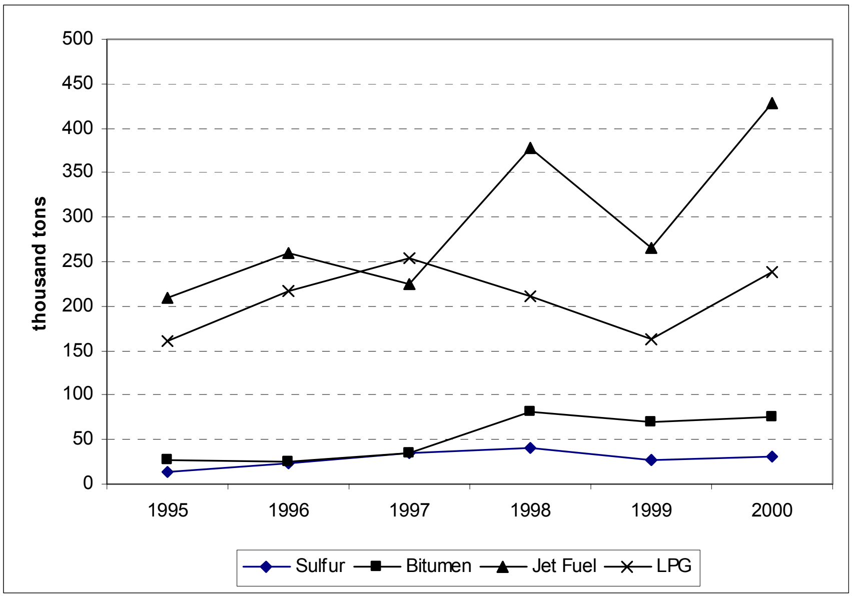
- Atmospheric distillation – 15 million tons per year;
- Catalytic reforming – 2 million tons per year;
- Kerosene hydrotreating – 1 200 tons per year;
- Diesel hydrotreating – 4 million tons per year;
- Vacuum fuel oil distillation – 5.3 million tons per year;
- Vacuum distillate hydrotreating – 2.4 million tons per year;
- Catalytic cracking – 2 million tons per year;
- Absorption and gas fractionation – 450 000 tons per year;
- MTBE production – 80 000 tons per year;
- Bitumen production – 350 000 tons per year;
- Sulphur production – 70 000 tons per year;
- Visbreaking – 1.6 million tons per year;
- Hydrogen production – 20 000 tons per year.

The refinery regularly improves product quality and the efficiency of feedstock processing. In 1995 production of leaded gasoline was ceased. From 1996, the refinery began to produce new, high quality unleaded gasoline with multifunctional additives under the VENTUS trademark, as well as winter diesel fuel. Production of Jet A-1 aviation fuel, which conforms to world standards, was also initiated. In 1999, multifunctional additives were employed to improve diesel quality, and the production of polymer-modified road bitumen was started.

The present product range of Mazeikiai Refinery includes:

- Unleaded gasoline A-98, A-95, A-92, A-80;
- VENTUS A-98, VENTUS A-95, VENTUS A-92 gasoline with multifunctional additives;
- Summer and winter diesel fuel;
- VENTUS diesel fuel with multifunctional additives;
- Fuel oil;
- Jet A-1 aviation fuel;
- LPG;
- Road, roof and construction bitumen;
- Sulphur.

Currently, the refinery produces jet and diesel fuel, which meets European Union (EU) specifications, while approximately 40% of gasoline production also meets current EU specifications. Production of oil products at Mazeikiai Refinery is shown in Fig. 4.4.



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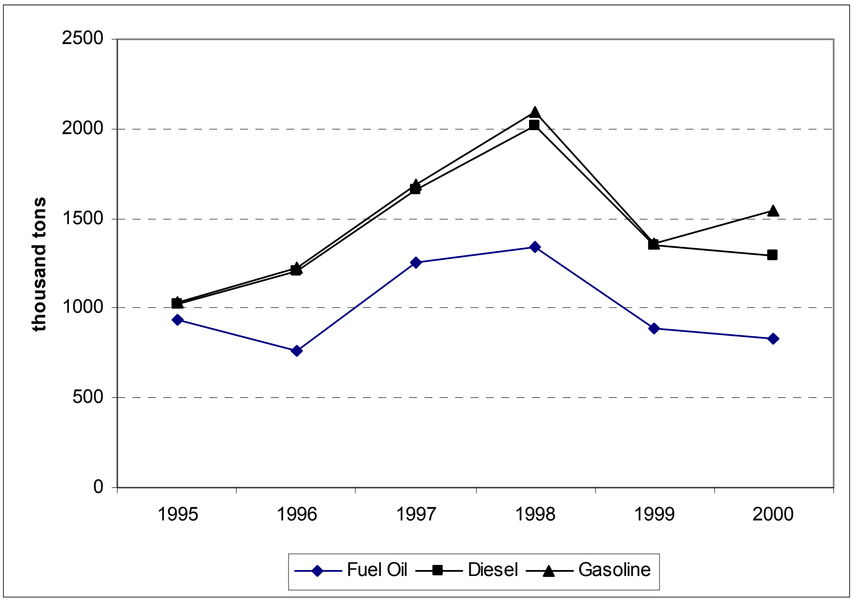


(b)

Figure 4.4. Production of Oil Products at Mazeikiai Refinery in 1995–2000 [26].

JSC Mazeikiu Nafta serves the majority of the market in Lithuania. A small portion of the refinery products was exported to the European markets (e.g. in Latvia, Ukraine, Belarus, Poland and Estonia). In 1999 more than 5.12 Mt of oil products were refined and sold on the domestic and international markets.

JSC Mazeikiu Nafta is undertaking a modernization programme during 2000–2004. This programme aims at significant improvement of the economic performance of JSC Mazeikiu Nafta. The modernization programme also aims at meeting EU specifications for gasoline and diesel fuels, increasing production and sales of higher value products, making significant environmental improvements, improving processing reliability, and reducing operating expenses through an overall efficiency upgrade program. The principal units to be constructed or upgraded under above mentioned modernization programme are [25]:

- Isomerization Unit;
- Fluid Catalytic Cracker (FCC) Complex Upgrades;
- Product Blending/Treating/Loading;
- Sulphur Plant/Amine Treating Upgrades;
- LK-6U-2 Upgrades;
- Reformer Modifications;
- Environmental/Safety/Quality Control;
- Small Fast Payout Projects.

As a result of these improvements, the refinery's gasoline yield will rise from 29.4% per ton of refinery charge in 1999 to 33.9% by the end of the modernization programme. By producing EU specification products, the entire European markets of petroleum products will be open to JSC Mazeikiu Nafta. Accordingly, refinery throughput will be increased from the current 6 Mt per year to 8 Mt until the end of 2004, with a view of further expansion of capacities depending on market demand. The modernization programme will result in significant environmental improvement in terms of improving product quality and reduction in emissions. Emissions of volatile organic compounds (VOC) will be substantially reduced by the modernization of rail loading operations and other off-site modifications. Sulphur emissions will be reduced directly by improvements of the sulphur recovery units and indirectly by producing lower sulphur distillate products.

About US$ 400 million are required to implement this modernization programme. Of this, US$ 300 million are used for the reconstruction of the refinery. Approximately US$100 million are used for the construction of the pipeline from Mazeikiai to the Lithuanian seacoast as well as for additional storage capacity at Butinge terminal.

4.1.2.5. Import-Export of Oil Products

Import and export of oil products to and from Lithuania has been mainly based on railway transportation. Lithuania has a well developed railway network (see Fig. 4.5) and transportation of oil products from and to Lithuania, as well as inside the country has no restrictions. Before the commissioning of the Butinge oil terminal the Klaipeda oil terminal (which was built under the Soviet time and came into operation on November 27th, 1959) was the only facility for import-export of oil products via sea routes. The design capacity the Klaipeda terminal was just 4.5 Mt of oil products. However, it was subsequently raised gradually and reached 11 Mt by the end of 1980s. The main terminal equipment underwent no major repairs ever since.

After the restoration of Lithuania's independence, the operation of the Klaipeda oil terminal acquired a new significance in view of the necessity for alternative oil supplies apart from the FSU. In 1993 the Lithuanian Government approved the plan for reconstruction of the Klaipeda terminal. In 1994 a joint Lithuania — USA venture, the Stock Company Klaipedos Nafta was founded, charged with the reconstruction of the terminal. Total expenditure on the reconstruction works amounts to approximately US$ 130 million [27]. After the reconstruction (95 percent of which has already completed) the capacity of the terminal will increase to 7.1 Mt per year. Storage capacity will increase from 350 000 m^3 to 520 000 m^3 [27].

Figure 4.5. Network of Lithuanian Railways.

The range of oil products handled at Klaipeda terminal includes (Fig. 4.6):

- Fuel oil M-100 (of primary distillation and cracking);
- Fuel oil M-40 (of primary distillation and cracking);
- Marine fuel oil F-5;
- Technological fuel E-4;
- Vacuum gasoil VGO;
- Diesel fuel of various kinds;
- Gasoline of various kinds;
- Jet fuel A-1;
- Other oil products.

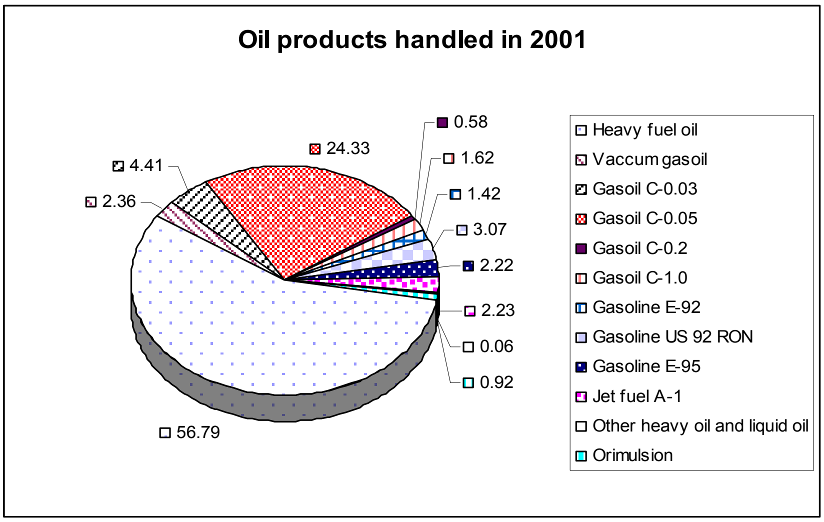


Figure 4.6. Structure of Oil Products Handled via Klaipeda Oil Terminal in 2001[27].

The dynamics of oil products handled via Klaipeda oil terminal in the last 10 years are shown in Fig. 4.7.

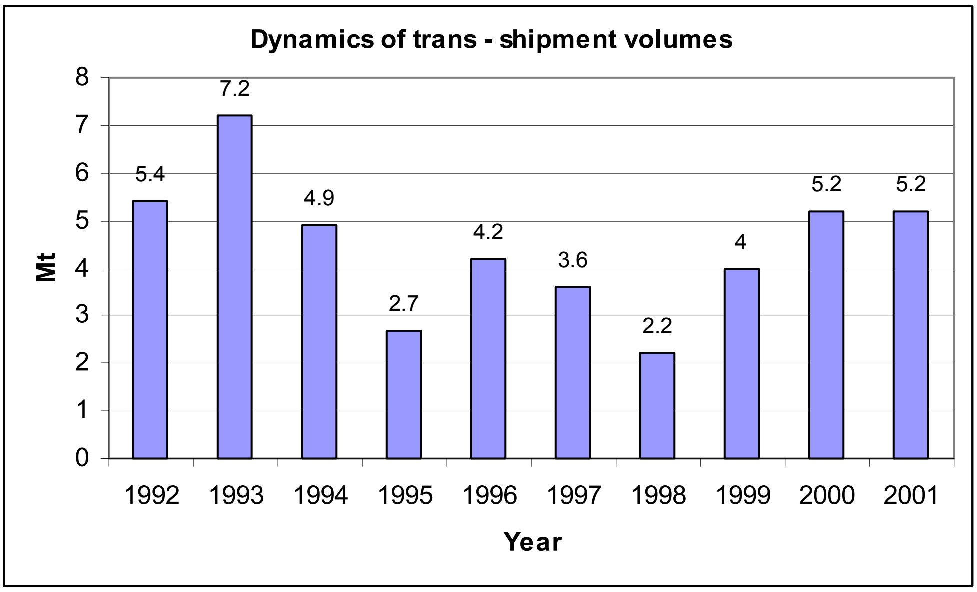


Figure 4.7. Turnover of the Klaipeda Oil Terminal in 1992–2001[27].

4.1.3. Gas Supply System

Gas is supplied to Lithuania via a high-pressure pipeline coming from Belarus in the Vilnius region. In the territory of Lithuania there are two main high-pressure gas networks — one in the Northern part of the country and the second in the Southern part of the country, which extends to the Kaliningrad region of the Russian Federation. The Lithuanian high-pressure gas network is shown in Fig. 4.8.

Figure 4.8. High Pressure Gas Network of Lithuania.

The Northern branch of the Lithuanian gas network has a connection with the Latvian gas system. The Latvian gas system has storage of 2.1 billion cubic meters (BCM) at Incukalns which could be used to supply gas to Lithuania in the event of an interruption of supply via Belarus or in order to cover seasonal fluctuation of gas demand. However, currently the pipeline from Latvia to Lithuania is not in operation due to the absence of a metering station at the Latvian-Lithuanian border. After the construction of such a metering station, a supply up to 0.5 BCM of gas to Lithuania will be possible. This gas pipeline may be very useful in wintertime when gas supply via Belarus is constrained. In the Northern part of Lithuania, in the Pasvalys region, there is a possibility to construct gas storage with the capacity of 1 BCM, which would be the alternative or supplementary to gas supply from Latvian gas storage.

The gas network in Lithuania was designed to transfer about 12 billion cubic meters of gas in a year. However, gas consumption and consequently gas supply decreased from 6 billion cubic meters in 1991 to 1.8 billion cubic meters in 1993 due to the deep economic recession. After that the consumption of natural gas stabilized at a level of 2.1–2.6 billion cubic meters.

JSC Lietuvos Dujos is responsible for import of natural gas, transmission, distribution and sales in the Republic of Lithuania. The company owns the absolute majority of the natural gas supplies infrastructure in Lithuania. JSC Lietuvos Dujos was registered as a joint-stock company in 1995. The company has taken over from the State Company Lietuvos Dujos and is continuing the natural gas business within the territory of Lithuania dating back to 1961. The main objectives of the company's business activities are:

- to secure the supply of natural gas to the consumers in Lithuania,
- to assure the gas sector development and expansion and
- to ensure the safe operations of the gas supply systems.

Key facts and figures of the JSC Lietuvos Dujos are presented in Table 4.2.

Table 4.2. Key Facts and Figures of the JSC Lietuvos Dujos [28]

As of December 31:	1997	1998	1999	2000	2001
Sales and services, million LTL	675	589	559	570	462
Profit (Loss), million LTL	16.8	(20.9)	(13.5)	(0.114)	13.0
Natural gas sales, million cubic meters	1,464.7	1,230.8	1,128.9	968.9	822.3
Natural gas transportation in Lithuania, million cubic meters	982.7	943.4	1,117.4	1,575.0	1,817.0
Number of Industrial enterprises connected to the natural gas grid.	1,452	1,555	1,853	2,373	2,725
Number of Household customers connected to the natural gas grid.	490,0	499,0	510,0	518,0	520,4
Staff size, person	4,265	3,878	3,681	3,365	2,326

Since 1992, the Government of Lithuania has allowed both state and private enterprises to supply natural gas to Lithuania without any quantity limitations. Moreover, the Government of Lithuania has decided that the Ministry of Energy has to allow authorized entities and individuals that are suppliers of natural gas to use the transmission and distribution pipelines on contractual basis. Before 1992, JSC Lietuvos Dujos had the monopoly on natural gas transmissions and sales in Lithuania. However, since 1992 other gas importers, who either sold gas to JSC Lietuvos Dujos or directly to major end users, have gradually emerged in Lithuania. Currently besides the JSC Lietuvos Dujos there are other enterprises in Lithuania involved in gas business, for example, JSC Stella Vitae. This company imports 40% of all natural gas used in Lithuania and sells directly to major end users.

Another company is the Lithuanian-American JSC Itera Lietuva, which also imports natural gas and LPG to Lithuania. JSC Itera Lietuva has a long term agreement with Itera International Energy L.L.C. for delivery of natural gas until 2005 amounting 4.4 billion cubic meters. A fertilizer factory in Jonava — JSC Achema — also has direct contracts with the Russian company OAO Gasprom. JSC Achema directly purchases natural gas from OAM Gasprom and transports it using the united gas network of JSC Lietuvos Dujos. JSC Achema also supplies some amount (13.2 million cubic meters in 2000) of natural gas to JSC Lietuvos Dujos as a barter payment for gas transportation services. In 2000 JSC Lietuvos Dujos accounted for 968.9 million cubic meters (38% of the wholesale markets) while other gas suppliers accounted for 1,575.0 million cubic meters (or 62% of the whole sale markets). (See Tables 4.3 and 4.4.). Evolution of the natural gas consumption in Lithuania during the last decade is shown in Fig. 4.9.

Table 4.3. Breakdown of Gas Volumes Directly Sold to Consumers by AB Lietuvos Dujos in 1996–2001, million cubic meters [28]

	1996	1997	1998	1999	2000	2001
Heat and power generating enterprises	1,026.7	914.6	706.8	633	483.1	297.7
Industrial enterprises	268.8	270	265.2	251.3	271.8	288.2
Agricultural enterprises	20.9	28.2	26.6	21.2	20.9	20.7
Commercial utilities	85.4	90.1	81.3	71.3	63.2	81.4
Residential consumers	185.8	161.6	150.9	151.9	129.9	134.3
As vehicle fuel	2.7	0.2	0	0	0	0

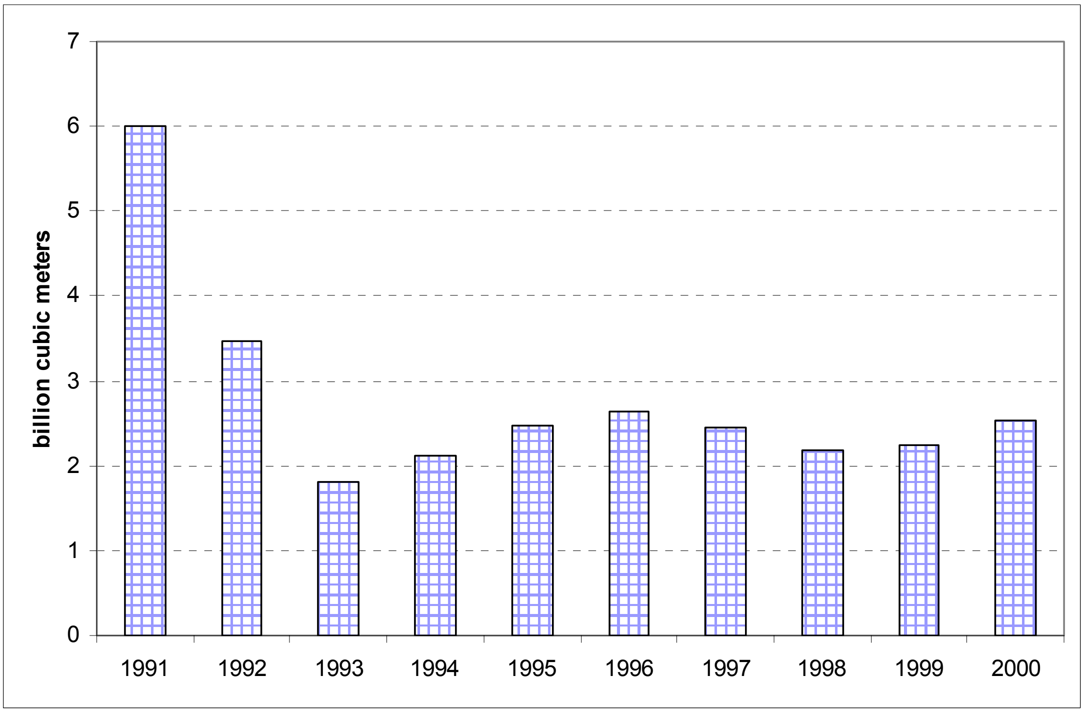


Figure 4.9. Dynamics of Gas Consumption in Lithuania during Last Decade [28].

Table 4.4. The Volumes of Natural Gas Sold by Other Wholesalers but Transported by JSC Lietuvos Dujos in 1996–2001, million cubic meters [28]

	1996	1997	1998	1999	2000	2001
AB Achema	773.4	652.1	682	650	679.5	730.2
Heat and power generating enterprises	259.9	313.7	241.9	452.5	872.9	1,060.1
Industrial enterprises	12.3	16.9	19.5	14.9	22.6	25.9

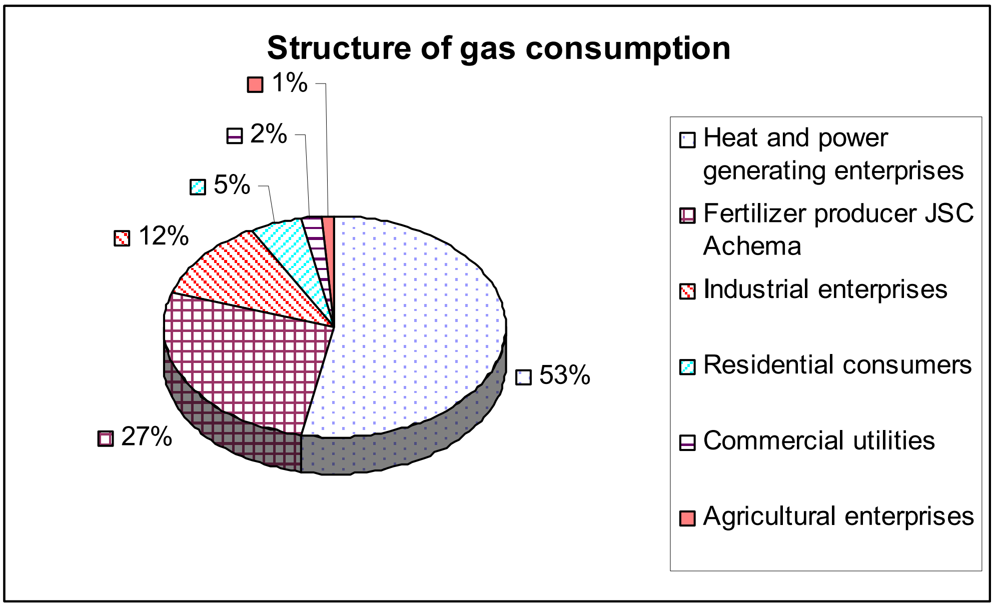


Figure 4.10. Structure of Natural Gas Consumption in Lithuania in 2000 [14].

In terms of end users, heat and power producers are the largest consumers of natural gas. They consumed 53% of gas in 2000. Fertilizer production (i.e. JSC Achema) was in the second place making up 27% from total consumption of natural gas. A breakdown of gas consumption in 2000 is shown in Fig. 4.10.

4.1.4. Electricity Supply

Before Lithuania re-established its independence, its power system was an integrated part of the Soviet grid — the so-called North-Western United System. Although oil, natural gas, coal and uranium were imported, Lithuania was a net exporter of electricity. The Lithuanian thermal power plant at Elektrenai (hereafter, Lithuanian TPP), built in the sixties and seventies, and the Ignalina NPP, built in the eighties, were designed with capacities to satisfy the demand of the Northern – Western region of the FSU rather than the needs for electricity within Lithuania.

In 2000, the total installed capacity of all power plants in Lithuania was 6568 MW (Table 4.5). At the same time, the maximum load of all Lithuanian power plants in December 2000 was only 2370 MW and the peak demand was 1775 MW.

The Ignalina nuclear power plant (hereafter Ignalina NPP) consists of two power reactors of the water cooled graphite moderated, channel type (RBMK-1500). The thermal power output of each unit is 4800 MW; the corresponding electrical power capacity is 1500 MW. Each unit has two turbines (750 MW). Unit 1 was built in 1984 and Unit 2 in 1987 with the purpose of serving regional electricity demand and the plant was part of the large Soviet Northwestern System. Lately, for safety reasons, the operation capacity of the Ignalina NPP was de-rated to 2600 MW.

Table 4.5. Main Characteristics of Lithuanian Power Plants

	Power Plant	Installed capacity (MW)	Available capacity (MW)
1.	Lithuanian TPP	1800 (4x150+4x300)	1800 (4x150+4x300)
2.	Vilnius CHP (total) - CHP 3 - CHP 2	384 360 24	364 340 24
3.	Kaunas CHP (total) - Kaunas CHP - Petrasiunai CHP	178 170 8	178 170 8
4.	Mazeikai CHP	194	99
5.	Klaipeda CHP	11	11
6.	Total Thermal (1- 5)	2567	2452
7.	Kaunas HPP	101	101
8.	Small HPP	15	15
9.	Kruonis HPSPP	800	760
10.	Total - HPS (7-9)	916	876
11.	Ignalina NPP	3000	2600
12 .	Other power plants	85	76
	Total all plants	*6568*	*6003*

The first unit of the Lithuanian TPP was commissioned in 1963. At present the total installed capacity of Lithuania TPP is 1800 MW. Four units with 300 MW capacities produce only electricity (without heat). Two out of four 150 MW units supply heat to the residential consumers in town Elektrenai and other consumers. The plant is fuelled by gas and heavy fuel oil. In addition, one out of 4 units (150 MW and 300 MW alike) can burn orimulsion. There are three large CHP plants in Lithuania (in Vilnius, Kaunas and Mazeikiai). There are also several small public CHPs and industrial cogeneration plants. Mazeikiai CHP is oil-fired and all other plants are dual fuelled (oil or gas). Before 1992, combined heat and power plants in Lithuania played an important role in the electricity supply system as well as in the heat supply sector. During the last decade electricity and heat production at CHP's decreased significantly due to lowered demand and unfavourable prices.

The Kaunas hydro power plant (Kaunas HPP) was built in 1959 on the bank of Nemunas River and started full capacity operation in 1960. The total capacity of 4 units of this hydro power plant is 100.8 MW. The electricity generated at Kaunas HPP is supplied to the 110 kV voltage grid. Annual electricity production varies between 280 GW·h and 440 GW·h depending on water flow in river Nemunas.

The Kruonis hydro power station pumped-storage type (Kruonis HPSPP) was built from 1992–1998 and comprises of four units of 200 MW. This hydro power plant is charged with covering peak and semi-peak electricity demand in Lithuania and previously also in the Northwestern region of the Former Soviet Union. This plant takes up peak loads and compensates for the night drops in demand, serving as a frequency and short term emergency reserve. Further, it allows Ignalina NPP to operate at a higher power load factor. Apart from pumping, there is no natural flow of water to the storage. Main technical parameters of the Kruonis HPSPP are presented in Table 4.6.

Table 4.6. Main Technical Characteristics of the Kruonis HPSPP

Turbine pump	
Type	Axis
Capacity at turbine mode	205 MW
Capacity at pump mode	217 MW
Revolutions	150 rev./min.
Debit at turbine mode	226 m³/s
Debit at pump mode	189 m³/s
Nominal pressure	100 m
Upper pool	
Area	306 ha
Dam length	6,3 km
Perimeter of pool	6,8 km
Water level: maximum minimum	 153,5 m alt. 140, 0 m alt.
Bottom	138 m alt.
Full pool volume	48 mil. m³
Useful pool volume	41 mil. m³

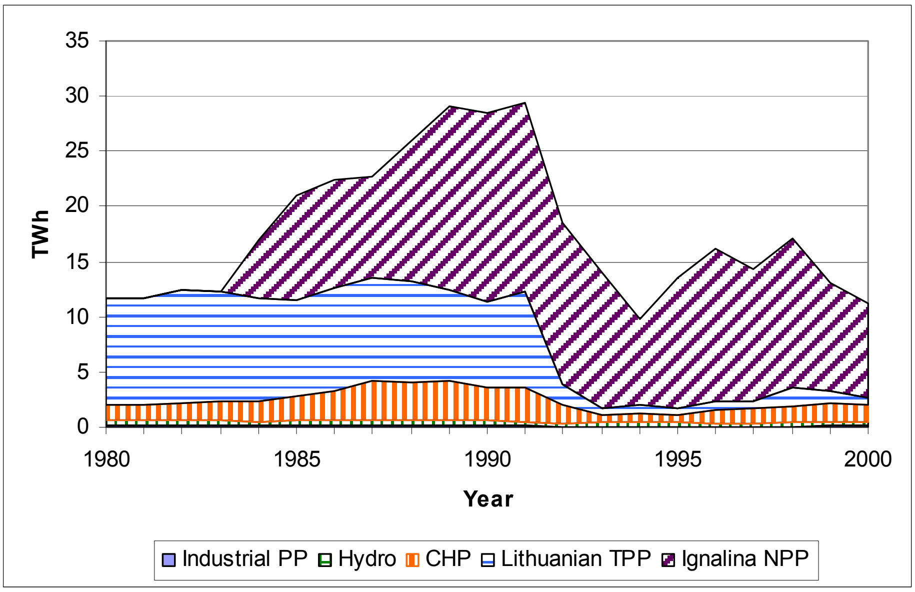


Figure 4.11. Electricity Production in Lithuania.

There are about 40 small hydro power plants located in different parts of the country. Evolution of electricity production since 1980 by plant types and their respective shares in total electricity generation are shown in Fig. 4.11 and 4.12 respectively.

Total gross electricity production in 2000 in Lithuania was 11.41 TW(h), merely 60% of the 1991 production level. This decrease was mainly due to the reduction of electricity export and of domestic consumption. After 1992 Lithuania was among the world leaders in terms of nuclear-based electricity generation. In 2000, countries with the highest reliance on nuclear power were: France 76.4%, Lithuania 75.7%, Belgium 56.8%, Slovakia 53.4%, Ukraine 47.3%, Bulgaria 45.0%, Hungary 42.2%, the Republic of Korea 40.7% and Sweden 39.0% [29]. Gross electricity production at Ignalina NPP in 2000 was 8.42 TW(h).

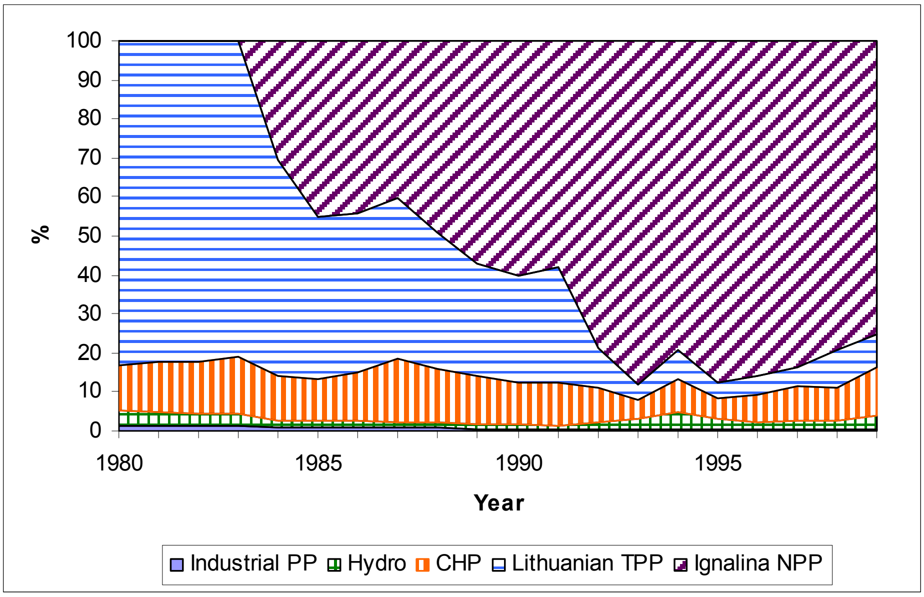


Figure 4.12. Structure of Electricity Production in Lithuania.

Figure 4.13. Grid of the Lithuanian Power System, 330 kV and 110 kV [30].

Lithuania has a well-developed electricity network and strong connections with northern and eastern neighboring countries. However, it has no direct connection with its southern neighbour — Poland. The entire Lithuanian grid of 330 and 110 kV is shown in Figure 4.13 and connection of Lithuanian power system with electricity grid of neighbouring countries is shown in Fig. 4.14.

Figure 4.14. Interconnections of the Lithuanian Power System with Power Systems of Neighboring Countries [31].

Until recently Lithuanian Power Company Lietuvos Energija remained a vertically integrated state owned monopoly. It possessed all power plants and electricity transmission and distribution networks, as well as the majority of boiler houses and district heating networks. After the decentralization of the district-heating sector in 1997, all boiler houses, district heating distribution networks, CHP plants, except the Mazeikiai CHP, were transferred to the municipalities. At the beginning of 2002 the power company was unbundled further and now the Lithuanian power system includes the following enterprises:

- JSC Lietuvos Energija, which is in charge of high voltage (330-110 kV) transmission lines and substations, ensures reliable and efficient electricity transmission from Lithuanian power plants to electric distribution utilities and large customers. Via the dispatch center it continuously coordinates the operation of Lithuanian power plants and neighbouring energy systems, creates non-discriminatory conditions for all users of the transmission grid, and ensures a balance between electricity generation and consumption and reliability of the electricity system. It also organizes electricity trade, coordinates electricity export and import, as well as electricity transit among neighbouring power systems. JSC Lietuvos Energija owns also Kaunas HPP and Kruonis HPSPP;
- State company Ignalinos Atomine Elektrine in charge of the Ignalina NPP — the main electricity supplier in the country;
- JSC Vakaru Skirstomieji Tinklai (western distribution network), which supplies electricity to eligible consumers at a negotiated price and to other consumers at tariffs approved by the National Regulatory Agency. This company operates in the western part of the country and has two divisions – Klaipeda division and Siauliai division;
- JSC Rytu Skirstomieji Tinklai (eastern distribution network), which supplies electricity to eligible consumers at a negotiated price and to other consumers at tariffs approved by the National Regulatory Agency. This company operates in the eastern part of the country and has three divisions — Panevezys division, Kaunas division and Vilnius division;
- JSC Lietuvos Elektrine (the Lithuanian thermal power plant), which functions mainly as a reserve capacity for the Ignalina NPP and supplies heat to Elektrenai town and nearby consumers;
- JSC Mazeikiu Elektrine, whose main function is to supply heat to the Mazeikiai Refinery and to serve as reserve capacity for the Ignalina NPP;
- JSC Vilniaus Energija (Vilnius CHPs) consisting of Vilnius CHP-2 and Vilnius CHP-3. Its main duty is to supply heat and electricity to Vilnius. Vilnius CHP also serves as reserve capacity for the Ignalina NPP;
- JSC Kauno Energija (Kaunas CHPs) consisting of Kaunas CHP and Petrasiunai CHP. JSC Kauno Energija is in charge of heat and electricity supply to Kaunas city. Kaunas CHP also serves as reserve capacity for the Ignalina NPP;
- Klaipeda CHP, that belongs to the JSC Klaipedos energija which is in charge of heat supply in Klaipeda city and electricity production;
- Industrial and small private electricity producers.

The structure of the Lithuanian electricity market is presented in Fig. 4.15.

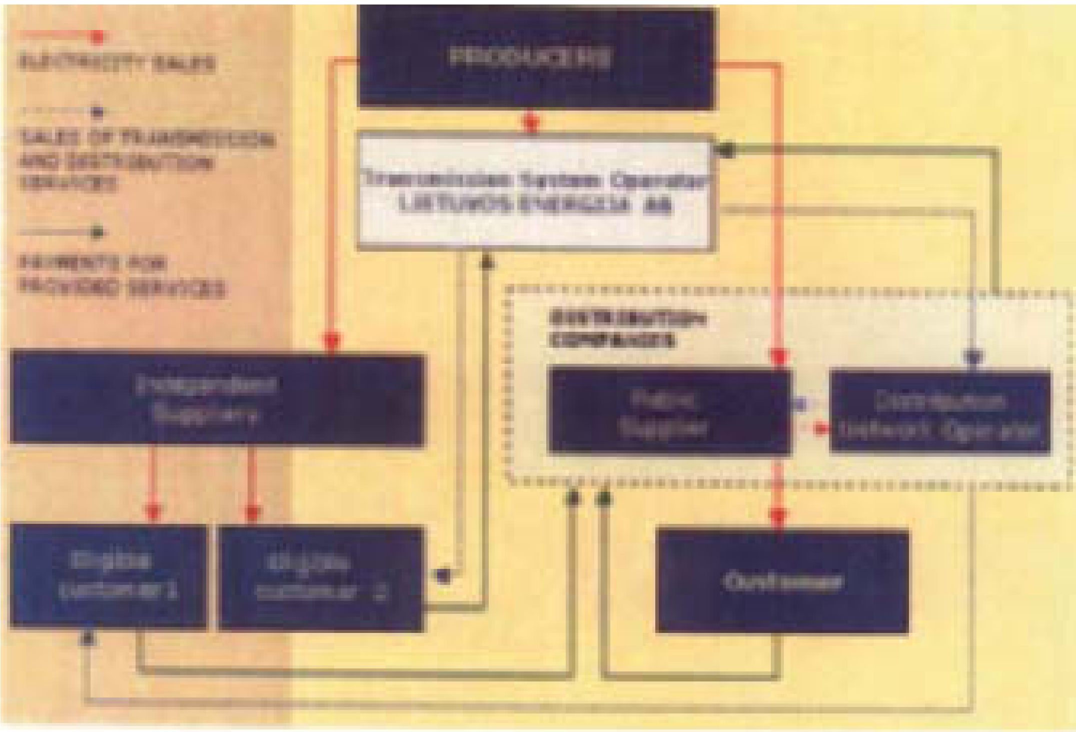


Figure 4.15. Structure of the Lithuanian Electricity Market.

4.1.5. Heat Supply System

Economic recession after 1991 and efficiency increase in heat utilization in the ensuing years resulted in the significant reduction of heat consumption. After 1996, with the stabilization of the Lithuanian market-oriented economy, heat consumption (and thus heat production) decreased further. In 2000 heat production was at about 34 % of the 1990 level. Two major factors drove this reduction in heat consumption, namely (i) efficiency increase in heat utilization and (ii) heat consumers in industry, services and other sectors disconnected from district heating utilities and shifted to self-production. It is important to note that such a disconnection and shift away from the district-heating network does not in any way mean that heat is not used any more. This is more related to accounting practice in the Lithuanian statistics: when an enterprise is disconnected from the district heating network and starts to generate its own heat, the statistic records in this case fuel consumption (in order to generate heat) rather than heat itself. Thus, official statistical data in effect reflects heat production in district heating utilities and heat supply to various consumers.

The balance of heat production and consumption for the period 1990–2000 is presented in Table 4.7. It is necessary to point out that heat production in the "industrial utilization equipments" row of Table 4.7 is the by-product of the industrial processes, not the production of heat *per se*. The use of this by-product heat in fact reduces fuel consumption. In the year 2000 such a heat production "in industrial utilization equipments" was accounted from the following industrial factories: Mazeikiai Refinery (635 GW·h), fertilizer factory JSC Achema (733 GW·h), Kedainiai fertilizer factory (785 GW·h) and other enterprises (23 GW·h) [33].

Table 4.7. Heat Production and Consumption in Lithuania in Selected Years, GW·h [14, 32]

Year	1990	1996	1997	1998	1999	2000
Produced	*39737.2*	*22605.8*	*20850.4*	*20083.8*	*16235.4*	*13726.9*
Power plants	13162.8	8056.7	7347.4	7263.2	6112.2	5256.3
Heat only boilers	24791.9	13015.6	11709.4	10739.8	8139.7	6294.5
Industrial utilization equipment	1782.6	1533.5	1793.6	2080.8	1983.5	2176.1
Gross consumption	*39737.2*	*22605.8*	*20850.4*	*20083.8*	*16235.4*	*13726.9*
Consumption of the energy branch	2039.5	1304.8	1407.4	1635.2	1325.2	1057.1
Losses in transportation and distribution	1679.1	5057.7	4031.3	3892	3336.3	2813.2
Final consumption	*36018.6*	*16243.3*	*15411.7*	*14556.6*	*11573.9*	*9856.6*
Industry	19136.0	5115.5	4759.7	4703.5	2789.1	2115.6
Construction	869.8	21.6	14.2	45.4	31.3	24.6
Agriculture	2222.1	375.1	433.2	416.7	230.8	136.8
Commercial and public services	130.2	2641	2804.1	2373.2	2307.5	1953.7
Households	13660.5	8090.1	7400.5	7017.8	6215.2	5625.9

In Lithuania, heat is produced from two types of facilities: boiler-houses and power plants. For example, at the Lithuanian TPP two units of 150 MW, converted to combined heat and electricity production have an equivalent heat production capacity of 2 x 174.4 MW. Vilnius CHP-3 has two turbines with heat capacity 2 x 302.3 MW, thermal capacity of Kaunas CHP turbines is 186 MW and 203.5 MW. In addition, Kaunas CHP has 4 x 116 MW + 1 x 209 MW of water heating boilers and 255 MW of heat exchangers that can convert high-pressure and high-temperature heat from steam boilers into low-temperature heat that can be delivered to residential consumers. Thermal capacity of Mazeikiai CHP turbines is 2 x 215.1 MW. Turbines of Vilnius CHP-2, Petrasiunai CHP and Klaipeda CHP have comparatively low thermal capacity (2 x 51.2 MW, 73.6 MW and 43.8 MW correspondingly), however they have large capacities in water heating boilers. Capacities of boilers at those CHPs are 814 MW, 232 MW and 174 MW respectively.

Capacity and other important parameters of heat generators in all district heating utilities or companies involved in district heat production are presented in Table 4.8. It can be seen that in all district-heating utilities (DHU) there is a big overcapacity and it is caused by significant reduction of heat consumption. The utilization factor of installed thermal capacities of boiler houses usually does not exceed 10%.

Table 4.8. Selected Parameters of District Heating Utilities in Lithuania [34, 35]

No	Enterprise	Available capacity, MW	Throughput capacity of network, MW	Maximal demand in 2001, MW	Heat production, GW·h	Heat distribution losses, %
1	JSC Vilniaus energija	2432	5308	1029	3039.3	20.4
	- power plant	1344	3091	867	2606.0	0.0
2	JSC Kauno energija	2134	3130	584	2015.5	25.1
	- power plant	1646	2062	502	1710.6	0.0
3	JSC Klaipedos energija	1042	1713	481	919.0	15.2
	- power plant	312	0	176	372.0	0.0
4	JSC Panevezio energija	1023	1896	161	883.6	17.0
5	JSC Siauliu energija	709	877	203	588.3	23.5
6	Jonava DHU	159	445	129	175.1	20.2
7	Mazeikiai DHU	214	307	60	171.1	22.6
8	Utena DHU	134	107	56	169.9	20.1
9	Druskininkai DHU	163	185	66	136.3	26.5
10	Taurage DHU	179	168	31	89.1	21.0
11	Silute DHU	115	100	48	88.9	26.7
12	Plunge DHU	82	94	50	42.3	25.7
13	Radviliskis heat	81	46	20	69.2	24.3
14	Raseiniai DHU	71	60	19	51.2	27.5
15	Birzai DHU	72	56	28	52.7	21.9
16	Kaisiadoriai heat	63	71	22	43.5	20.2
17	Prienai energy	69	39	36	41.6	26.9
18	Ignalina DHU	49	19	13	40.0	27.5
19	Lazdijai DHU	36	*	15	22.1	19.5
20	Svencionys energy	38	47	15	28.0	25.9
21	DHU of Vilnius region	38	7	6	11.1	15.1
22	JSC "Litesco"	1047	731	478	626.0	22.1
	- Alytus energy	430	495	156	162.6	14.9
	- Marijampole heat	388	*	234	241.1	24.2
	- Telsiai heat	82	82	33	90.6	24.4
	- Palanga heat	125	141	33	106.7	27.5
	- Vilkaviskis heat	*	*	*	*	*
	- Kelme heat	23	13	22	25.0	16.0
23	*Total*	*9949*	*15406*	*3550*	*9303.9*	*21.1*

* Data are not available.

4.2. Fuel Prices

Lithuania has quite active trade relations with neighbouring countries. It imports about 90% of its total primary energy requirements and exports mostly oil products and electricity. Taking into account the existing capacities in the power system, refinery and oil terminals, flows of energy trade might be even much larger. However, economy decline in neighbouring countries and financial difficulties hinder this possibility for higher energy trade. Given the level of Lithuanian dependency on energy trade prices of fuels on the international market have a crucial impact on the whole Lithuanian energy system and its future development. Prices of the main energy products imported in 1997–2001 are shown in Table 4.9. Prices of exported fuels and electricity for the same time period are shown in Table 4.10.

Table 4.9. Prices of Imported Fuels and Electricity, LTL/t [33, 34, 36]

Imported fuel	Calorific value, kcal/kg	Year					Average in 1997–2001
		1997	1998	1999	2000	2001	
Coal	6000	216	159	140	140	155	162
Antracite	7000		203	198			201
Coal blocks	6000		154	176	180	137	162
Coke	7000		438	332	325	420	379
Brown coal	4500	197	95		80	82	114
Crude oil	10000	453	322	423	775	651	525
Condensate of natural gas	10430		341	356	770	695	541
Petrol < 95	10500	810	648	622	1010	847	787
Petrol = 95 - < 98	10500	810	648	791	1100	764	823
Petrol >= 98	10500	810	755	937	1440	1554	1099
Diesel oil	10150	715	572	914	1005	739	789
Light fuel oil	10080		374	320	725	739	540
Jet kerosene	10290		611	727	1010	999	837
Jet petrol	10290				1300	1011	1156
Petrol	10290		2204	2023	3100	2548	2469
Heavy fuel oil HSC	9550	333	235	209	500	399	335
Shale oil	10500		400	384	480	487	438
Propane	10500	589	542	588	920	915	711
Butane	10500	589	582	540	920	915	709
Natural gas, LTL/1000 m^3	8000		435	372	390	439	409
Oil bitumen	9450	423	548	590	650	628	568
Lubricants	6510	197		3440	3920	3203	2690
Orimulsion	6700	184	216	180	200	200	196
Electricity, LTL/MWh	860*		59	59	65.9	67.8	63

* kcal/kWh

An important factor in making assumptions about future oil prices is that the ratio of the prices of Russian oil supplied to Lithuania to the ones of the Brent crude oil was more or less constant and averaged over the period 1997–2000 at 0.926. One of the factors leading to the lower price of Russian crude oil delivered to Lithuania in comparison with the Brent crude oil is lower transportation cost owing to the existing pipeline system through which Russian oil is transported to Lithuania.

Table 4.10. Prices of Exported Fuels and Electricity, LTL/t [33, 34, 36]

Exported fuel	Calorific value, kcal/kg	1997	1998	1999	2000	2001	Average in 1997-2001
Coal	6000	177					177
Antracite	7000						
Coal blocks	6000						
Coke	7000			497	520		509
Brown coal	4500	296					296
Peat	2310		155	160	153	152	155
Crude oil	10000	537	357	492	775	692	571
Condensate of natural gas	10430						
Petrol <95	10500	849	604	596	1025	1049	825
Petrol =95-<98	10500	849	642	634	1110	957	838
Petrol >=98	10500	849	735	843	1250	1112	958
Diesel oil	10150	685	522	532	990	866	719
Light fuel oil	10080	667					667
Jet kerosene	10290		547	630	1110	951	810
Jet petrol	10290				1250	1564	1407
Petrol	10290		5636	5381	3990	4111	4780
Heavy fuel oil HSC	9550	322	238	212	440	379	318
Shale oil	10500						
Propane	10500	498	408	323	1150	738	623
Butane	10500	498	454	347	845	807	590
Natural gas	8000	655					655
Oil bitumen	9450	476	360	296	490	515	427
Lubricants	6510	296	1789	1342	1540	1938	1381
Orimulsion	6700						
Electricity, Lt/MWh	860 *		83.2	82.3	58.21	51.73	68.86

* kcal/kWh

Concerning the prices of oil products, they also vary slightly over the period 1997–2000 but no clear trend can be detected. Thus, for the analysis in this study, these prices are calculated in fixed proportion to the price of Russian crude, which in turn is assumed to be constant over time and is equivalent to the average ratio of the price of corresponding oil products over the average Russian crude oil price during 1997–2001 (Table 4.11).

Table 4.11. Ratio of Fuel Prices to the Price of Crude Oil Imported from Russia

Fuel type	1997	1998	1999	2000	2001	Average in 1997–2001
Russian crude oil	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Lithuanian crude oil	1.1854	1.1087	1.1631	1.0000	1.0630	1.0873
Petrol < 95	1.7029	1.9166	1.4004	1.2412	1.2391	1.4289
Petrol = 95 - < 98	1.7029	1.9166	1.7809	1.3518	1.1177	1.4928
Petrol >= 98	1.7029	2.2331	2.1096	1.7696	2.2734	1.9948
Diesel oil	1.5550	1.7501	2.1288	1.2776	1.1184	1.4812
Light fuel oil	-	1.1523	0.7505	0.9281	1.1262	1.0199
Jet kerosene	-	1.8440	1.6702	1.2665	1.4913	1.5495
Jet petrol	-	-	-	1.6301	1.5092	2.1397
Petrol	-	6.6518	4.6477	3.8873	3.8037	4.5716
Heavy fuel oil HSC	0.7697	0.7642	0.5174	0.6756	0.6418	0.6688
Propane	1.2383	1.6031	1.3239	1.1306	1.3386	1.2899
Butane	1.2383	1.7214	1.2158	1.1306	1.3386	1.2870
Oil bitumen	0.9881	1.8009	1.4760	0.8875	1.0208	1.1449
Lubricants	0.6680	-	12.4921	7.7697	7.5578	7.8737

In Lithuania, wood delivered to final consumers is priced at of 32–50 LTL/m^3 [37] which is equivalent to 43.0–67.3 US$/kWa. Other authors [38] predicted some increase in wood price due to the increasing wood demand. According to [38], average wood price in 2001–2005 will be 313 LTL/toe (58.9 US$/kWa) and in 2006–2010 will be 337 LTL/toe (63.5 US$/kWa). This price projection fits well into the price range mentioned in [37]. Therefore, for this study wood prices presented in [38] are used, extrapolating to the period after 2010. Taking into account that the wood distribution cost is about 15.3 US$/kWa, the average wood price before distribution (price of prepared wood) is 43.6 US$/kWa in 2001–2005 and 48.2 US$/kWa in 2006–2010.

Price of wood waste is in the range 6–25 LTL/m^3 [37] or 8.1-33.6 US$/kWa. Taking into account a distribution cost of 15.3 US$/kWa, the average price of wood waste is 5.55 US$/kWa. For future prices the same growth rate as for wood prices is assumed for the analysis. The price of straw is in the range 35–80 LTL/t [37] or 20.2–46.3 US$/kWa. Assuming a distribution cost of 19.2 US$/kWa the average price of straw becomes 14.1 US$/kWa. The price growth rate is assumed to be the same as for wood because those fuels are competing with one another.

The price of peat recommended for heat generation is about 130 LTL/t [39] or 106 US$/kWa. Assuming a distribution cost of 23.1 US$/kWa, the price of peat before distribution (or extraction cost only) is 82.9 /kWa. It is necessary to mention that this price is rather high but this is related to the peat use in agriculture. Peat used for agricultural purposes is even exported and the export price is about 155 LTL/t (Table 4.10). The limited peat resources in Lithuania and export possibilities for non-energy needs set rather a high market price of peat.
For this study, the forecast of crude oil prices presented in [37] was taken as a basis for

projecting future prices of all oil products. In [37] there are three scenarios of the future price of crude oil, namely: high scenario, average scenario and low scenario. According to the high price scenario, the price of crude oil imported into Western Europe stands at 220 US$/toe in 2005 and 225 US$/toe in 2020 respectively. Crude oil prices for the average and low price scenarios are 170 US$/toe and 125 US$/toe in 2005 and 180 US$/toe and 127 US$/toe in 2020 correspondingly. Taking into account that crude oil prices according to the low price scenario [37] are much lower than current oil prices in Lithuania, the scenario of low crude oil prices is not considered in this study and only the high and average price scenarios for crude oil are studied. A forecast of prices for natural gas and high sulphur content heavy fuel oil can also be found in [37]. Those prices are as shown in Table 4.12. The same argument as that for crude oil prices applies: only the high price and the average price scenarios for natural gas and heavy fuel given in [37] oil are analyzed in this study. In addition, prices of crude oil, gas and heavy fuel oil of the average price scenario in [37] is termed as a “low fuel price scenario” in this study. The coal price projection is taken from [38]. The prices of lignite and coke are calculated from the coal price and the average ratios of the price of coal and that of lignite and coke (see Table 4.9).

Table 4.12. Prices of Natural Gas and Heavy Fuel Oil with High Sulphur Content on the Lithuanian Border, US$/toe [37]

Fuel	In 2005			In 2020		
	Price scenario			Price scenario		
	High	Average	Low	High	Average	Low
High sulphur heavy fuel oil	115	89	70	120	96	70
Natural gas	161.5	124.2	91.9	168.9	134.1	94.5

Based on the assumptions described above, fuel prices for all energy forms are estimated. Fuel prices for high fuel scenario of this study are shown in Table 4.13. Corresponding values for the low fuel scenario of this study are shown in Table 4.14. In addition, the base scenario of this study uses fuel prices that are assumed to be stable during the whole study period and correspond to the values of year 2000 presented in Table 4.13. Prices of oil products, coke and lignite in 2000 are calculated from actual oil and coal prices in Lithuania using the principles described above. Prices for exported fuels shown in Tables 4.13 and 4.14 are negative only because of modelling principles. This means that Lithuania receives revenue from exporting fuels.

Table 4.13. Forecast Fuel Prices for the High Fuel Price Scenario, US$/kWa

Fuel	2000	2005	2010	2015	2020	2025	2030
Import prices							
Crude oil (Russia)	146.0	153.5	154.6	155.8	156.9	158.1	159.3
Crude oil (West)	165.2	173.3	174.5	175.8	177.0	178.3	179.5
Own crude	158.7	166.9	168.1	169.4	170.6	171.9	173.2
Refinery additives	144.1	151.6	152.7	153.8	155.0	156.1	157.3
Coal (Russia)	60.3	55.2	52.7	51.2	50.2	50.2	50.2
Coal (Poland)	55.6	51.0	48.7	47.2	46.4	46.4	46.4
Coal (West)	58.5	53.9	51.6	50.1	49.3	49.3	49.3
Lignite (Russia)	56.3	51.6	49.3	47.8	46.9	46.9	46.9
Lignite (West)	52.0	47.6	45.5	44.1	43.3	43.3	43.3
Lignite (Ship)	54.7	50.3	48.2	46.8	46.0	46.0	46.0
Coke (Russia)	120.8	110.7	105.7	102.5	100.6	100.6	100.6
Coke (West)	111.5	102.2	97.6	94.6	92.9	92.9	92.9
Coke (Ship)	117.3	108.0	103.4	100.5	98.7	98.7	98.7
Light distillates	217.9	229.1	230.8	232.6	234.3	236.0	237.7
Medium distillates	216.2	227.3	229.0	230.8	232.5	234.2	235.9
Heavy fuel oil HSC	90.8	78.8	80.0	81.3	82.6	83.8	85.1
LPG	188.3	198.0	199.5	201.0	202.4	203.9	205.4
Other oil products	167.1	175.7	177.0	178.4	179.7	181.0	182.3
Heavy fuel oil LSC	105.6	110.5	111.3	112.1	112.8	113.6	114.3
Natural gas (Russia)	91.2	121.7	123.5	125.4	127.3	129.1	131.0
Natural gas (Latvia)	100.6	131.0	132.9	134.8	136.6	138.5	140.4
Natural gas (West)	110.0	140.4	142.2	144.1	146.0	147.9	149.7
Wood	43.6	45.4	50.0	54.6	59.2	63.8	66.6
Wood chips	43.6	45.4	50.0	54.6	59.2	63.8	66.6
Wood waste	5.6	5.8	6.4	7.0	7.5	8.1	8.5
Straw	14.1	14.7	16.2	17.7	19.2	20.6	21.5
Peat	82.9	82.9	82.9	82.9	82.9	82.9	82.9
Orimulsion	68.5	69.4	69.4	69.4	69.4	69.4	69.4
Nuclear	25.7	25.7	25.7	25.7	25.7	25.7	25.7
Export prices							
Lithuanian crude oil	-158.7	-166.9	-168.1	-169.4	-170.6	-171.9	-172.7
Light distillates	-222.1	-233.5	-235.3	-237.0	-238.8	-240.5	-241.6
Medium distillates	-197.0	-207.2	-208.7	-210.3	-211.8	-213.4	-214.3
Light fuel oil	-184.0	-193.5	-195.0	-196.4	-197.9	-199.3	-200.2
Heavy fuel oil HSC	-86.2	-74.8	-76.0	-77.2	-78.4	-79.6	-80.8
LPG	-165.1	-173.6	-174.9	-176.2	-177.6	-178.9	-179.6
Other oil products	-125.8	-132.3	-133.3	-134.3	-135.3	-136.3	-136.9
Gas	-91.2	-121.7	-123.5	-125.4	-127.3	-129.1	-130.3

Table 4.14. Forecast Fuel Prices for the Low Fuel Price Scenario, US$/kWa

Fuel	2000	2005	2010	2015	2020	2025	2030
Import prices							
Crude oil (Russia)	146.0	118.7	121.0	123.3	125.5	127.8	130.1
Crude oil (West)	165.2	135.8	138.2	140.7	143.1	145.6	148.0
Own crude	158.7	129.1	131.6	134.0	136.5	139.0	141.4
Refinery additives	144.1	117.2	119.5	121.7	124.0	126.2	128.5
Coal (Russia)	60.3	55.2	52.7	51.2	50.2	50.2	50.2
Coal (Poland)	55.6	51.0	48.7	47.2	46.4	46.4	46.4
Coal (West)	58.5	53.9	51.6	50.1	49.3	49.3	49.3
Lignite (Russia)	56.3	51.6	49.3	47.8	46.9	46.9	46.9
Lignite (West)	52.0	47.6	45.5	44.1	43.3	43.3	43.3
Lignite (Ship)	54.7	50.3	48.2	46.8	46.0	46.0	46.0
Coke (Russia)	120.8	110.7	105.7	102.5	100.6	100.6	100.6
Coke (West)	111.5	102.2	97.6	94.6	92.9	92.9	92.9
Coke (Ship)	117.3	108.0	103.4	100.5	98.7	98.7	98.7
Light distillates	217.9	177.2	180.6	184.0	187.4	190.8	194.2
Medium distillates	216.2	175.9	179.2	182.6	186.0	189.3	192.7
Heavy fuel oil HSC	90.8	59.2	61.0	62.7	64.5	66.2	67.3
LPG	188.3	153.2	156.1	159.0	161.9	164.9	167.8
Other oil products	167.1	135.9	138.5	141.1	143.7	146.3	148.9
Heavy fuel oil LSC	105.6	87.6	89.1	90.6	92.1	93.6	95.1
Natural gas (Russia)	91.2	93.6	96.1	98.6	101.1	103.5	105.0
Natural gas (Latvia)	100.6	102.9	105.4	107.9	110.4	112.9	114.4
Natural gas (West)	110.0	112.3	114.8	117.3	119.8	122.3	123.8
Wood	43.6	45.4	50.0	54.6	59.2	63.8	66.6
Wood chips	43.6	45.4	50.0	54.6	59.2	63.8	66.6
Wood waste	5.6	5.8	6.4	7.0	7.5	8.1	8.5
Straw	14.1	14.7	16.2	17.7	19.2	20.6	21.5
Peat	82.9	82.9	82.9	82.9	82.9	82.9	82.9
Orimulsion	68.5	69.4	69.4	69.4	69.4	69.4	69.4
Nuclear	25.7	25.7	25.7	25.7	25.7	25.7	25.7
Export prices							
Lithuanian crude oil	-158.7	-129.1	-131.6	-134.0	-136.5	-139.0	-140.5
Light distillates	-222.1	-180.7	-184.1	-187.6	-191.0	-194.5	-196.5
Medium distillates	-197.0	-160.3	-163.3	-166.4	-169.5	-172.5	-174.4
Light fuel oil	-184.0	-149.7	-152.6	-155.4	-158.3	-161.2	-162.9
Heavy fuel oil HSC	-86.2	-56.2	-57.9	-59.6	-61.3	-62.9	-63.9
LPG	-165.1	-134.3	-136.9	-139.5	-142.0	-144.6	-146.1
Other oil products	-125.8	-102.3	-104.3	-106.2	-108.2	-110.2	-111.3
Gas	-91.2	-93.6	-96.1	-98.6	-101.1	-103.5	-105.0

4.3. Options for Future Supply System and their Characteristics

4.3.1. System of Electricity Supply

The Lithuanian TPP consists of four units of 150 MW and four units of 300 MW numbering from 1 to 8. The oldest two units (Units 1 and 2) underwent a major refurbishment before 1990, which extends their lifetime to 2035. The possible operating time of other units ranges from 81.9 to 124.4 thousand hours (see Fig. 4.16 in which the horizontal axis shows the calendar year, the vertical axis shows the unit number and the number inside the bars indicate the possible operating time of the corresponding unit). Currently the Lithuania TPP serves as reserve capacity for the Ignalina NPP only. Actual utilization of the Lithuania TPP at full capacity will start only after the shut down of the second unit of the Ignalina NPP. It means real operation time of units No 3–8 of the Lithuanian TPP may reach the year 2029–2031. However, for the reliable operation of these units after 2010 some modernization works are necessary (e.g. replacement of control devices and instrumentation and control room equipment, refurbishment of steam turbines, etc.). The total investment for such kind of modernization is estimated to be about 54 million Euro, without accounting for the interest of capital. Investments for environmental protection measures will require an additional 249 million Euro. A detailed breakdown of these expected investments in order to modernize the Lithuania TPP is presented in Table 4.15.

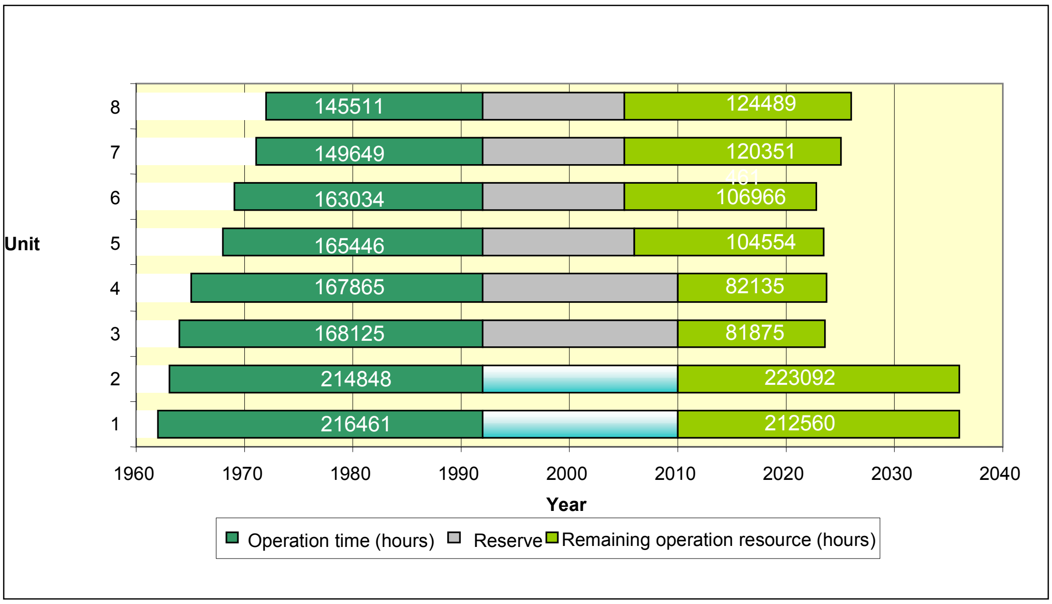


Figure 4.16. Operational History and Remaining Lifetime (in hours) of Different Units at the Lithuanian TPP [40].

In addition, based on the estimates made by Siemens, all 300 MW units can be repowered by installing a 70 MW gas turbine in front of each existing boiler and at the same time increasing the capacity of the existing steam turbine by 30 MW. The total capacity of one unit will then be 400 MW. Total overnight investment cost for such kind of reconstruction is estimated to be about US$ 47.5 million per unit (475 US$ for each additional kW). The thermal efficiency of these units would be increased to 43.4 %. The gas turbines of the repowered units will be fired with natural gas and the steam boiler will be fired with gas, heavy fuel oil or orimulsion. This future supply option may be considered for capacity increase or for efficiency improvement cases.

Table 4.15. Investments into Environmental Protection Measures and Equipment .Modifications of the Lithuanian TPP (1 Euro = 3.4528 LTL)

No	Measures	Reference	Investment, million LTL (million EUR)	Civil work, contingency million LTL
1.	Installation of Low NOx burners on boilers No. 8A, 8B, 7A, 7B, 5A, 5B, 1, 2	[41]	56	0.5
2.	Erection of flue gas desulphurization plant on boilers No. 8A, 8B, 7A, 7B, 6A, 6B, 5A, 5B, 1, 2	[41]	455	7.0
3.	Erection of Electrostatic Precipitator on boilers No. 8A, 8B, 7A, 7B, 6A, 6B, 5A, 5B, 1	[42]	95	4.5
4.	Construction of SCR deNOx equipment on boilers No. 8A, 8B, 7A, 7B	Estimation	240	2.0
		Subtotal	**846.0 (245)**	**14.0 (4.1)**
5.	Control System Modernization. Units No. 8, 7, 5, 1, 2	[43]	91.7	1.0
6.	Reconstruction of regenerative air preheater sealing system on boilers No. 8A, 8B, 7A, 7B, 6A, 6B, 5A, 5B (2 preheaters on each boiler part), 1 (1 preheater on each boiler)	[44]	18.9	0.3
7.	Implementation of antiexplosive safety devices and blocking system for boilers No. 8A, 8B, 5A, 5B	[45]	4.3	0.2
8.	Replace generator, unit No.5	[46]	46.0	0.4
9.	Replace feed water pump, unit No.5	[46]	12.0	0.2
10	Preparation for burning of orimulsion at 7 remaining boilers of 300 MW units	Estimation	7.5	
11	Preparation for burning of orimulsion at 3 remaining 150 MW units	Estimation	3.3	
		Subtotal	**183.7 (53.2)**	**2.1 (0.6)**
		Total	**1029.7 (298.2)**	**16.1 (4.7)**

However, such kind of modernization has never been done for Russian built turbines and other Russian types of equipment. Thus there is no guarantee that the performance of the high-pressure cylinder of the existing steam turbine after its capacity increase will be sufficiently reliable. Therefore, in this study, this option will not be considered in parallel with other possible modernization options.

The Vilnius CHP-3 can fired by both natural gas and heavy fuel oil. The choice of the fuel type depends on the fuel prices. It can easily be converted to orimulsion firing as well [47]. Preliminary calculations indicate that the cost of the Vilnius CHP-3 modernization in order to allow the usage of orimulsion amounts to LTL 3.8 million (Table 4.16).

Practical experience and the theoretical calculations show that firing by orimulsion produces the following pollutant concentrations in the flue gas:

- Sulphur anhydride (SO_2) 5 800 – 6 200 mg/Nm^3;
- Nitric oxide (NOx) 350 – 450 mg/Nm^3;
- Solid particles (ash, V_2O_5) 100 – 150 mg/Nm^3.

Thus, to achieve the ratings set out in the Directive 88/609/EEC, it appears essential to install the boiler flue gas treatment facilities as follows:

- Ash filters, with efficiency in excess of 67%;
- Desulphurization equipment, with efficiency in excess of 94%.

Table 4.16. Investment Cost of Conversion of the Vilnius CHP 3 to Orimulsion Firing, thousand LTL [47]

Equipment and Work Description	Unit Price	Total
a) Suction Drum Drainage Pumps, 2 units (80 m^3/hour, 3 bar)	30	60
b) Mains heating-system water line for circulation fuel heaters complete with instrumentation		50
c) Screw-type Pumps, 2 units (160 m^3/hour,10 bar) complete with motor speed regulators and fittings	80	160
d) Fuel line electric trace heating (3,400 m) and thermal insulation		1130
e) TGME-206 Steam Boiler fuel feed arrangement: filters (700 µm), 2 units; screw pumps (80 m^3/hr, 10 bar), 2 units; speed regulator, 2 units; water/orimulsion heat exchangers; and piping, fittings, instrumentation.	300	600
f) Steam Boiler and Economizer convection superheater cleaning equipment	900	1800
Total		**3800**

Therefore, based upon the ecological, engineering and economic considerations, the optimal flue gas sweetening technique has been identified as the one using an electrostatic filter coupled with the desulphurization process, which will ensure the following [47]:

- High treatment efficiency in accordance with the EU Ecological Codes;
- Easy solution to the waste disposal problem;
- Low operating costs (approx. 300 LTL per 1 ton of SO_2);
- Relatively low capital outlay.

Total investment cost for the electrostatic filter and the desulphurization unit will be about LTL 76 million [47].

In order to comply with environmental standards on NO_x emissions installation of low NO_x burners will be required. Investment cost would be about LTL 8–14 million [41, 48]. In addition to the above mentioned, modification of air preheaters, control and instrumentation system and reconstruction of the electrical system to meet UCPT requirements will require additionally about LTL 58 million [48, 49].

The existing steam units at the plant have a ratio of 0.6 between electrical and heat capacity. This ratio can be raised by substituting the steam units with combined cycle units utilizing modern gas turbine technology in combination with conventional steam turbine technology. One of the possible options is the installation of an additional gas turbine in front of the existing steam boiler as for the Lithuanian TPP that was described above. Exit gas from the gas turbine in this case is utilized as combustion air to the existing boilers. However, evaluation of performance as well as investments requires extensive knowledge of the existing plant and deep analysis. Therefore, in this study this option, which raises electrical capacity by about 20% of the steam turbine driven generator, should be considered only as a preliminary assessment. The investment cost for that was assumed to be equivalent to the construction cost of the new gas turbine power plant, i.e. 370 US$/kW.

Kaunas CHP: Similar to the Vilnius CHP-3, modernization of the Kaunas CHP includes the installation of low NO_x burners at steam boilers, electrostatic precipitators and flue gas desulphurisation plants. Based on the cost estimation for the Lithuanian TPP [41, 42] investments for the above mentioned environmental measures of the Kaunas CHP are estimated as follows:

Low NO_x burners	LTL 21 million,
Electrostatic precipitator (one common per power plant)	LTL 11 million,
Flue gas desulphurization plant (one common per power plant)	LTL 46 million.
Total for environmental measures	LTL 78 million.

The control system of the Kaunas CHP is similar to that of the Vilnius CHP-3 and its modernization will require about LTL 30 million. The reconstruction of the regenerative air preheater sealing system on steam boilers of the plant costs about LTL 6.3 million [44]. The improvement of the heat supply system inside the plant requires about LTL 10 million.

Mazeikiai CHP: Investment cost for modernization of the Mazeikiai CHP is estimated as follows:

Low NO_x burners	LTL 18.6 million,
Flue gas desulphurization plant (one common per power plant)	LTL 46 million.
Total for environmental measures	LTL 64.6 million.

Modernization of the control system will also require about LTL 30 million and the reconstruction of the regenerative air preheater sealing system on four steam boilers of the plant costs about LTL 8 million. The Mazeikiai CHP conversion to use natural gas requires LTL 20 million. In addition to that the construction of the pipeline linking the CHP plant with Mazeikai costs LTL 120 million.

Kaunas hydro power plant and Kruonis hydro pumped storage plant: The Kaunas Hydro Power Plant has been in operation since 1960. Some parts of the generation and control systems are obsolete and have to be renovated in order to prolong the lifetime of the plant and increase reliability of operation. The cost for refurbishment of the power plant is estimated to be Euro 14 million.

The Kruonis hydro pumped storage plant has four 200 MW units and additionally four other units can be installed according to the plant design. The necessary investments for each additional unit are about LTL 150–200 million.

New CHP plants: In addition to the above mentioned existing power plants it will be possible to install new CHP plants for supply of electricity and heat in existing district heating systems in Lithuania. Possible electrical capacities and investment costs for new CHPs in the biggest Lithuanian towns are listed Table 4.17 below [50]. All of them are designed such that they are suitable for combined cycle operations.

Table 4.17. New CHP

New CHP	
Name of the electricity plant with capacity	**Estimated investment coast**
Klaipeda 225 MW	LTL 630 million
Alytus 90 MW	LTL 270 million
Marijampole 50 MW	LTL 175 million
Siauliai 138 MW	LTL 385 million
Panevezys 130 MW	LTL 375 million

New hydro power plants: Four sites for building new hydro power plants on the rivers Nemunas and Neris have been considered in Lithuania. The plant capacities, investment costs and operation hours at full capacity for each potential site are presented below:

- Alytus HPP about 72 MW, LTL 600 million, 4600 hours;
- Birstonas HPP about 72 MW, LTL 600 million, 4200 hours;
- Karmelava HPP about 30 MW, LTL 135.6 million, 6700 hours;
- Jonava HPP about 30MW, LTL 89 million, 6500 hours;

New CCGT: a new nuclear power plant (NPP) and a new CCGT plant can be built at the site of Ignalina, after its decommissioning to utilize existing site, infrastructure and qualified personnel. The investment cost in this case is lower in comparison with the cost of construction of a completely new plant at a new site. In this study it was assumed that investment cost for a new CCGT at the Ignalina site will be 400 US$/kW. In order to avoid concentrating big capacities at one site, the total capacity of new installations at the site of Ignalina NPP should not exceed 600 MW. In addition, a new gas fired power plant will require construction of a new gas pipeline which will cost about LTL 80 million [51].

Similarly, the existing space on the site of the Lithuanian TPP can be used for construction of new CCGT units. This can be done in addition to the existing capacities or instead of the rehabilitation of existing units. Advantage of this site in comparison with the site of the Ignalina NPP is that extension of the gas network will be not necessary. It was assumed that the investment costs for a new CCGT at both Ignalina's and Lithuanian TPP's sites are the same. The same capacity constraint of 600 MW was also applied.

New CCGT plants also can be constructed at new sites in Lithuania. This however will require higher investment costs and extension of the gas network. The investment cost for such type of installation was assumed to be 500 US$/kW. The investment cost per capacity unit of additional pipeline is assumed to be at the same level as for the Ignalina case.

New wind power plants: Given that Lithuania does not have sufficient domestic primary energy resources, electricity production based on renewable energy sources is very attractive. One possible way to utilize renewable energy is to construct wind power plants. One feasible option for wind energy is wind farms, to be constructed in the southwest of Lithuania on the border with Poland and the Russian Federation. The estimated capacity of this farm is 10 MW. The estimated investment cost is LTL 38 million or about 1050 US$/kW. In this study, the same investment requirement is assumed for other potential wind power plants in Lithuania. Taking into account the economy of scale and technological development which would eventually lead to a decrease of investment cost per kW of installed capacity of wind power plants this study assumes a 2% per annum reduction in investment costs of wind farms during the study period. However, the total installed capacity was constrained by 180 MW taking into account the limited number of available sites with comparatively high wind speed.

4.3.2. *System of Heat Supply*

Conversion of existing boiler-houses into CHPs: Existing boiler-houses can be converted into CHPs. For this purpose an additional gas turbine with generator can be installed in front of the existing boilers. Flue gas from the turbine in this case will be used as hot air in a steam or water heating boiler in addition to fuel being used before modernization. According to expert opinion, the capacity of the gas turbine in this case would be small (about 25%) in comparison with boiler capacity. This means that a gas turbine of about 25–30 MW might be used for the PTVM-100 boiler. The investment cost for such gas turbine would be about 350 US$/kW and about 6.5 US$/kW for reconstruction of the boiler.

Another way of converting boilers into CHPs is to install a steam turbine with a corresponding generator. The investment cost for such a set of steam turbine-generators was assumed to be 400 US$/kW. Installation of a steam turbine can also be combined with construction of an additional gas turbine in front of the boiler.

Conversion of existing boilers into biomass-fired boilers: More stringent environmental standards in the future will necessitate the reduction of heavy fuel oil consumption. Heavy fuel oil then can be substituted by natural gas or biomass. The utilization of biomass in boiler houses can be increased in three ways:

- Construction of new biomass fueled boilers;
- Conversion of existing boilers into biomass;
- Construction of CHPs based on biomass.

The investment cost for construction of a new biomass fuelled water heating boiler of 5–10 MW capacity is about 200 US$/kW, while conversion of an existing boiler into biomass will require about 140 US$/kW of investment cost [38]. The investment cost for a new biomass fuelled CHP was assumed to be1000 US$/kW.

Conversion of existing boilers into natural gas based boilers: Stricter environmental standards in the future will also lead to the higher utilization of natural gas in boiler-houses and conversion of boilers for gas firing. This option is very realistic when the natural gas network is not far away from the boiler-house and few boiler-houses in Lithuania have already been converted from heavy fuel oil into gas firing. A majority of the large boiler-houses in Lithuania is connected to the natural gas system and in this case replacing heavy fuel oil with natural gas will require little or no investment. Thus, the cost associated with switching from heavy fuel oil to natural gas will be related to the price difference between heavy fuel oil and natural gas.

In the case when the boiler-house is not already connected to the natural gas system, its conversion to a gas-fired boiler-house requires the upgrade of the existing boilers. This option is more complicated because according to the Lithuanian legislation, the conversion of boiler-house from heavy fuel oil to natural gas is considered equivalent to the reconstruction of the boiler-house. This requires obtaining a license from the State Energy Inspectorate, which in turn would require that the boiler operating on natural gas should have a metering system, and its control and safety systems should be much more advanced in comparison with the ones in boilers operating on heavy fuel oil. A list of particular requirements is elaborated upon by the State Energy Inspectorate for each type of boiler to be converted from burning of heavy fuel oil to burning of natural gas.

Lithuanian boiler-houses that might be connected to the gas grid in the future are equipped with boilers of the following marks DKVR 10/13, DKVR-6,5/13, KVGM-20, and PTVM-30M. However, the experience with the conversion of boiler-houses from heavy fuel oil to natural gas in Lithuania is still limited and therefore there is little information about the associated costs incurred with such a conversion. One source of information is available, namely data from the Utena boiler-house. According to these data, the costs for conversion of a boiler-house from heavy fuel oil to natural gas, taking into account the fulfillment of the requirements of the State Energy Inspectorate, is estimated to be 16 US$ per kW of boiler installed capacity. This cost includes the necessary development of the gas supply system inside the boiler-house.

According to the data for the Utena boiler-house, conversion of three DKVR-20/13 boilers to natural gas costs about LTL 1.3 million or 7.5 US$/kW of installed capacity. Conversion of the PTVM-30 boiler to natural gas costs about LTL 1.2 million or about 8.5 US$/kW. Those numbers do not include the cost of development of the gas supply system and take into account boiler modernization only.

In some boiler-houses the conditions are such that the construction of new gas fired boilers instead of conversion of the existing boilers can be a more economically attractive option. The investment cost for new boilers is estimated to be about 23 US$–25 US$/kW of installed capacity for steam boilers or about 20 US$/kW of installed capacity for water heating boilers. These cost estimates take into account only investments of new boilers to be fitted into an existing boiler-house. It, however, does not include the investment cost for the building and the necessary infrastructure of the boiler-house.

4.3.3. System of Oil Supply

Mazeikiai Refinery: The main direction of modernizing The Mazeikiai Refinery is the quality improvement of light and medium distillates in order to make them competitive in the European market. This may increase the export of those products and increase the general utilization factor of the refinery. However, officially available information about investment costs necessary for the modernization, as well as possible changes in refinery performance is not sufficient. Therefore, in this study refinery modernization is modelled only by a constantly increasing possibility of export of light and medium distillates.

Desulphurization of heavy fuel oil: The Mazeikiai Refinery can also be upgraded in order to produce low sulphur content heavy fuel oil in Lithuania. This will require installation of the Residue Hydro Treating Unit. A low sulphur residue and small amount of light products would be produced by this unit. According to data for the Mazeikiai Refinery the investment cost for a residue hydro treating unit with a processing capacity of 2.5 million tons per year is about US$ 340 million (or 106.7 US$/kW). The selling price of such high-quality residue would increase by about 30 USD/t on average.

4.4. Modelling of the Lithuanian Energy System

In the sections that follow, techniques of representing various technological processes in the energy supply system including those of the existing system and the candidates for future development are discussed in detail. Special attention is given to the way technologies are modelled in the MESSAGE model.

In order to apply the MESSAGE model for the analysis of the energy system, the system in real life should be encoded in a special way. First of all *energy levels* and *energy forms* for each energy level should be specified by the user. Examples of *energy level*s are *Useful energy level*, *Final energy level*, *Primary energy level* or any other level that the user deems necessary for clear representation of the system. Examples of *energy forms* are *coal, oil, kerosene, electricity, heat* and others, depending on the system complexity and tasks of analysis. Technologies either transform one fuel type or energy form into another form or transport fuels or energy forms from one location in the system into another. Therefore, each technology links one or a few fuels or energy forms with others either at different energy levels or at the same level.

4.4.1. System of Oil Supply

The Lithuanian *system of oil and oil products* in the form applicable in the MESSAGE model is shown in Fig. 4.17. First of all this system includes import of crude oil from the Russian Federation (technology *crud-imp-rus*). The extraction of domestic crude oil processed at the Mazeikiai Refinery is modelled by *own-crud-extr*. The extraction of oil for export is not considered in this study because it has no impact on the remaining part of the system. The price of extracted crude oil is assumed to be equal to the export price of Lithuanian crude because the major part of it goes to export and sets the price. In principle it is possible to consider import by sea of medium (*mcrud-imp-west*) and light (*lcrud-imp-west*). The unloading cost of light or medium crude oil at the Butinge oil terminal is 7 US$/t or 4.84 US$/MWa.

In parallel with the import and extraction of crude oil, Lithuania can import oil products through the Klaipeda oil terminal or by trains. The variable costs of technologies representing the import of crude oil and oil products reflect fuel prices on the border of Lithuania and are taken from Tables 4.14–4.15. The variable cost of crude oil extraction, as already mentioned, represents the export price of crude oil and is also shown in Tables 4.14–4.15. These prices are different in different scenarios. The import of crude oil from the Russian Federation cannot exceed 16 Mt per year (or 21238 MWa/year), corresponding to the throughput capacity of the pipeline. The import volumes of other oil products are not constrained. Domestic crude oil may be transported to the Mazeikiai Refinery by trucks (*own-crud-trans*). The transportation cost in the form of a variable cost was assumed to be 10 US$/t or 6.92 US$/kWa.

Table 4.18. Representation of Refinery in the MESSAGE Model

Input products	**Value, ktoe**	**Input shares**	**Output products**	**For base year**		**For other years**	
				Value, ktoe	**Output shares**	**Value, ktoe**	**Output shares**
Crude oil	4659.4	0.8680	LPG	250.9	0.0467	260.8	0.0527
Additives (natural gas, liquids, refinery feedstock, half-finished products, additives)	311.5	0.0580	Heavy fuel oil	895	0.1667	941.6	0.1903
Electricity	43	0.0080	Medium distillates	1219.3	0.2271	1334.2	0.2696
Heat	28.55	0.0053	Refinery gas	140.7	0.0262	140.7	0.0284
Fuel	325.6	0.0607	Other oil products	185.4	0.0345	184.4	0.0373
			Light distillates	1999.5	0.3725	2086.8	0.4217

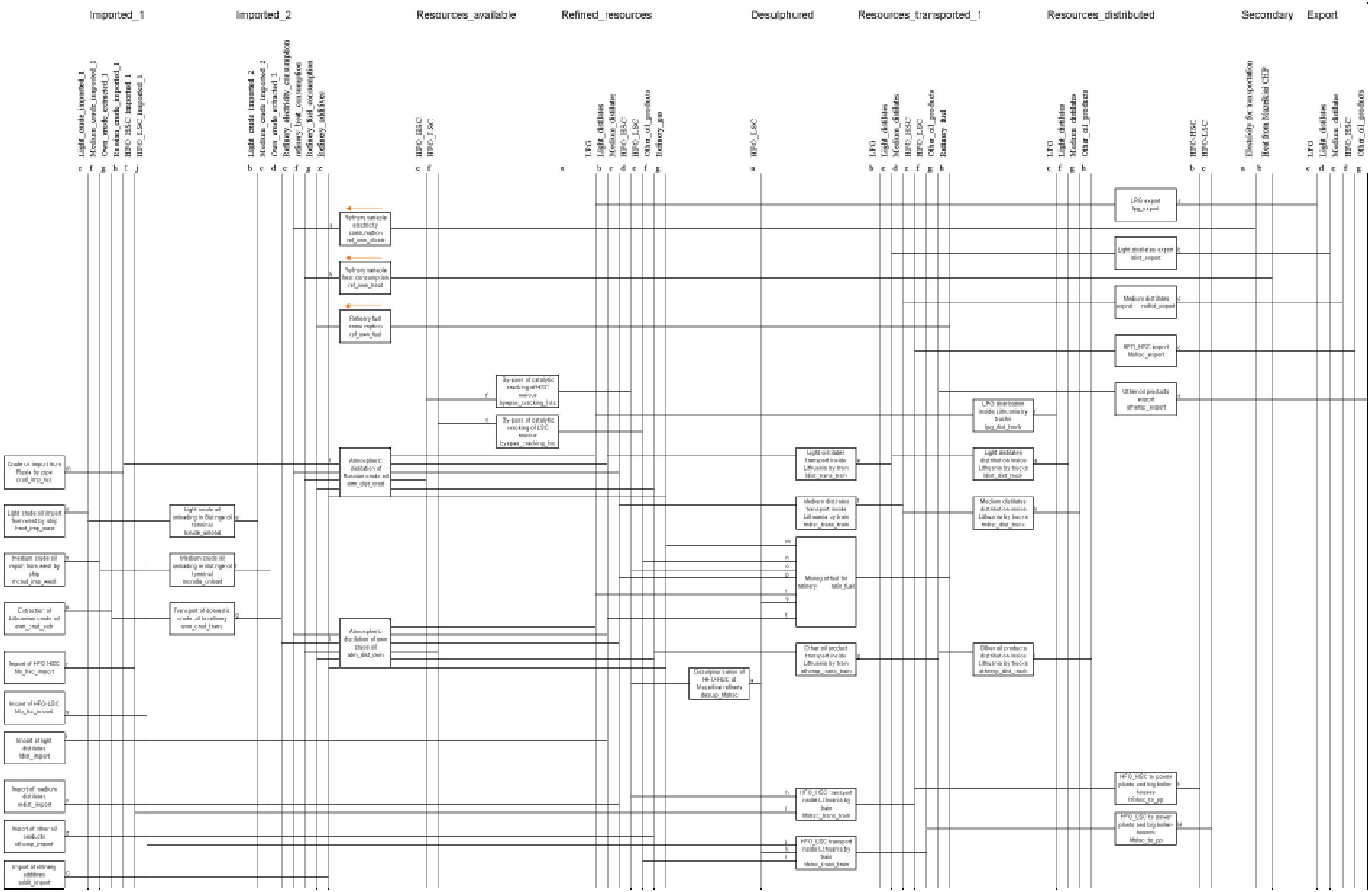


Figure 4.17. System of Oil and Oil Product Supply

The Mazeikiai Refinery processes either domestic crude oil or the crude oil imported from the Russian Federation. Thus, it is represented by a two-input technology — one for Russian crude oil (*technology atm-dist-crud)* and another for Lithuanian crude oil (*technology atm-dist-own*). Shares of product input and output to/from technology representing the refinery have been calculated using actual data for refinery operation in 2000. This information is presented in Table 4.18. The refinery output includes: refined oil products; some recovered products and inter-product transfers.

The composition of oil products by shares when Lithuanian oil is refined is different from that when Russian crude is processed. However, refining volumes of Lithuanian crude are very small in comparison with Russian crude; in addition, information about product output when Lithuanian crude is processed is officially not available. Taking this into account, the product output for Lithuanian crude in the MESSAGE model was assumed to be the same as for Russian crude. There is only one difference: if Russian crude is processed — heavy oil with high sulphur content is obtained; if Lithuanian crude is processed — heavy oil with low sulphur content is obtained.

The refining cost is 24 US$/toe [26, 52], which is equivalent to 323 US$/kWa for the main output of refinery (LPG). The capacity of the oil refinery is 15 Mt of crude oil [25]. Taking into account that for the existing representation of technology in the model, oil and all additives account for 92.6% of the total input, and that with the share of the main output being only 0.0486, the capacity of the refinery related to the main output is 1045 MW.

Own fuel consumption in the refinery is modelled using two technologies: *refin-fuel* and *ref-own-fuel*. The first one prepares a mix of fuel that is used in the refinery. Generally, all kinds of refinery products may be used for own consumption. The second one, *ref-own-fuel,* relates the output of *refin-fuel* with the input of refinery *atm-dist-crud* and others.

Desulphurization of high sulphur content heavy fuel oil is foreseen as a new option in the refinery. The investment cost for the desulphurization unit was assumed to be 106.7 US$/kW. This figure was calculated from data presented by the refinery (i.e. 340 million of US$ for 2.5 Mt of desulphurization) [53]. Technologies *ref-own-electr* and *ref-own-heat* correspondingly allocate electricity and heat for refinery own consumption. Heat and electricity are mainly taken from the Mazeikiai CHP. That is why no transportation losses and cost were assumed for electricity and heat.

Transportation of oil products in Lithuania by trains is represented by the following technologies:

ldist-trans-train – transportation of light distillates;
mdist-trans-train – transportation of medium distillates;
hfohsc-trans-train – transportation of high sulphur heavy fuel oil;
hfolsc-trans-train – transportation of low sulphur heavy fuel oil;
otherop-trans-train – transportation of other oil products.

A transportation cost of 10 US$/t is introduced into the model as a variable cost and correspondingly the following cost figures are used as inputs: 7.39 US$/kWa for light distillates, 7.42 US$/kWa for medium distillates, 7.85 US$/kWa for heavy fuel oil and 7.53 US$/kWa for other oil products. No constraints on transport volumes are foreseen because there are no technical constraints for railway transportation in Lithuania.

Oil products are first transported by train from the refinery to oil bases located in different places in the country. Further from those bases oil products are distributed to consumers by truck. In the model this feature is modelled using the following technologies:

ldist-dist-truck – distribution of light products;
mdist-dist-truck – distribution of medium products;
otherop-dist-truck – distribution of other products.

A distribution cost of 10 US$/t is used for all kinds of oil products and has been recalculated, taking into account different calorific values of oil products, to arrive at the distribution costs of various oil products: for LPG — 7.24 US$/kWa; for light distillates — 7.39 US$/kWa and for medium distillates — 7.42 US$/kWa and for other oil products — 7.53 US$/kWa.

The technologies *hfohsc-to-pp* and *hfolse-to-pp* represent the allocation of heavy fuel oil to power plants. These technologies have no costs and losses. The export of oil products is represented by the technologies:

lpg-export – export of liquid petroleum gas;
ldist-export – export of light distillates;
mdist-export – export of medium distillates;
hfohsc-export – export of heavy fuel oil;
otherop-export – export of other oil products.

The variable cost of these technologies represents prices of exported oil products, given in Table 4.14–4.15, and varies in different scenarios. In order to reflect the revenue from export — the prices of export fuels are accounted for as negative value. The export of oil products, especially motor fuels, will probably grow in future since the modernization of the Mazeikiai Refinery is aimed at quality improvement of light products. Taking this into account the export possibilities of light and medium distillates are assumed to increase by 5% annually. Exports of heavy fuel oil and other oil products are considered to increase by 2% per annum.

4.4.2. System of Gas Supply

The Lithuanian gas supply system as modelled in MESSAGE is shown in Fig. 4.18. Three alternative gas supply sources have been considered:

- Gas import from the Russian Federation through the existing gas pipeline (technology *gas_import_rus*),
- Gas import from Latvian gas storage (technology *gas_latvia_stor*),
- Gas import from Western countries (technology *gas_import_west*).

The third option requires construction of a new pipeline or Baltic gas ring. Construction of such a gas ring would require a lot of time and resources. So, in this study, importing gas from the West is assumed possible only after 2015.

The variable costs of technologies representing gas import are equal to the gas prices, shown in Tables 4.14–4.15. They are different in different scenarios. The volume of gas import from the Russian Federation is not limited because the Lithuanian gas network was designed for 12 billion m^3 of gas and current use is only about 2 billion m^3. However, seasonal variations in gas demand may cause constraints on the volume of gas import because of extraction limitations that could occur in Russian gas fields.

Beside the gas price, the variable cost of technology *gas_latvia_stor* also includes the cost of gas storage (9 US$/1000 m^3) and the additional transportation cost 0.8–1.2 US$/1000 m^3 [54]. After conversion into US$/kWa those costs correspond to 8.42 US$/kWa and 0.93 US$/kWa. The technologies *gas_to_stor*, *gas_from_stor* and *gas_storage_vask* model the possible construction of a new underground gas storage in Lithuania. The investment cost for an underground gas storage of 1 billion m^3 capacity is US$ 150 million or 140 US$/kW. The storage cost is taken to be similar to that of the Latvian gas storage, i.e. 8 US$/kWa.

Gas is being supplied to consumers within the Lithuanian territory through networks of high, middle and low pressure. These networks are modeled individually to reflect the situation that different consumers purchase gas from different pressure networks. In the MESSAGE model these networks are represented by the following technologies: *gas_high_pre* for the high pressure network*;* *gas_midl_pres* for the middle pressure and *gas_low_pres* for the low pressure networks correspondingly.

The transportation costs in these networks with different pressures are based on existing data established by the Price Committee [55]. In particular the transportation cost in the high pressure network is 30.72 LTL/1000 m^3 or 7.19 US$/kWa and that of the middle pressure network is 130.4 LTL/1000 m^3 or 30.51 US$/kWa. The latter corresponds to the gas distribution cost to consumers with annual gas consumption from 1 to 5 million m^3. It was assumed that those consumers are connected to the middle pressure gas network. The gas distribution cost for small consumers consuming up to 800 m^3 of gas is 420.51 LTL/1000 m^3. Assuming that the middle pressure and low pressure gas networks are involved in gas distribution activity, the cost of gas distribution through the low pressure network is therefore calculated as the difference between the two distribution costs and equal to 290.11 LTL/1000 m^3 or 67.87 US$/kWa.

The technology *gas_to_expo* represents the allocation of natural gas to all existing power plants and boiler houses. The technology *gas_to_newpp* models the connection of all new power plants to the existing gas network, meaning that the construction of these new power plants does not require any work related to the extension of the gas network. If, on the other hand, the construction of new power plants is related to the construction of an additional gas pipeline then a separate technology is used. For example, technology *new_gaspipe_ign* is related to the possible construction of a new CCGT at the site of the Ignalina NPP and represents the construction of a new pipeline of 70 km. The investment cost for such pipeline is LTL 80 million. Assuming that half of the pipeline capacity will be used to supply gas to the new power plant (another half for other consumers) then the investment cost for this technology is 61 US$/kW. Similarly, the technology *new_gaspipe_ccgt* represents the extension of the gas network in the case of a new CCGT being built far away from the existing high-pressure gas network. The investment cost for this new pipeline is similar to that of a new CCGT at the site of the Ignalina NPP, i.e. 60 US$/kW. The technology *gas_to_smallchp* models the extension of the middle pressure gas network in the case where a new small scale CHP is developed in future, and the technology *gas_netw_ext* models the extension of the middle pressure gas network if a decentralized heating system is developed instead of an existing district heating system. Both technologies involve investment in a gas network extension and additional gas losses.

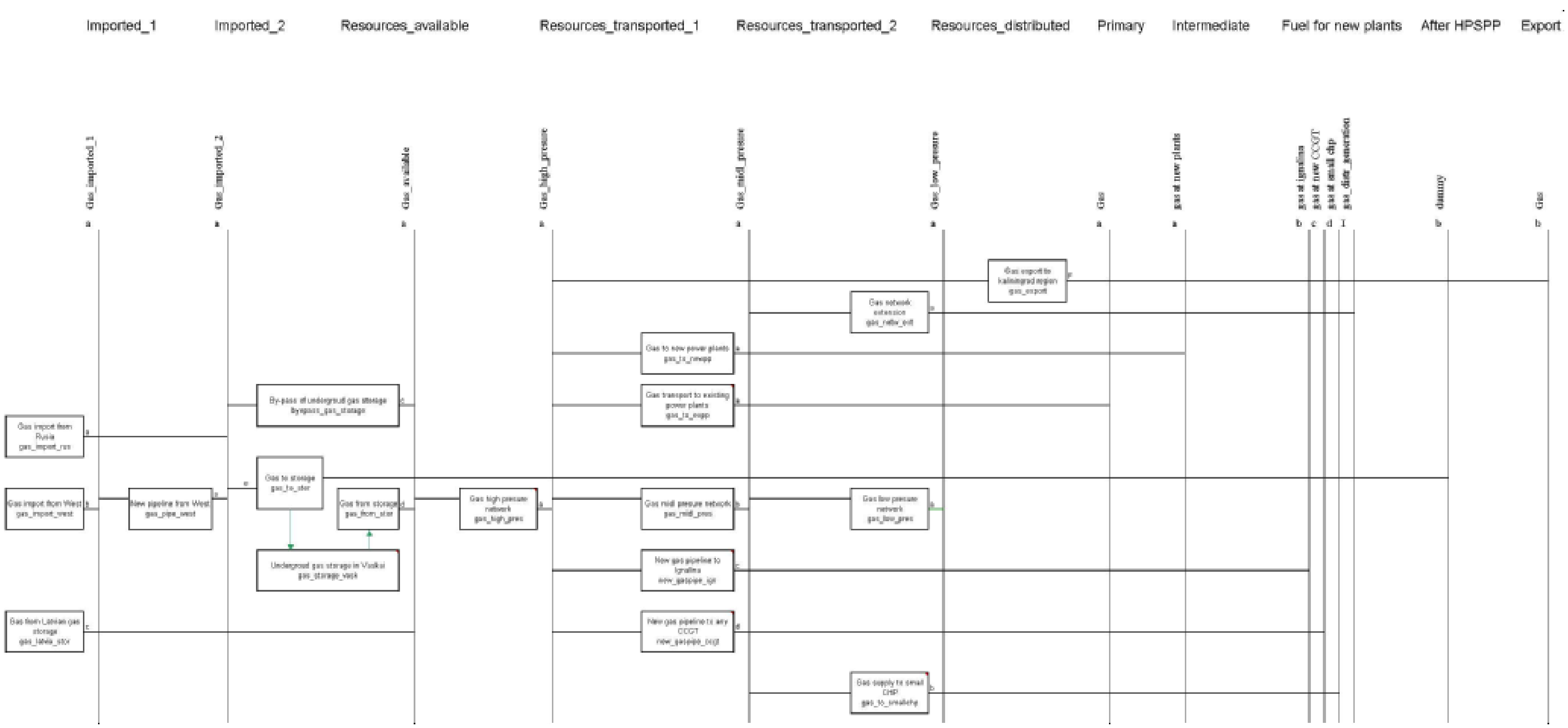


Figure 4.18. System of Gas Supply

4.4.3. System of Other Fuel Supply

The system of other fuel supply is shown in Fig. 4.19. It represents import, preparation, transportation and distribution of coal, lignite, coke, wood, wood waste, wood chips, straw, biogas, peat, orimulsion and uranium. The import of coal, coke and lignite is foreseen from the Russian Federation, Poland or other countries. The import may be carried out by train or ship. The second option involves an additional activity – unloading of ships and loading of trains at Klaipeda port. The technologies *coal-unload-load*, *lignite-unload-load* and *coke-unload-load* are devoted to the modeling of these processes.

The variable costs of technologies representing the import of various fuels include fuel prices in the world market and the transportation cost up to the Lithuanian border (see Tables 4.14–4.15). The variable costs of technologies *orimulsion_import* and *uranium_import* represent the fuel price at the power plant, which can be found in Tables 4.14–4.15. The fuel unloading/loading cost at Klaipeda port was assumed to be 10 US$/t. Thus, the unloading/loading cost for coal is 12.56 US$/kWa, for lignite 18.83 US$/kWa and for coke 10.76 US$/kWa. The variable costs of the technologies representing the preparation of wood (*wood_prepar*), wood chips (*wood_chip_prepar*), straw (*straw_prepar*), biogas (*biogas_prepar*), peat (*peat_preparation*) and wood waste collection reflect the price of prepared fuels. Prices of these fuels are discussed in Chapter 4.2.

Coal, lignite and coke for large consumers are transported by train. The transportation cost inside Lithuania has been assumed to be 10 US$/t. If coal is used by small consumers it firstly is transported to coal stores, from where it is further distributed by truck. The distribution cost has also been assumed to be 10US$/t. Wood, peat, straw and similar fuels are usually distributed locally. The distribution costs for wood, wood waste, straw and peat correspondingly are 15.3 US$/kWa, 15.5 US$/kWa, 19.2 US$/kWa and 23.1 US$/kWa. The technologies *wood_pp_boil*, *biomass_pp_boil* and *peat_pp_boil* represent the allocation of wood, biomass and peat to boiler houses and possible new power plants.

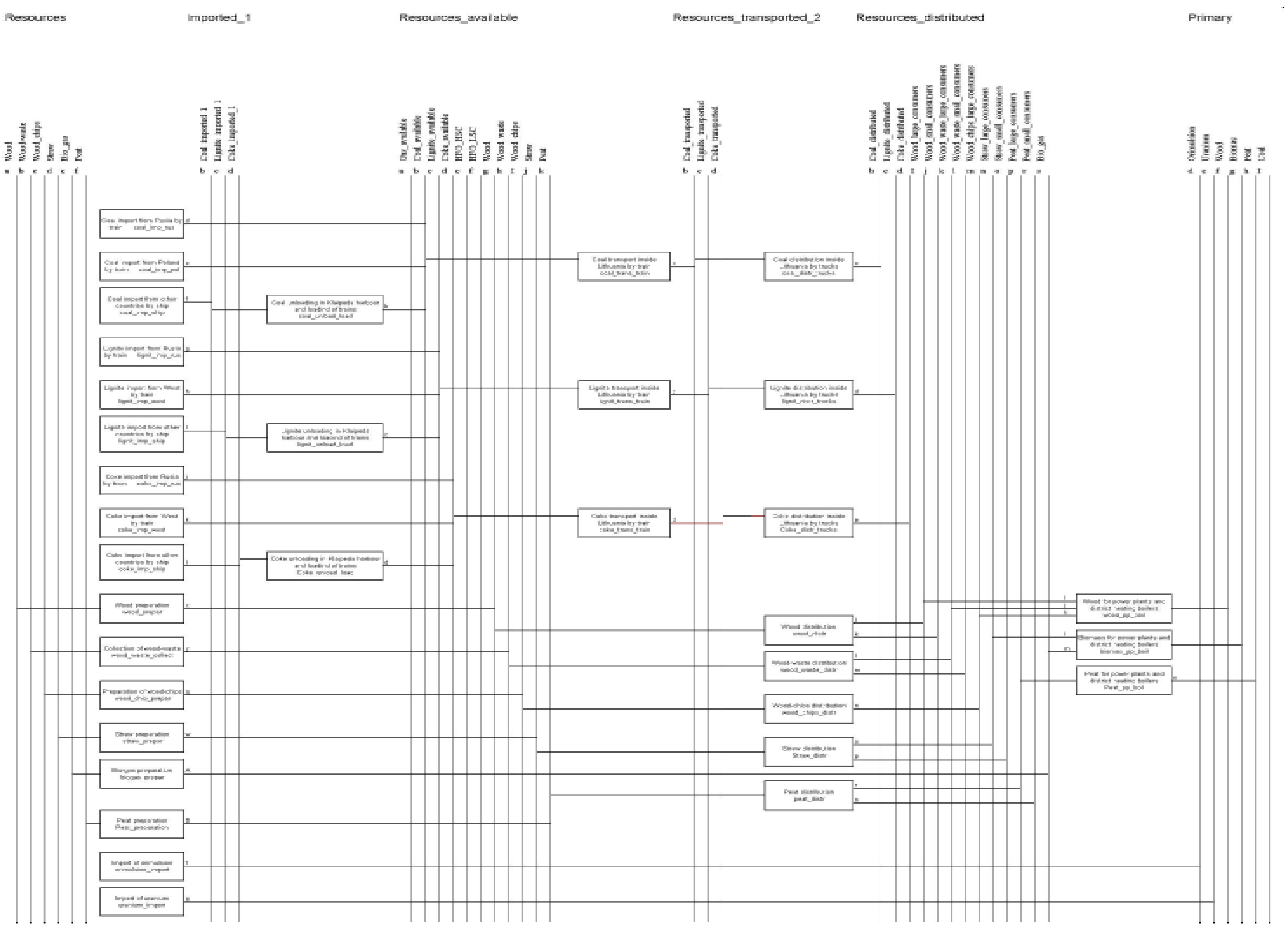


Figure 4.19. System of Other Fuel Supply.

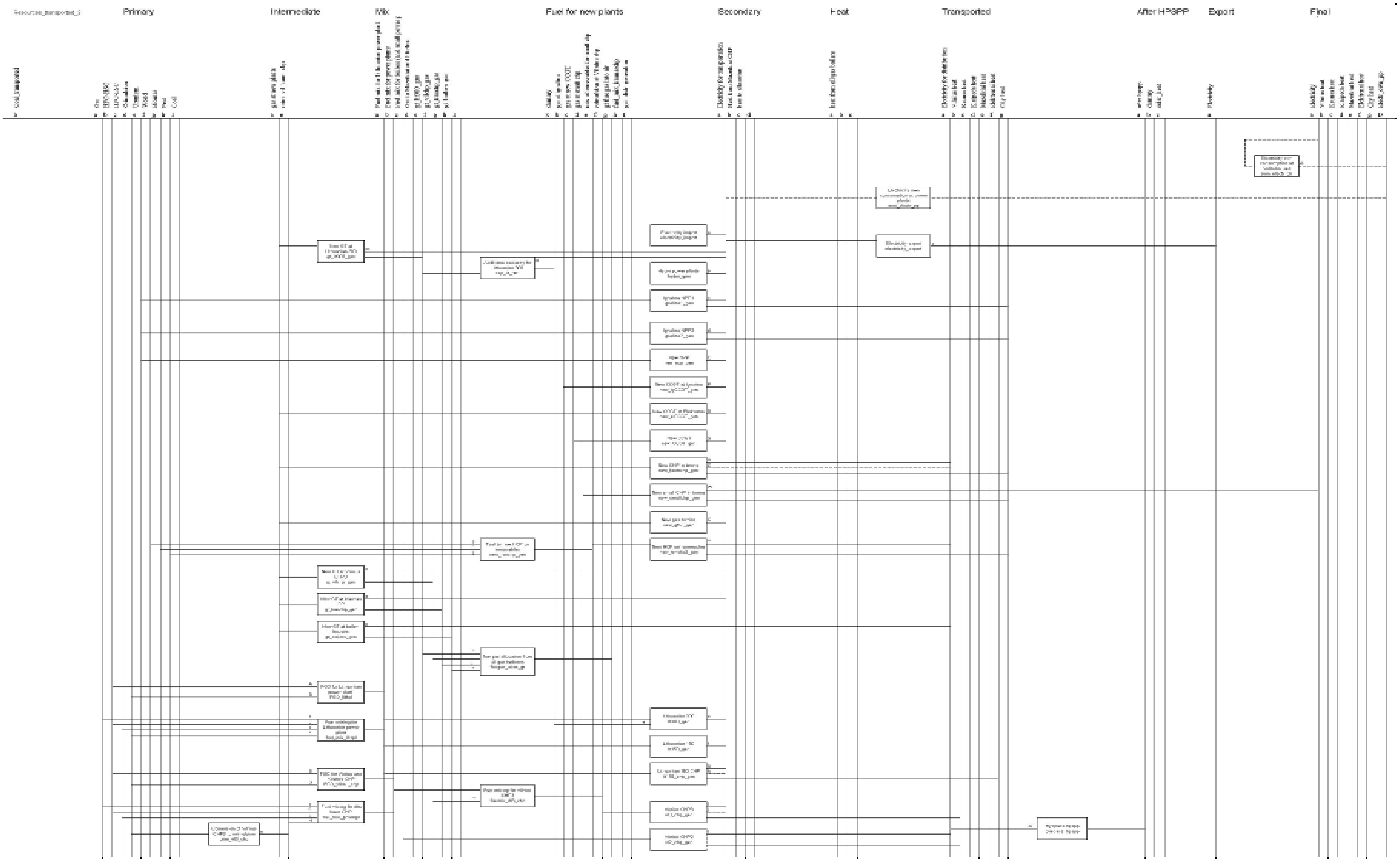


Figure 4.20. System of Electricity and Heat Generation (Part 1).

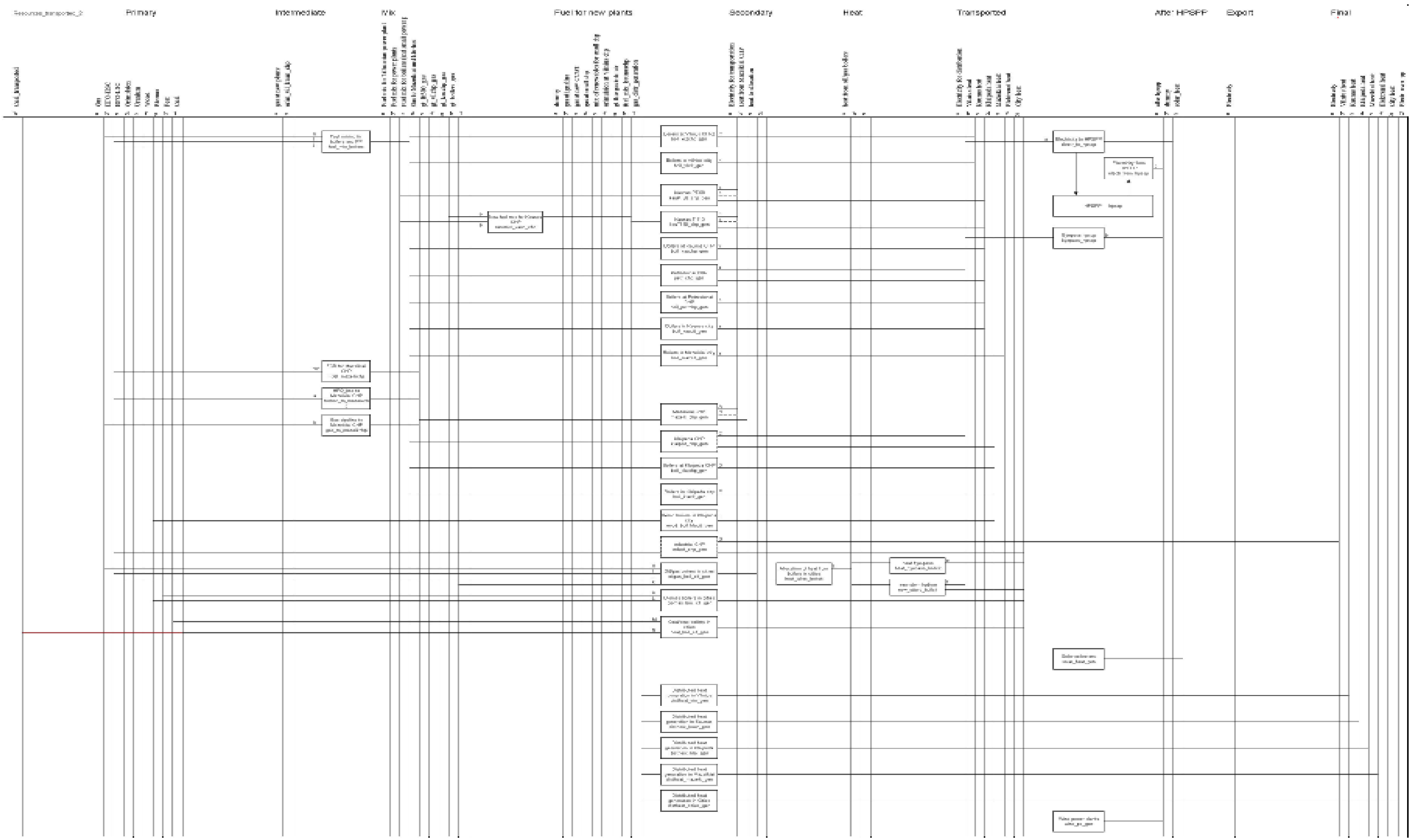


Figure 4.21. System of Electricity and Heat Generation (Part 2).

Table 4.19. Technologies Representing System of Electricity and Heat Generation (Part 1)

Plant name	Name of technology in the MESSAGE model	First year of operation	Plant factor	Operation time	Plant life	Construction time*	Investment cost**	Fixed cost	Variable cost
		Year	Fraction	Fraction	Year	Year	US$/kW	US$/kW	US$/kWa
New NPP	new_npp_gen	2010	0.9	0.9	30	4	1500	57.74	3.68
New CCGT at Ignalina	new_igCCGT_gen	2007	0.9	0.9	25	2	400	14.59	4.64
New CCGT at Elektrenai	new_elCCGT_gen	2007	0.9	0.9	25	2	400	14.54	4.64
New CCGT	new_CCGT_gen	2007	0.9	0.9	25	3	500	14.59	4.64
New CHP in towns	new_townchp_gen	2005	0.9	0.9	30	3	800	21.91	5.61
New small CHP in towns	new_smallchp_gen	2004	0.9	0.9	15	1	500	46.00	18.00
New gas turbine	new_gt50_gen	2005	0.9	0.9	20	1	350	9.24	8.76
New CHP on renewables	new_renchp2_gen	2005	0.9	0.9	30	2	1000	21.91	5.55
Electricity import	electricity_import		1						306.60
Existing hydro power plants	hydro_gen		0.9	0.9	30	1	123	9.41	3.47
New hydro power plants						5	2000		
Ignalina NPP1	Ignalina2_gen		0.9	0.76	20		0	33.69	10.52
Ignalina NPP2	Ignalina2_gen		0.9	0.76	30	4***	1500***	33.69	10.52
Lithuanian 300	lit300_gen		0.9	0.9	20	1	36	8.77	21.10
Lithuanian 150	lit150_gen		0.9	0.75	20		0	8.77	21.10
Lithuanian 150 CHP	lit150_chp_gen		0.9	0.82	25	1	36	8.77	21.10
Vilnius CHP3	vil3_chp_gen		0.9	0.82	20	1	40	18.23	4.73
Vilnius CHP2	vil2_chp_gen		0.9	0.72	5		0	65.14	87.04
Boilers at Vilnius CHP2	boil_vil2chp_gen		0.9	0.8	30	1	20	5.04	3.22
Boilers in Vilnius city	boil_vilcit_gen		0.9	0.8	30	1	20	7.27	21.82

*Construction time for existing power plants represents time necessary for their modernization.
**Investment cost for existing plants represent investment cost for their modernisation.
***For new unit at the site of Ignalina NPP.

Table 4.20. Technologies Representing System of Electricity and Heat Generation (Part 2)

Plant name	Name of technology in the MESSAGE model	First year of operation	Plant factor	Operation time	Plant life	Construction time*	Investment cost**	Fixed cost	Variable cost
		Year	Fraction	Fraction	Year	Year	US$/kW	US$/kW	US$/kWa
Kaunas PT-60	kauPT60_chp_gen		0.9	0.82	20	1	86	18.78	32.25
Kaunas T-110	kauT110_chp_gen		0.9	0.82	31	1	86	18.78	32.25
Boilers at Kaunas CHP	boil_kauchp_gen		0.9	0.8	30	1	20	4.37	6.35
Petrasiunai CHP	petr_chp_gen		0.9	0.72	5		0	65.14	87.04
Boilers at Petrasiunai CHP	boil_petrchp_gen		0.9	0.8	30	1	20	4.37	6.35
Boilers in Kaunas city	boil_kaucit_gen		0.9	0.8	30	1	20	7.27	21.82
Boilers in Mazeikiai city	boil_mazcit_gen		0.9	0.8	30	1	20	7.27	21.82
Mazeikiai CHP	mazeik_chp_gen		0.9	0.82	20	1	71	31.74	30.48
Klaipeda CHP	klaiped_chp_gen		0.9	0.72	5		0	65.14	87.04
Boilers at Klaipeda CHP	boil_klaichp_gen		0.9	0.8	30	1	20	13.44	7.37
Boilers in Klaipeda city	boil_klacit_gen		0.9	0.8	30	1	20	7.27	21.82
Wood boil. in Klaipeda city	wood_boil_klacit_gen		0.9	0.8	30	1	30	10.00	21.82
Industrial CHP	indust_chp_gen		0.9	0.72	30		0	65.14	87.04
Oil/gas boilers in cities	oilgas_boil_cit_gen		0.9	0.8	30	1	25	10.00	21.82
Biomass boilers in cities	biomas_boil_cit_gen		0.9	0.8	30	1	30	10.00	21.82
Coal/peat boilers in cities	coal_boil_cit_gen		0.9	0.8	30	1	30	10.00	21.82
New GT at Lithuanian 300	gt_lit300_gen	2007	0.9	0.9	20	2	320	6.51	0.88
New GT at Vilnius CHP3	gt_vilchp_gen	2006	0.9	0.9	20	2	370	6.51	0.88
New GT at Kaunas CP	gt_kauchp_gen	2006	0.9	0.9	20	2	370	6.51	0.88
New GT at boiler-houses	gt_boilers_gen	2006	0.9	0.9	20	2	400	6.51	0.88

*Construction time for existing power plants represents time necessary for their modernization.

**Investment cost for existing plants represent investment cost for their modernisation.

4.4.4. System of Electricity and Heat Generation

The system of electricity and heat generation including emission abatement technologies is shown in Fig. 4.20 and Fig 4.21. The main parameters of technologies producing electricity and heat are summarized in Tables 4.19 and 4.20.

Electricity own consumption at power plants is modelled using the additional technology *own_electr_pp* whose input is *Electricity for transportation* at the *Secondary* level and output is *Electr_own_pp* at the *Final* level. Electricity flow through technology *own_electr_pp* represents all electricity consumed at power plants for their needs (electricity and heat production). The electricity flow through technology *own_electr_pp* is represented by the additional equation:

$$X = \sum_{i=1}^{N} (k_{ia} x_{ia} + k_{ib} x_{ib}), \qquad (4.1)$$

where:

X – electricity flow through additional technology *own_electr_pp*,
k_{ia} – coefficient representing electricity own consumption when energy is produced in alternative “a” of the technology representing power plant i (electricity production at CHP in condensing mode),
k_{ib} – coefficient representing electricity own consumption when energy is produced in alternative “b” of the technology representing power plant i (electricity production at CHP in combined heat and power production mode),
x_{ia} – energy flow through alternative “a” of the technology representing power plant i,
x_{ib} – energy flow through alternative “b” of the technology representing power plant i,
N – number of power plants in the model.

Coefficients representing own electricity consumption at existing power plants and boiler-houses are presented in Table 4.21. For some power plants they are lower after closure of the first and second unit of the Ignalina NPP because it is expected that the load of those power plants will be higher, and leading to the lower own electricity consumption expressed per unit of energy output.

The obligatory limitation of SO_2 concentrations is also considered in the model. According to existing regulations in Lithuania the permissible level of SO_2 concentration is 2700 mg/Nm^3. before 2004, and 1700 mg/Nm^3 between 2004 and 2007. After 2008 the permissible level of SO_2 concentration for large combustion plants using liquid fuel will be 400 mg/Nm^3.

The abatement of SO_2 emissions from the Lithuanian TPP is modelled using the two technologies *FGD_lithpl* and *fuel_mix_lithpl*. The first technology models flue gas desulphurization (FGD) unit, while the second technology represents the supply of various fuels to the power plant by-passing FGD. The limitation of SO_2 concentration in the flue gas is modelled using the equation:

$$\frac{\sum_{i=1}^{n} e_i x_i + \sum_{j=1}^{m} e_j x_j}{\sum_{i=1}^{n} d_i x_i + \sum_{j=1}^{m} d_j x_j} \le C_t \qquad (4.2)$$

where:

e_i - SO_2 emission factor when fuel of type i is used in technology by-passing FGD,
e_j - SO_2 emission factor when fuel of type j is used in technology modelling FGD (t/MWa),
x_i – amount of fuel going through technology i by-passing FGD (MWa),
x_j – amount of fuel going through technology j modelling FGD (MWa),
n – set of fuels (liquid and gaseous) going through technology i by-passing FGD,
m – set of fuels (liquid and gaseous) going through technology j modelling FGD,
d_i – amount of flue gases going through technology i by-passing FGD (Billion Nm^3/MWa),
d_j – amount of flue gases going through technology j modelling FGD (Billion Nm^3/MWa),
C_t - Permissible concentration of SO_2 in flue gases (mg/Nm^3).

Table 4.21. Electricity Own Consumption at Existing Power Plants and Boiler-Houses

Power plant	**Alternative in MESSAGE model**	**GWh/GWh**		
		After 2000	**After 2005**	**After 2010**
Ignalina NPP		0.1190	0.1000	0.1000
Lithuanian TPP	Alternative a	0.1105	0.0715	0.0465
	Alternative b	0.1556	0.1132	0.0856
Vilnius CHP-3	Alternative a	0.0396	0.0500	0.0500
	Alternative b	0.1165	0.0865	0.0865
Vilnius CHP-2	Alternative a	0.2214	0.1382	0.1382
HOB at Vilnius CHP-2		0.0427	0.0427	0.0427
Kaunas CHP, PT-60	Alternative a	0.0493	0.0493	0.0485
	Alternative b	0.1754	0.1124	0.1116
Kaunas CHP, T-110	Alternative a	0.0493	0.0493	0.0485
	Alternative b	0.1322	0.0908	0.0900
Petrasiunai CHP	Alternative a	0.4250	0.2372	0.2364
HOB at Petrasiunai CHP		0.0384	0.0384	0.0384
Mazeikiai CHP	Alternative a	0.1074	0.0671	0.0671
	Alternative b	0.2468	0.1020	0.1020
Industrial CHP	Alternative a	0.2294	0.2294	0.2294
Klaipeda CHP	Alternative a	0.1739	0.1739	0.1739
HOB at Klaipeda CHP		0.0205	0.0205	0.0205
Other HOB		0.0418	0.0418	0.0418

Equation (4.2) may be transformed into equation (4.3):

$$\sum_{i=1}^{n} x_i k_{it} + \sum_{j=1}^{m} x_j k_{jt} \le 0, \qquad (4.3)$$

where coefficients k_{it} and k_{jt} are calculated using equations (4.4) and (4.5)

$$k_{it} = e_i - C_t d_i , \qquad (4.4)$$
$$k_{jt} = e_j - C_t d_j . \qquad (4.5)$$

Equation (4.3) is used until 2008. After 2008 it is replaced by equation (4.6) or (4.7) due to the requirement that SO_2 concentration should not exceed 400 mg/Nm^3 for liquid fuel. If natural gas is used in the fuel mix the permissible level of SO_2 concentration is lower.

$$\frac{\sum_{i=1}^{p} e_i x_i + \sum_{j=1}^{p} e_j x_j}{\sum_{i=1}^{p} d_i x_i + \sum_{j=1}^{r} d_j x_j} \le C_t, \qquad (4.6)$$

where:

p belongs to the set of liquid fuel types by-passing FGD,
r belongs to the set of liquid fuel types going through FGD.

$$\sum_{i=1}^{p} x_i k_{it} + \sum_{j=1}^{r} x_j k_{jt} \le 0, \qquad (4.7)$$

The coefficients k_{it} and k_{jt} for technologies bypassing FGD and technologies modelling FGD depend on the fuel type because of the different sulphur content in the fuel and the allowed SO_2 concentration in flue gases. Numerical values of those coefficients are presented in Table 4.22.

Table 4.22. Numerical Values of Coefficients k_{it} and k_{jt} in Equations (4.3) and (4.7)

Fuel type	**Permissible concentration 2700 mg/m^3**		**Permissible concentration 1700 mg/m^3**		**Permissible concentration 400 mg/m^3**	
	k_{it}	**k_{jt}**	**k_{it}**	**k_{jt}**	**k_{it}**	**k_{jt}**
Heavy fuel oil high sulphur content	12.244	-25.032	22.241	-15.034	35.238	-2.037
Heavy fuel oil low sulphur content	-11.574	-26.485	-1.475	-16.385	11.655	-3.255
0rimulsion	32.313	-23.631	42.156	-13.788	54.952	-0.993
Gas	-30.246	-30.246	-19.044	-19.044	-4.481	-4.481

Before closure of the second unit of the Ignalina NPP it is assumed that the existing but unutilized capacity of the Lithuanian TPP and CHP serves as cold reserve capacity. Fast reserve capacity can be provided by the Kruonis HPSPP. In order to model the reserve margin after closure of the Ignalina NPP it was assumed that the full installed capacity of the power plants could not be utilized for demand coverage. For each power plant it was assumed that the utilized capacity does not exceed 90% of the installed capacity, i.e. the installed capacity of each power plant was derated by 10%. Such a modelling approach, depending on total demand, guarantees about 300 MW reserve capacity in the power system. In addition the capacity of the Kruonis hydro power plant can also serve as short term reserve capacity. Modelling of the reserve capacity by derating of installed capacity was used for all scenarios analyzed. For scenarios with the new 600 MW nuclear power plant it was foreseen that two 150 MW units of the Lithuanian TPP would be kept in cold reserve. The cost of such reserve capacity for the whole study period was assumed to be at the current level and used in the form of a fixed O&M cost. Therefore, for nuclear scenarios the reserve capacity consisted of the unutilized capacity at all power plants (about 300 MW), two 150 MW units at the Lithuanian TPP and the available capacity at the Kruonis HPSPP. In the case when a 1000 MW new nuclear power plant was considered, reserve capacity was additionally increased by one additional 150 MW unit of the Lithuanian TPP.

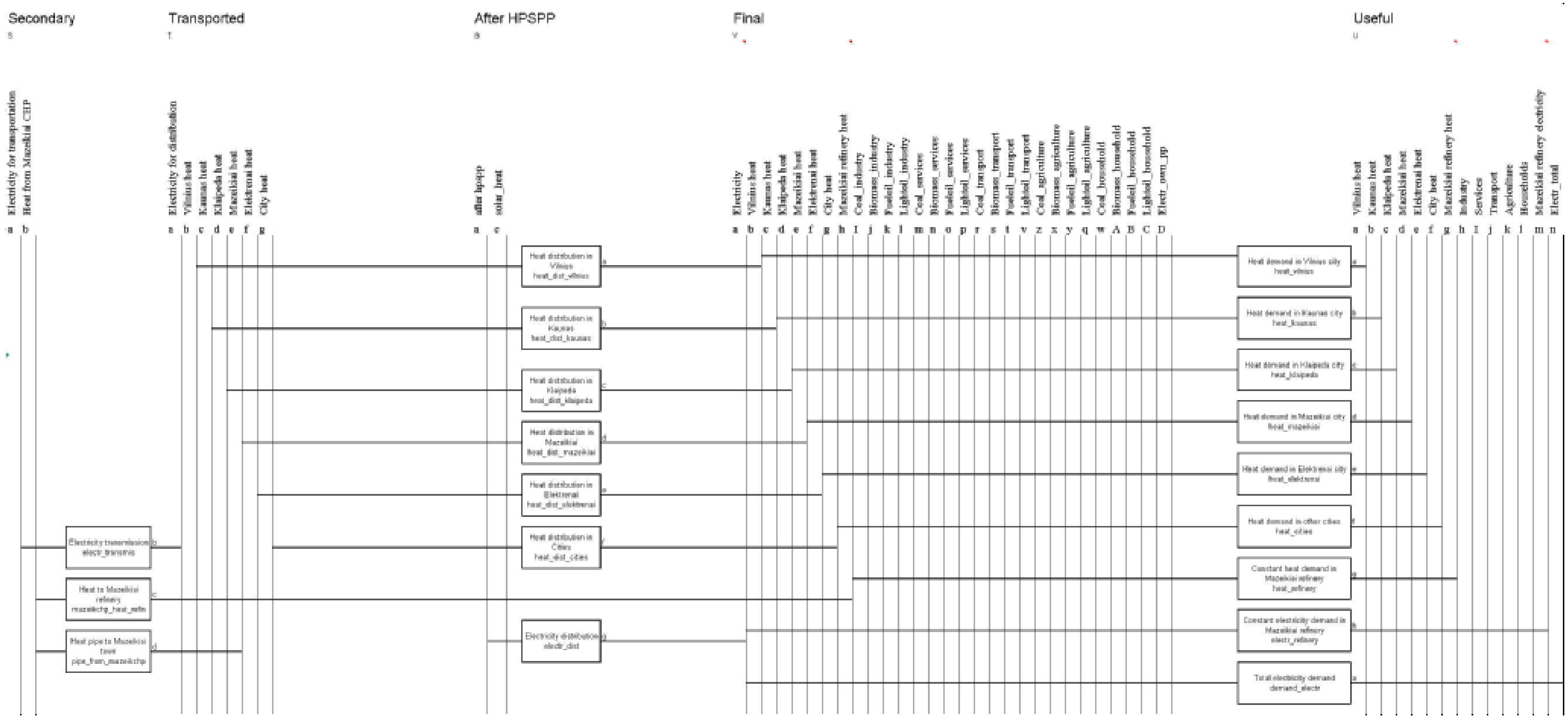


Figure 4.22. Transmission, Distribution and Demand of Heat and Electricity.

4.4.5. Transmission, Distribution and Demand of Heat and Electricity

Modelling of electricity and heat transmission and distribution systems is presented in Fig. 4.22. The technology *electr_transmis* models electricity transmission using a 110 - 330 kV power grid. According to data from the Lithuanian power company, the electricity transmission cost is 3 Lct/kWh or 65.7 US$/kWa. The transmission losses are 2.5 %. The high voltage electricity network has no bottlenecks because it was developed for much higher electricity flows and technology *electr_transmis* has no constraints on throughput capacity. Electricity distribution is modelled using technology *electr_dist*. The cost of electricity distribution according to data from the Lithuanian power company is 4.4 (Lct/kW·h) or 96.36 US$/kWa. Distribution losses are assumed to decrease from 14.6 % in 2000 until 11.0 % in 2025.

Heat distribution networks are modeled separately for Vilnius, Kaunas, Klaipeda, Mazeikiai and Elektrenai district heating systems. District heating in all remaining areas has been lumped into a single technology *heat_dist_cities*. Technologies modeling heat transmission and distribution are characterized by cost of district heat supply and distribution and by heat losses in the network. The average heat distribution cost for all district heating networks is 131.4 US$/kWa. This average cost is calculated based on official statistics, showing the total cost for heat production and distribution in the company.

Heat losses are different in different towns and they have been assumed to be decreasing from the current level of 9.4–31.4 % to 9.4–18.8 % in 2024. The technologies *heat_vilnius, heat_kaunas* and *heat_refinery* and *demand_electr* allocate heat or electricity from the final to the useful level.

4.4.6. Modelling of Energy Demand

As mentioned in the previous section, heat demand is allocated to 6 district heating areas. Electricity demand is modelled as a common demand for the whole country. Three seasons (end of winter, summer and beginning of winter) have been defined in order to represent the variation of the electricity demand from one season to the other during the year. Each season is represented by a working day and a day symbolizing Saturday, Sunday and holidays (SSH).

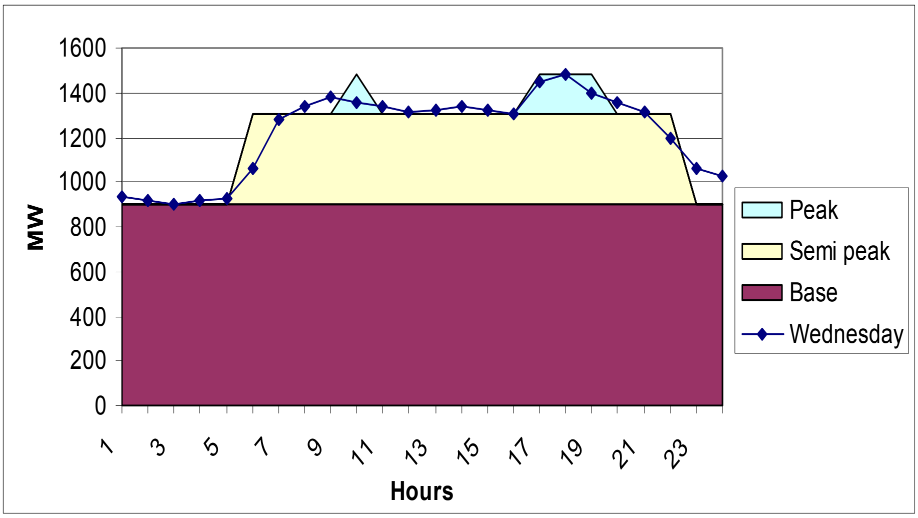


Figure 4.23. Typical Load Shape of the Working Day in the Season Beginning of Winter.

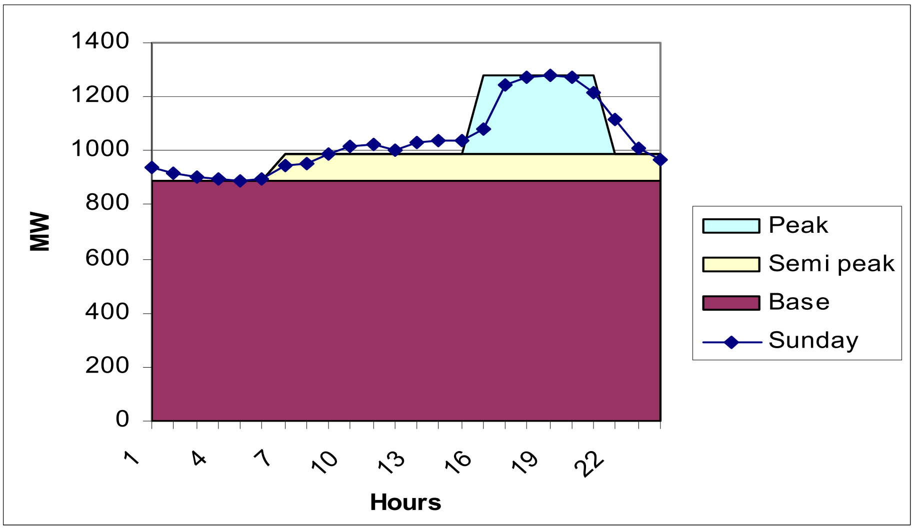


Figure 4.24. Typical Load Shape of Holiday and Weekends in the Season Beginning of Winter.

The electricity load shape of typical days representing the beginning of winter is shown in Fig. 4.23 and Fig. 4.24. Parameters characterizing electricity and heat demand variations are summarized in Table 4.23 and Table 4.24. The heat demand during a typical day was assumed to be constant because there are no reliable data on heat demand variation during the day in Lithuania.

Table 4.23. Length of Load Regions

Period	Day	Length of load regions, fraction						
		1	2	3	4	5	6	7
End of winter	WD	0.2500	0.1250	0.0417	0.2083	0.1250	0.1667	0.0833
	SSH	0.2917	0.3333	0.2083	0.1250	0.0417		
Summer	WD	0.2500	0.0833	0.3333	0.3333			
	SSH	0.0833	0.1667	0.5833	0.1250	0.0417		
Begin of winter	WD	0.2083	0.1667	0.0417	0.2500	0.1250	0.1250	0.0833
	SSH	0.2500	0.3750	0.2500	0.1250			

Table 4.24. Energy Fraction in Load Regions

	Period	Energy fraction in season	Day	Energy fraction in days	Energy fraction in load regions						
					1	2	3	4	5	6	7
Electricity	End of winter	0.3622	WD	0.7195	0.198	0.135	0.049	0.225	0.147	0.180	0.066
			SSH	0.2805	0.257	0.335	0.246	0.126	0.037		
	Summer	0.4413	WD	0.7360	0.172	0.087	0.395	0.346			
			SSH	0.2640	0.085	0.122	0.596	0.154	0.043		
	Begin of winter	0.1965	WD	0.7393	0.154	0.179	0.051	0.268	0.152	0.134	0.062
			SSH	0.2607	0.215	0.358	0.308	0.119			
Heat	End of winter	0.4592	WD	0.7195	0.250	0.125	0.042	0.208	0.125	0.167	0.083
			SSH	0.3085	0.292	0.333	0.208	0.125	0.042		
	Summer	0.2195	WD	0.7096	0.250	0.083	0.333	0.333			
			SSH	0.2904	0.083	0.167	0.583	0.125	0.042		
	Begin of winter	0.3213	WD	0.7132	0.208	0.167	0.042	0.250	0.125	0.125	0.083
			SSH	0.2868	0.250	0.375	0.250	0.125			

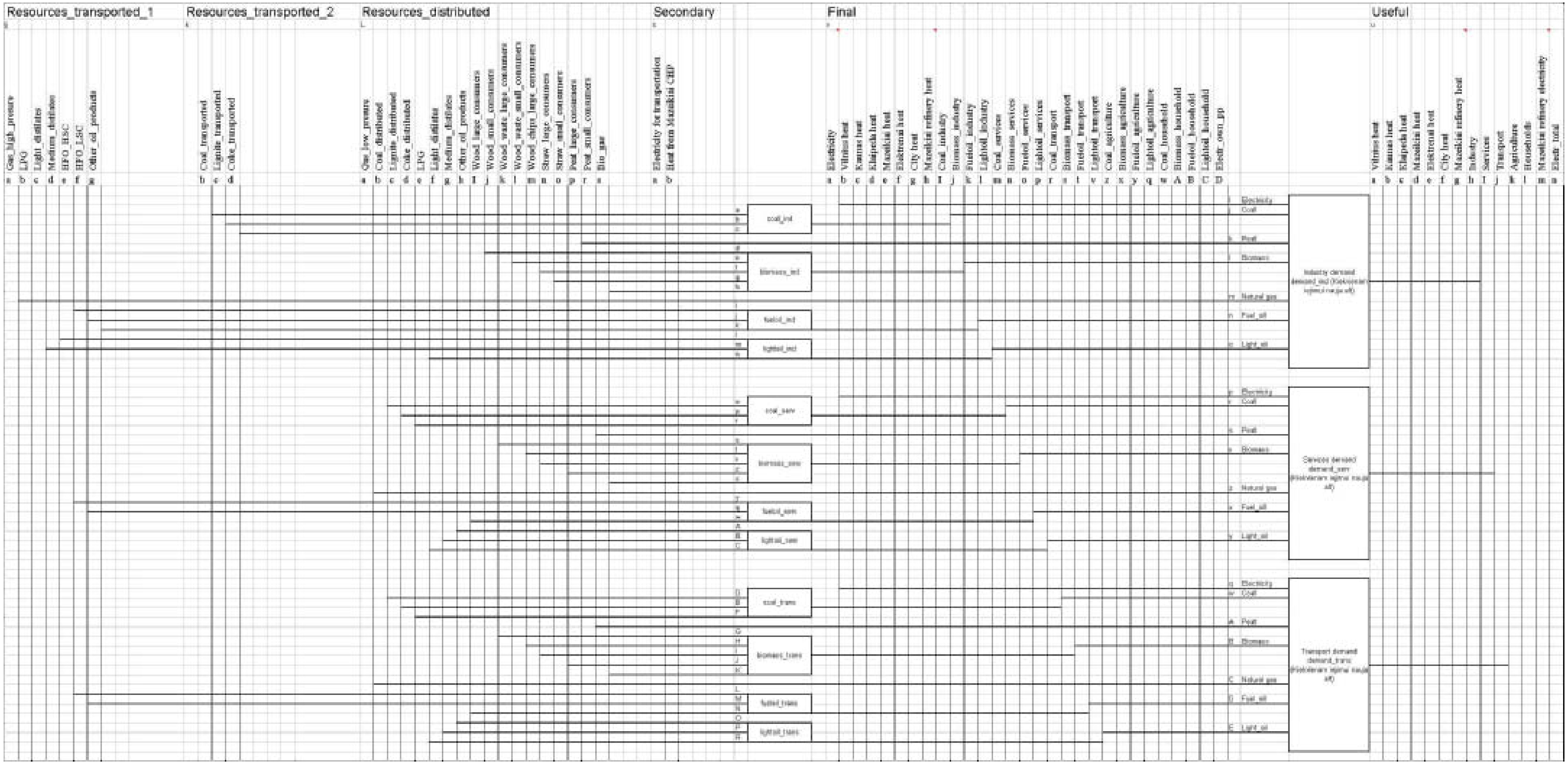


Figure 4.25. Demand of Other Energy Forms in Economy Branches (Part 1).

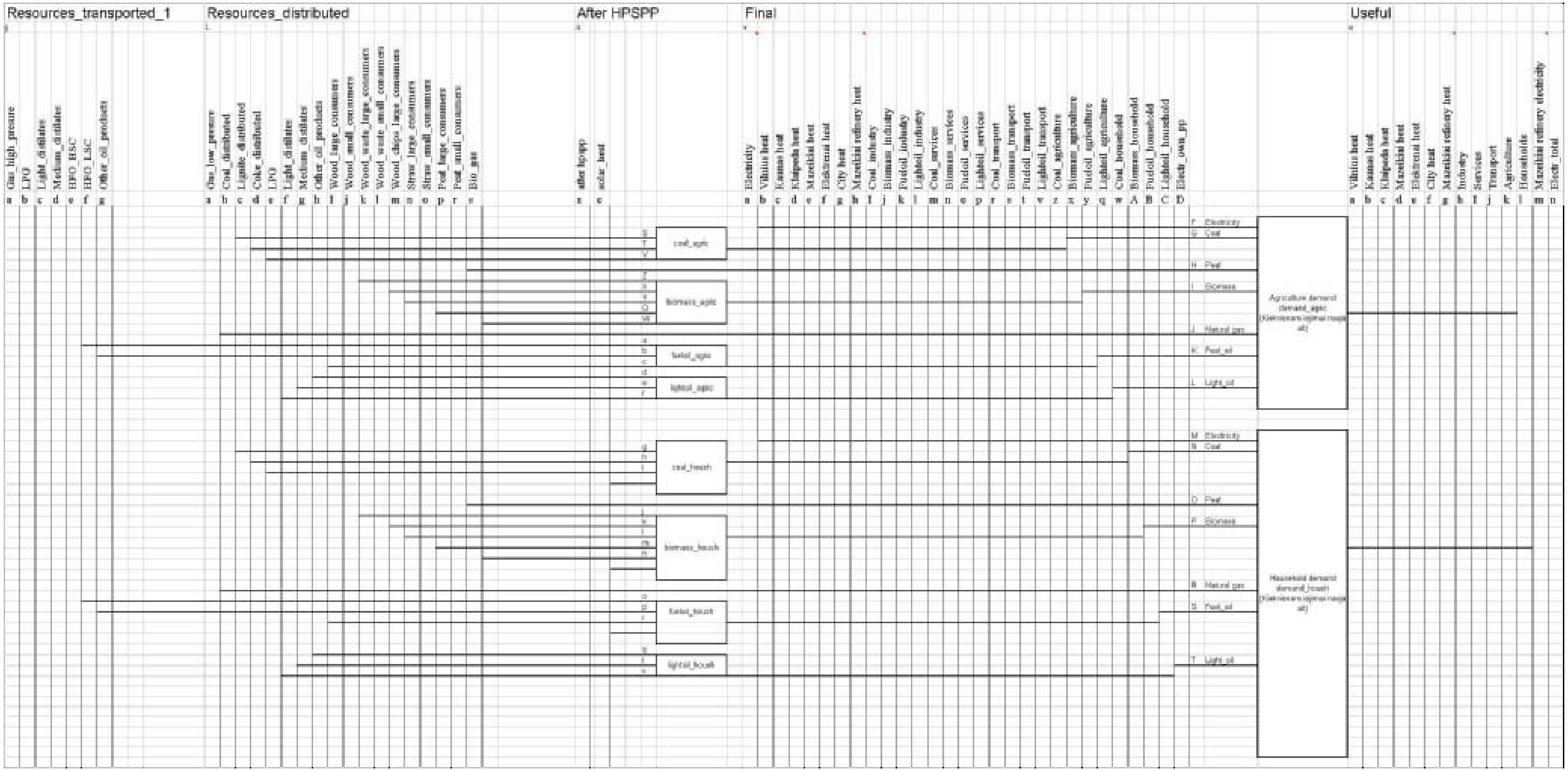


Figure 4. 26. Demand of Other Energy Forms in Economy Branches (Part 2).

Demands for other fuels in all sectors of the national economy are aggregated into one demand sector and are shown in Figs. 4.25 and 4.26. They are represented by the following technologies:

*industry_de*mand – represents common demand of industry and construction. Non-energy demand of gas is also included here,
services_demand – represents common demand of the service sector,
transport_demand – models fuel consumption in the transportation sector,
agriculture_demand – represents common fuel consumption in the agriculture sector,
household_demand – represents common fuel demand in the household sector.

Technologies linking the secondary level with the final energy level represent the aggregation of demand over several fuel types by specifying the share of each fuel type in the total energy demand by sector of the economy.

4.5. Definition of Supply Scenarios

Development of the Lithuanian energy sector was analyzed during the study period 2000–2025. The Lithuanian energy system, including existing and new alternatives, as well as environmental constraints, in the MESSAGE model for all analyzed scenarios is represented in the way as described in Section 4.3 and Section 4.4. Demand of all energy forms corresponds to values of basic demand scenario described in Chapter 3. Fuel prices for all energy curriers during the whole study period remain constant for all main scenarios and represent the values of the year 2000 (See table 4.10). The discounting factor was assumed to be 10% for all main scenarios. Additional characteristics of the main scenarios analyzed are summarized in Table 4.25. Differences between the main scenarios are only related to the time of forced commissioning of the new nuclear power plant, the possibility to construct new CCGT units at the site of Lithuanian TPP and with the availability of electricity import.

Characteristics of other supplementary scenarios that have been modelled in order to evaluate the impact of some special factors on the future development of the Lithuanian energy sector are presented in Chapter 6 together with the study results.

Table 4.25. Additional Characteristics of Main Scenarios Analyzed

Scenario	Additional characteristics
1	All technologies are allowed to contribute to energy extraction, conversion, transportation and distribution without any constraints except those that were described in chapter 4.3 and 4.4 and are subject of optimization.
2	Construction of new CCGT at the site of Lithuanian TPP is not allowed.
3	Commissioning of a new, 600 MW, nuclear power plant in 2010 is foreseen.
4	Commissioning of a new, 600 MW, nuclear power plant in 2015 is foreseen.
5	Commissioning of a new, 600 MW nuclear power plant in 2015 is foreseen. Electricity import is not allowed in 2010–2015.
6	Commissioning of a new, 600 MW, nuclear power plant in 2015 is foreseen. Modernization of the Lithuanian TPP is postponed until the commissioning of the new nuclear power plant

5. RESULTS OF LITHUANIAN ENERGY SECTOR DEVELOPMENT ANALYSIS

5.1. Comparison of the Main Parameters

Scenarios defined in the previous chapter have been optimized using the MESSAGE model in order to determine the optimal development paths for the Lithuanian energy sector for the next 25 years. Based on the total system costs of the energy system discounted over the study period, three different development paths can be identified:

- A development when future electricity generation is based on fossil fuel (scenarios 1 and 2 – the so-called “fossil fuel” scenarios);
- A development when the decommissioned Ignalina NPP is immediately replaced by the new NPP (scenario 3 the so-called “immediate nuclear” scenario);
- A development when the decommissioned Ignalina NPP is replaced by the postponed commissioning of the new NPP (scenarios 4–6 – the so-called “postponed nuclear” scenarios).

The total discounted system costs for different scenarios are shown in Fig. 5.1. It can be seen from Fig. 5.1 that both fossil fuel development scenarios, i.e. construction of the new CCGT plant at the site of the Lithuanian TPP (scenario 1), and modernization and further operation of the Lithuanian TPP (scenario 2) are comparable from an economic point of view. The total discounted system costs of those scenarios differ by a negligible margin (US$ 12.1 million or 0.09% of the costs of any of them).

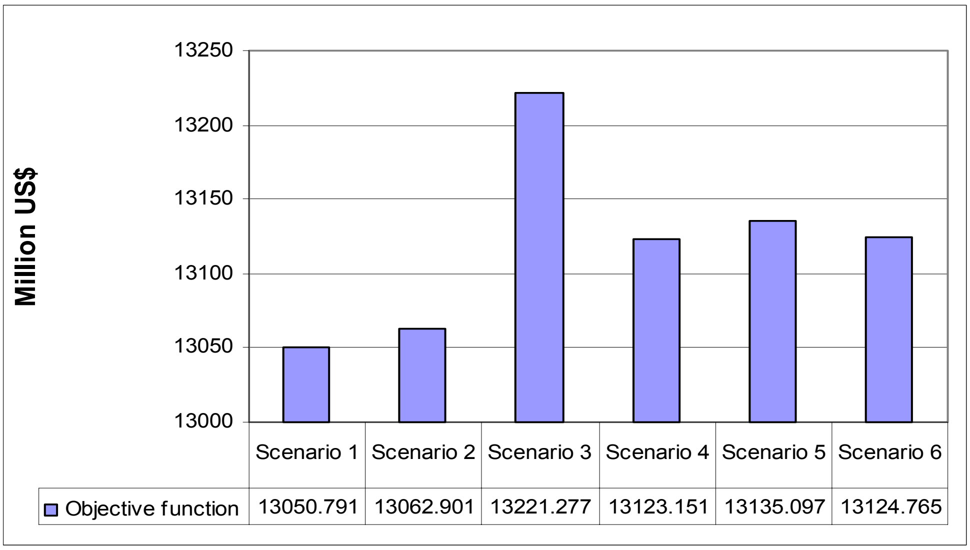


Figure 5.1. Discounted Cost of Energy System Operation and Development in 2000–2025.

The immediate replacement of the Ignalina NPP by a new nuclear power plant (scenario 3) would result in higher total system costs of the Lithuanian energy system. Compared with the “fossil fuel” scenarios total system costs in this case would be higher by US$ 158.4–170.5 million if the new nuclear power plant started operation immediately after closure of the second unit of the Ignalina NPP (scenario 3). In the case where the new nuclear power plant is brought into service in 2015 (postponed nuclear scenarios 4–6) the system costs will also be higher than that of the “fossil fuel” development (scenarios 1 and 2) by US$ 60.2 million and US$ 84.3 million respectively. The smaller difference in total discounted costs in this case is due to the postponed investments into new nuclear plant, which constitute the biggest share in the total investments of the whole system.

Scenario 6, building the new nuclear power plant in about 2015, stands the best chance among the so-called "postponed nuclear scenarios". In this case the Lithuanian TPP will cover the lack of capacities due to the shutting down of the Ignalina NPP during the period 2010–2014. Fuel prices will determine which fuel will be used in the Lithuania TPP, but it is likely that orimulsion will be used and flue gas desulphurization technologies will have to be installed to comply with environmental regulations. Scenario 5, modeling the modernization of the Lithuanian TPP coupled with its intensive use in 2010–2014 is the most expensive among the "postponed nuclear scenarios". However, the differences in cost between these three scenarios with postponed commissioning of the new nuclear power plant are small and do not exceed US$ 11.9 million. Scenario 4 representing electricity import in 2010–2014 is slightly cheaper than scenario 6. Given that Lithuania at present has excess electric capacity, the import option is considered to be a far future option. A summary of investment cost, operation and maintenance cost, and fuel cost is presented in Table 5.1.

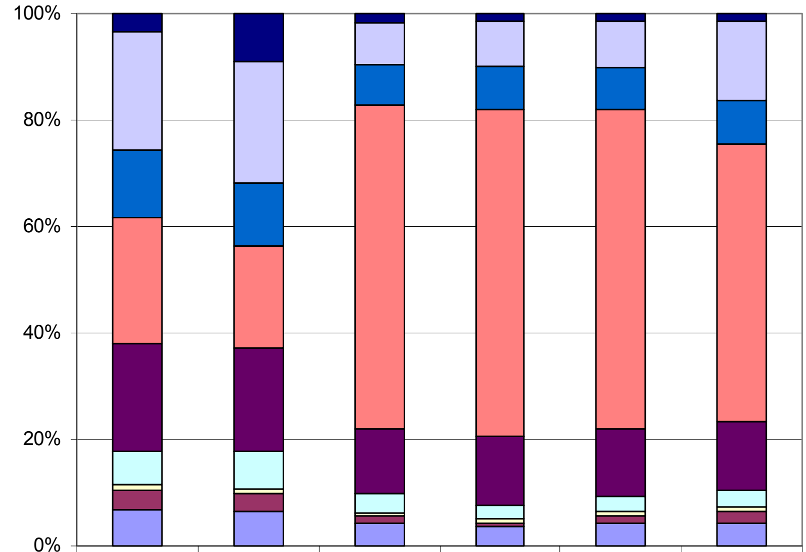
Table 5.1. Total Investment Cost and O&M Cost Including Fuel Cost in 2000–2025, million US$

Scenario	Investment cost	Fixed O&M cost	Variable O&M cost including fuel cost	Total O&M cost including fuel cost	Total investment and O&M cost
Scenario 1	1152.4	2787.6	38169.8	40957.4	42110
Scenario 2	1250.7	2765.3	38264.2	41029.5	42280
Scenario 3	1871.9	3338.4	36995.5	40333.8	42206
Scenario 4	1854.5	3083.4	37341.0	40424.4	42279
Scenario 5	1888.8	3144.1	37221.0	40365.1	42254
Scenario 6	1848.7	3176.2	37473.2	40649.5	42498

It can be seen from data presented in Table 5.1 that the main difference among all six scenarios is in the variable O&M costs, including fuel costs and in investment costs necessary for modernization and further development of the energy system. Investment costs for nuclear scenarios (scenarios 3–6) are US$ 598.0–736.5 million higher than those for the fossil fuel scenarios. The nuclear scenarios entail higher fixed O&M costs (e.g., by US$ 295.8 – 573.0 million) but lower variable O&M costs (by US$ 696.6 – 1268.7 million) compared with the fossil fuel scenarios. The combined effect is that the total O&M costs for nuclear scenarios are US$ 307.9 – 695.7 million lower than those for the fossil fuel scenarios. However in terms of undiscounted costs, including investment requirements, nuclear scenarios still have higher costs than the fossil fuel ones. On important factor in ranking the six scenarios is the value of the discount rate. Scenarios with the earlier commissioning of the new nuclear power plant are ranked better if the discount rate is small and vice versa. In other words, a higher value of discount rate leads to the postponement of large scale investments. The impact of discount rate on the economic preferences is discussed in Chapter 6 (sections 6.2 and 6.5). According to the minimum cost criterion, a discount rate of 10% gives greater preference for the fossil fuel scenarios.

A major part of capital in the case of fossil fuel development scenarios of the Lithuanian power system is invested in the construction of new generating capacities and environmental protection measures (Fig. 5.2). The investments in new condensing power plants and in new

CHPs account for 43.9% of the total investments in scenario 1 and 38.6% in scenario 2 correspondingly. The share of investments in environmental protection measures amounts to 22.2% and 23% in scenario 1 and scenario 2 correspondingly. Heavy investments in environmental protection measures are inevitable due to the fact that a large share of electricity is produced using fossil fuel including orimulsion whose utilization without flue gas cleaning technologies is prohibited. Another significant portion of the investments goes to the construction of new CHPs. In terms of the absolute value this part of the investments is practically equal in all scenarios. However since the total investments in scenario 1 and 2 are lower than the other scenarios, the shares of investments in CHPs are quite noticeable in scenarios 1 and 2 (20.3% in scenario 1 and 19.4% in scenario 2 correspondingly), while in all nuclear scenarios the share of investments for new CHP is only 12.1%–12.9%.



	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Gas supply system	3.4	9.0	1.6	1.5	1.3	1.5
Environmental measures	22.2	23.0	7.8	8.4	8.7	14.9
Power Plants on renewables	12.7	11.8	7.6	8.1	8.0	8.0
New TPP	23.6	19.2	60.9	61.5	60.0	52.2
New CHP	20.3	19.4	12.1	12.9	12.7	12.9
Heat only boilers	6.2	6.9	3.8	2.7	2.9	3.3
Hydro	1.1	1.0	0.7	0.7	0.7	0.7
Existing TPP	3.7	3.5	1.4	0.5	1.5	2.3
Existing CHP	6.8	6.4	4.1	3.7	4.2	4.2

Figure 5.2. Allocation of Total Investments in 2000–2025 by Scenarios.

In the case of nuclear scenarios, between 52% and 61% of the total investments are spent for the construction of new nuclear power plant and also thermal condensing power plants. Investments for environmental protection technologies and renewable power plants are small (in the range of 7.6%– 8.7%), except for scenario 6 in which environmental flue gas cleaning equipment must be installed at the Lithuanian TPP – the plant that runs extensively between the time period after the decommissioning of the Ignalina NPP and before the commissioning of the new nuclear power plant. Those investments may be reduced if natural gas were to be used instead of orimulsion at the Lithuania TPP but with higher O&M cost.

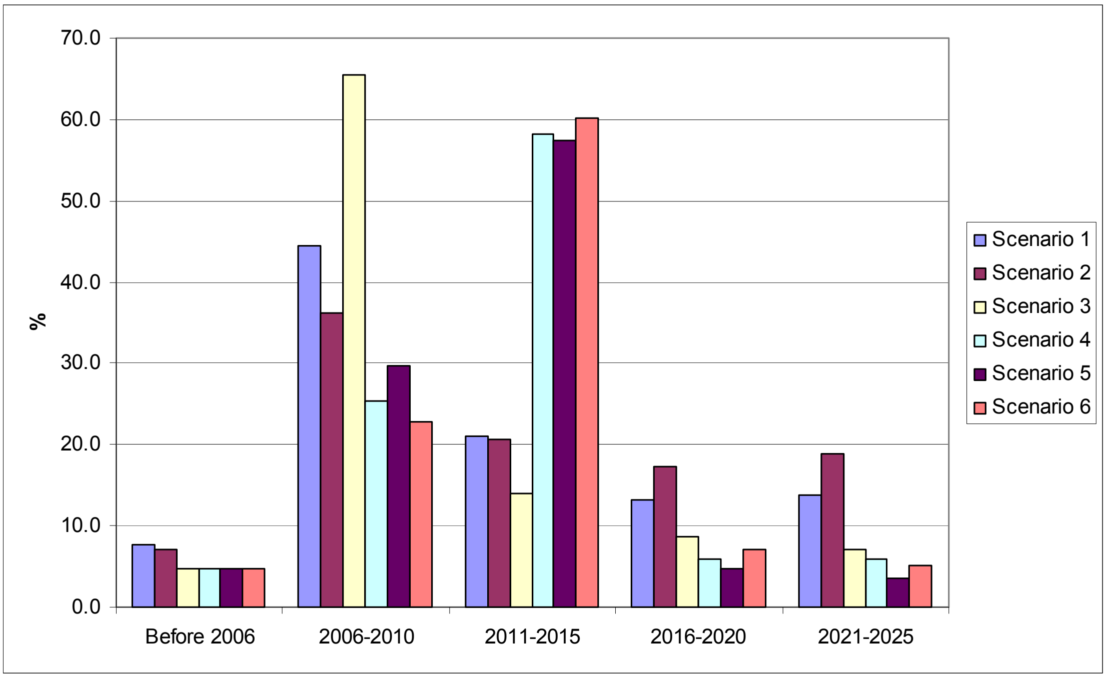


Figure 5.3. Distribution of Investments over Time by Scenarios.

The distribution of investments during the period 2000 – 2025 is shown in Fig. 5.3. The major part of the investments for the fossil fuel scenarios (1 and 2) and the scenario of immediate replacement of the Ignalina NPP by the new NPP (scenario 3) falls into the time period of 2006–2010 when all preparations for decommissioning of the second unit of the Ignalina NPP take place. In this time period the construction of a new CCGT, the modernization of the Lithuanian TPP or the construction of a new NPP take place. Capital requirements for scenarios 1–3 in this time period constitute between 36.1% and 65.6% of the total investments of those scenarios. For the postponed nuclear scenarios (scenarios 4–6) the major part of the investment is spent during the period 2011 – 2015, when a new nuclear power plant is to be built (e.g., from 57.4% to 60.1% of the total investment costs depending on the scenarios). The period 2006 – 2015 may be characterized as a period of the construction of new CHP and the modernization of boiler-houses, which also requires significant investments. A detailed breakdown of investments is presented in Appendix II.

The total fuel consumption for electricity and district heat generation in the period 2000–2025 is summarized in Table 5.2. Scenario 4 enjoys the lowest fuel consumption because some electricity is imported in 2010–2014. Scenario 1, with the highest overall efficiency of electricity production owing to the highest share of CCGT among all scenarios is the second lowest among scenarios in terms of fuel consumption. It can be noted that the difference in the total fuel consumption of all six scenarios is quite significant. The highest fuel consumption is observed in the case of scenario 6. The reason being that power plants, which play an important role in this scenario, by design have comparatively low efficiencies, e.g., Ignalina NPP, which operates till 2015 and Lithuanian TPP, which runs intensively during 2010–2014. Fuel consumption in other nuclear scenarios is 1.9%–4.2% higher than the fuel consumption in scenario 1 and is mainly related to the lower efficiency of the nuclear power plant in comparison with the CCGT. Fuel consumption in scenario 2 is 4.2% higher than in scenario 1. However scenario 2 has the advantage of higher fuel diversification. A detailed breakdown of fuel consumptions is presented in Appendix II.

Table 5.2. Total Fuel Consumption for Electricity and District Heat Generation, ktoe

Scenario	Fossil	Nuclear	Renewables	Total
Scenario 1	72439	20405	5642	98486
Scenario 2	74919	20405	5598	100923
Scenario 3	58603	38262	5807	102671
Scenario 4	57400	32673	5654	95727
Scenario 5	62126	32673	5589	100389
Scenario 6	65783	32681	5704	104168

5.2. Electricity Generation

After the closure of the Ignalina NPP, sources of electricity generation become more diversified, except in scenario 2. Fig. 5.4 graphically depicts electricity production by power plants in scenario 1. Similarly electricity generation by power plants in scenario 3 is shown in Fig. 5.5.

It can be seen from Fig. 5.4 and Fig. 5.5 that three main production sources producing an almost equal share in the total electricity generation throughout the planning period can be distinguished:

- New gas turbine combined cycles;
- Various combined heat and power plants;
- The Lithuanian TPP after modernization (or the new nuclear power plant in scenario 3).

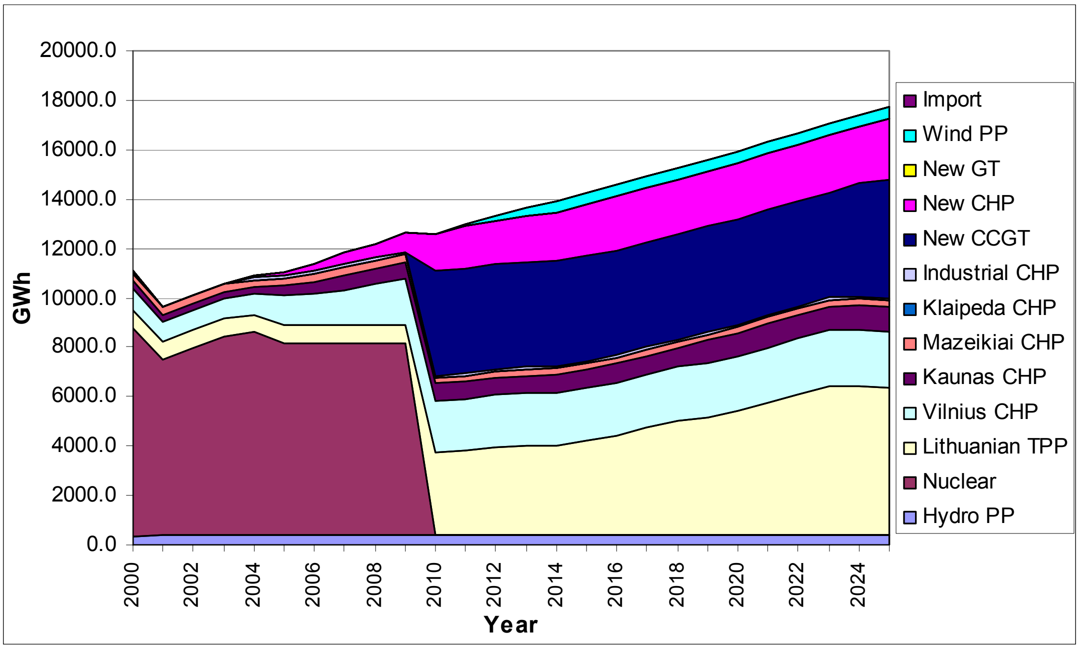


Figure 5.4. Electricity Production by Power Plants in Scenario 1.

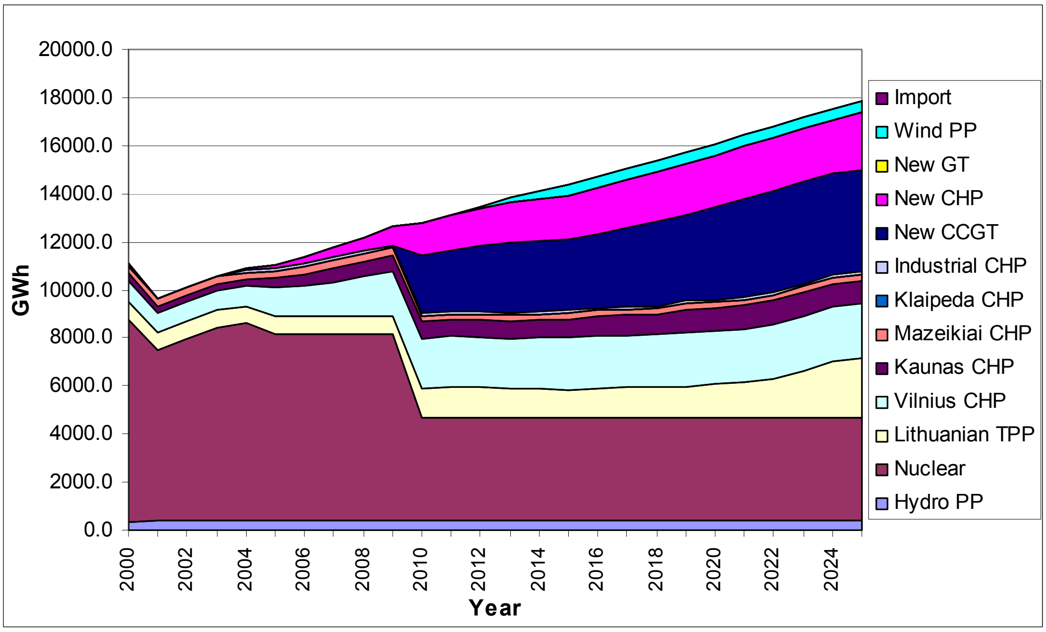


Figure 5.5. Electricity Production by Power Plants in Scenario 3.

After closure of the second unit of the Ignalina NPP each of the sources mentioned above generates about one third of the total electricity demand. Moreover, the share of the Lithuanian TPP increases as the demand for electricity grows while all CHPs and CCGTs have been installed to the extent possible. This means that modernization of the Lithuanian TPP is more a economically attractive option than a new CCGT at a new site but less economically attractive than a new CCGT at the existing site with existing infrastructure and gas supply.

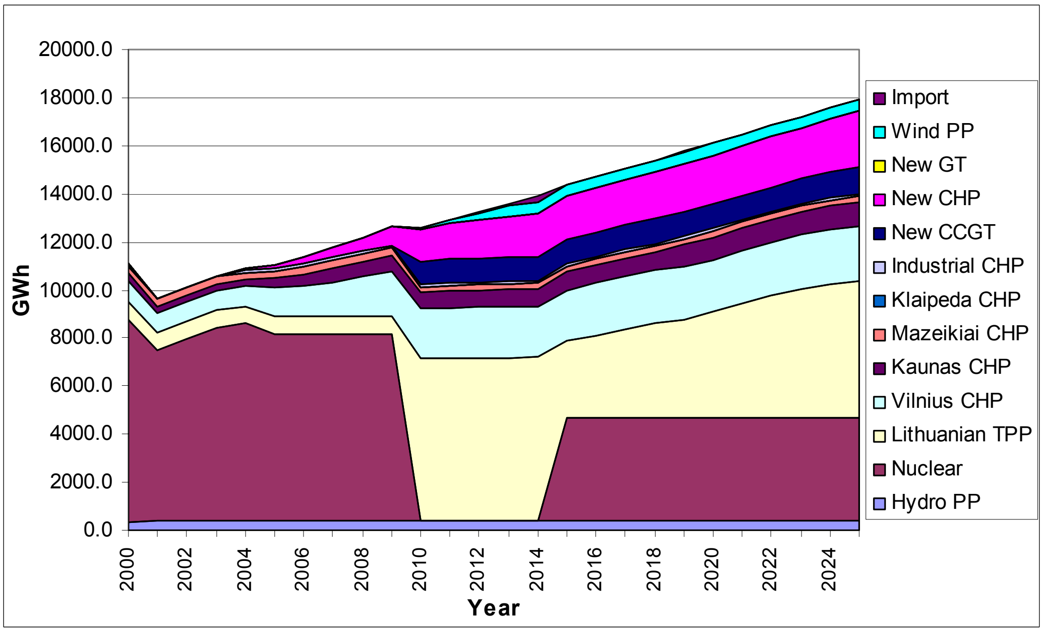


Figure 5.6. Electricity Production by Power Plants in Scenario 6.

According to scenario 3, a new nuclear power plant will be built in 2010 immediately after the closure of unit 2 of Ignalina NPP. It displaces the Lithuanian TPP in total electricity generation. Each of the three groups: CHP's; new CCGTs at the existing site and a new NPP make up about one third of the total Lithuanian electricity demand. In another case when the new nuclear power plant is brought into the grid only by 2015, the best option to make up for the loss of Ignalina NPP capacity would be to continue to operate the Lithuanian TPP at a higher utilization rate during the period 2010–2015 until the startup of the new NPP.

After the startup of the new nuclear plant, the Lithuanian TPP can reduce its production and then it will be possible to implement modernization measures for the Lithuania TPP, such as a new control system, new measurement systems, regenerative air pre-heaters and others. Subsequently the Lithuania TPP can raise electricity production again in parallel with the increasing domestic electricity demand. This is the situation simulated by scenario 6, whose electricity production by plants is shown in Fig. 5.6.

Consideration was given to the situation that the continual operation of the Lithuanian TPP at a high utilization rate would not be possible without first modernizing it. This situation is analyzed in scenario 4. In such a situation, the construction of new CCGTs and import of electricity during the period from 2010 to 2015 (i.e., after the closure of Ignalina unit 2 and before the commissioning of the new NPP) would be an economically attractive option. Electricity production in this scenario is presented in Fig. 5.7.

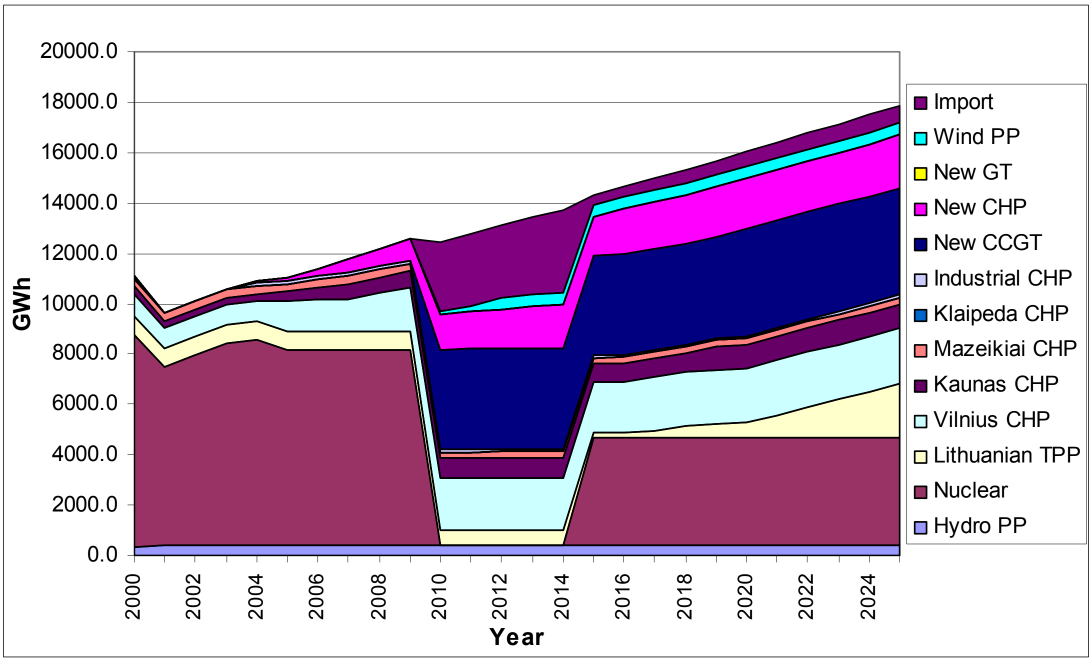


Figure 5.7. Electricity Production by Power Plants in Scenario 4.

In a similar manner, consideration was given to the situation when the construction of a new NPP proves to be too big a financial burden for Lithuania. In such a situation, Lithuanian energy system development will rely mostly on the construction of new CCGTs, analyzed in scenario 1 or the modernization of the Lithuanian TPP analyzed in scenario 2. The Lithuanian TPP with the necessary upgrade will be a major producer after the closure of Ignalina unit 2. Together with existing and new CHPs it will practically cover all Lithuanian electricity demand. Until 2020, the share of the electricity generated by the new CCGTs will be increasing but not significant. But from 2020 onward when two units of 150 MW at the

Lithuanian TPP will be decommissioned, more new CCGTs will have to be constructed and their share will become higher and at the end of the study period will reach 24% of the total electricity production.

5.3. Capacity Balance

Capacity balance for scenario 2 is shown in Fig. 5.8. The Lithuanian system peak load, comprising the electricity demand, electricity losses in the T&D network and the system own-uses, increases from 1856 MW in 2000 to 3357MW in 2025 (the solid line in the Fig. 5.8). On the other hand, the supply capacity (blocks in the Fig. 5.8) is made up by the capacities of the upgraded Lithuanian TPP, of existing and new CHPs, by the capacities of hydropower plants and wind power plants and that of the new CCGT. By 2010 the total capacity of new CHPs reaches 218 MW and increases further to 446 MW by the end of the study period. Capacity of the new CCGT increases constantly starting from 2010 and by the end of the study period reaches maximal allowable level of 600 MW. It is built only at the existing site of the Lithuanian TPP. No other new CCGT capacity at the site of the Ignalina NPP or other site is built because it is not necessary for covering domestic demand. Moreover, practically the whole installed capacity of the Kruonis HPSPP is used as reserve capacity. The total installed capacity of the whole supply system is 3288 MW in 2010 and 4476 MW in 2025.

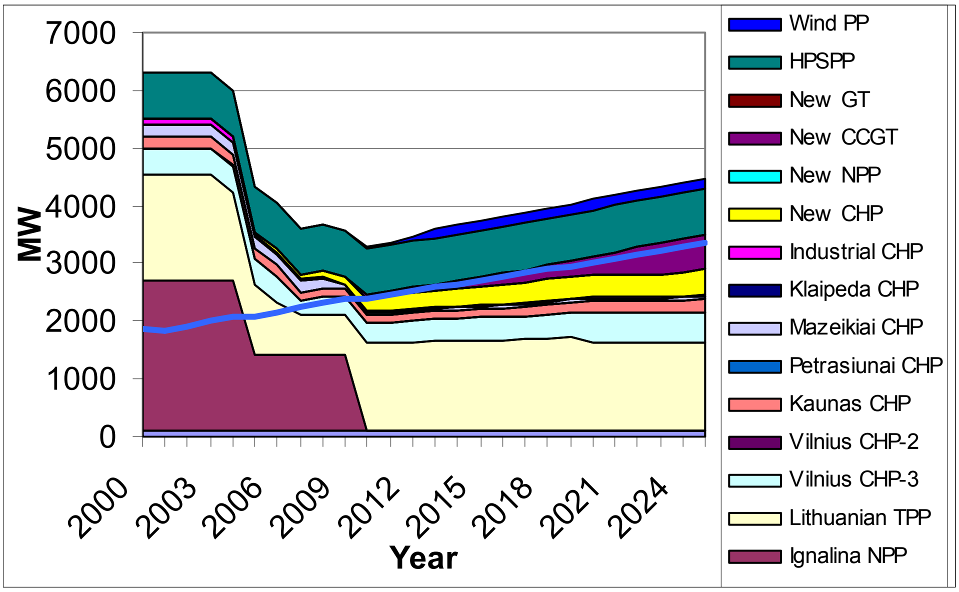


Figure 5.8. Capacity Balance in the Case of Scenario 2.

Scenario 1 differs from scenario 2 only in the higher capacity of the new CCGT. By 2010 the capacity of the new CCGT already reaches 600 MW and remains stable until the end the of study period. Conversely, the capacity of the Lithuanian TPP is lower in the time period 2010–2024.

The total supply system capacity in each of the nuclear scenarios is higher than that of the fossil fuel scenarios due to higher required reserve capacity. The capacity balance for scenario 3 is presented in Fig. 5.9. The total supply system capacity in 2010 is 3644 MW and increases to 4833 MW by 2025. A portion of the capacity of the Lithuanian TPP as well as of the Kruonis HPSPP is used as reserve capacity for the nuclear unit.

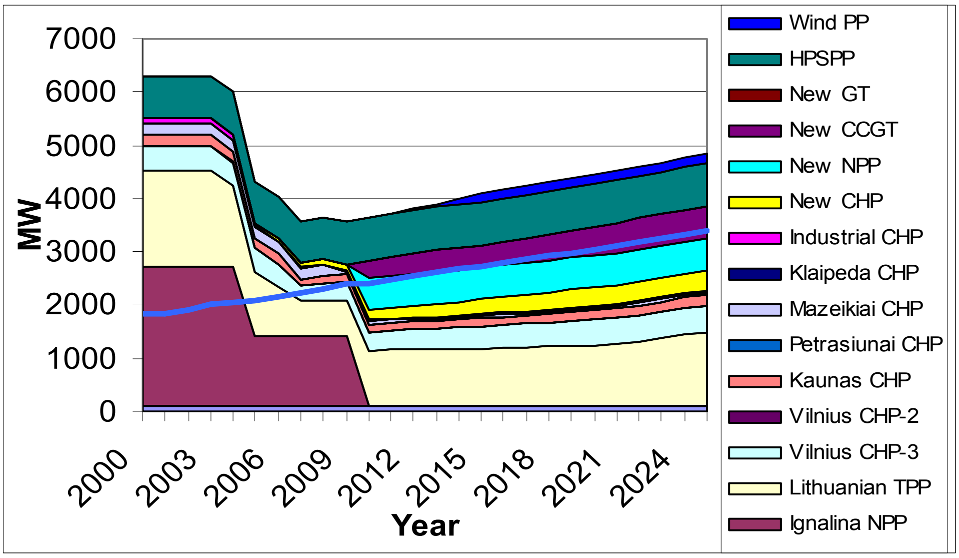


Figure 5.9. Capacity Balance in Scenario 3.

5.4. Heat Generation

The evolution of heat production over the study period is similar for all scenarios. Fig. 5.10 displays the dynamics of heat production in scenario 1. Other scenarios exhibit a very similar pattern of heat production by plants. This similarity among scenarios may be explained by the quite comparable utilization of existing and new CHPs in all scenarios. Unlike the electricity production pattern, the differences between scenarios due to the operation of the new CCGT, the Lithuanian TPP and the new nuclear power plant do not have significant impacts on the operation of existing and new CHPs. Consequently, the heat production patterns do not vary much from one scenario to other.

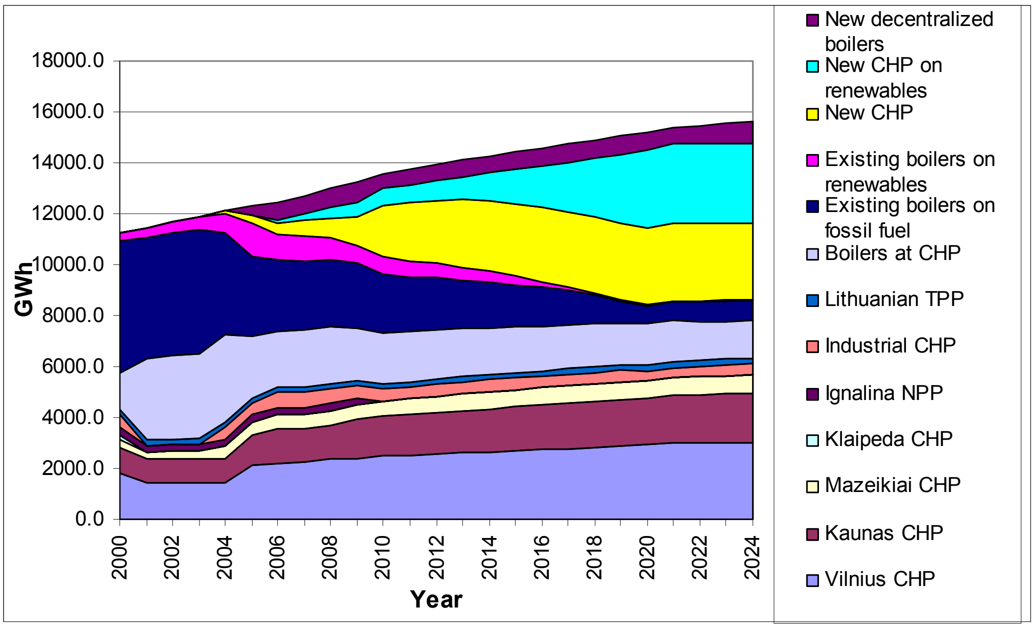


Figure 5.10. Dynamics of Heat Production in Scenario 1.

After the closure of the first unit of the Ignalina NPP the utilization of existing CHPs increases because they become competitive in the electricity market operating as combined heat and electricity producers. This leads to the higher heat output from turbines and lower heat production by boilers that produce only heat, most of them located at the same site as the turbines. The closure of the second unit of the Ignalina NPP has only a minor impact on the heat output from existing CHPs because these plants already operate at their maximum permissible load determined by the heat demand in the particular heat market and by the hydraulic regime of the heat supply network. Major changes in the heat production structure take place in the district heating systems that do not have existing CHPs. Here it is possible to see fast penetration of new CHPs that replace the existing boilers. The fastest growth of heat output belongs to the new renewable CHPs and the new small CHPs operating on natural gas. Boiler-houses converted into CHPs by the installation of steam turbines after the steam boilers or additional gas turbines in front of the boilers provide a significant contribution to the total heat production. Shares of heat output from different type of new CHPs as well as their total heat production are shown in Table 5.3 for scenario 1.

Table 5.3. Share (in%) and Total (GWh) Heat Output from New CHP in Scenario 1

Type of CHP	2005	2010	2015	2020	2025
Share of Middle scale CHP	0.0	12.6	5.3	4.5	7.4
Share of Small CHP	88.6	36.9	40.6	30.2	29.5
Share of CHP on renewables	11.4	24.6	32.7	50.6	48.7
Share of Boiler-houses converted into CHP	0.0	25.8	21.5	14.7	14.4
Total heat production, GWh	320.2	2689.8	4198.9	6111.3	6245.4

5.5. Fuel Consumption for Electricity and Heat Production

Fuels used for electricity and heat production are quite diverse, especially in the nuclear scenarios. In the fossil fuel scenarios, where a new CGGT or a modernized Lithuanian TPP take the role of the Ignalina NPP for electricity generation, three types of fossil fuels make up the balance of the primary energy used for electricity and heat generation. The fuel balance for scenario 1 is presented in Fig. 5.11.

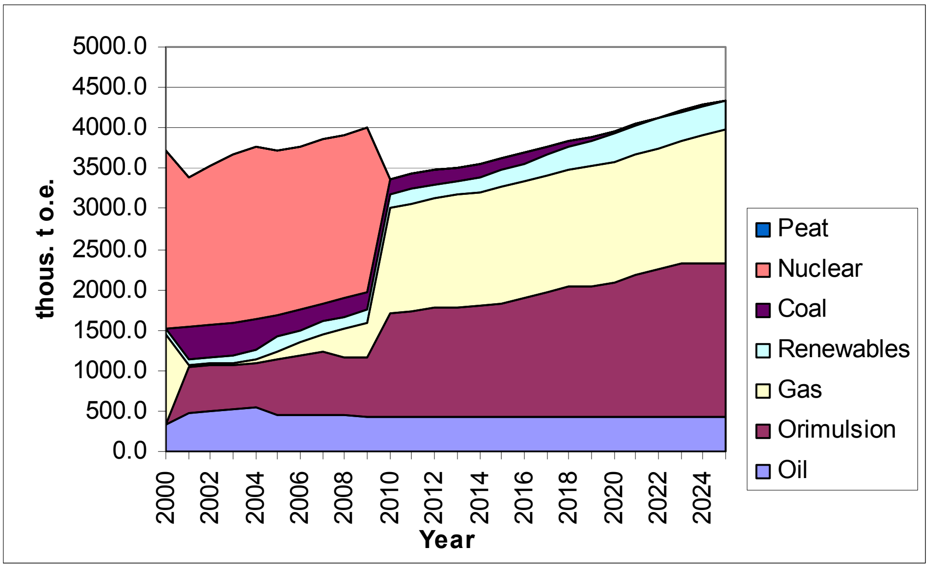


Figure 5.11. Fuel Consumption for Electricity and Heat Generation, Scenario 1.

After 2010 natural gas and orimulsion accounts for about 38% and 41% of the total fuel consumption respectively. Fuel oil accounts for about 11% of the total fuel consumption. In fact less oil may be used as shown in figure 5.11 if the limit on the SO_2 emissions is applied to all boiler-houses. More stringent environmental protection requirements, which will be enforced after 2007, will stipulate replacement of oil by natural gas. According to [38, 53] from 2008 onward, in all large combustion plants oil should be replaced by natural gas or renewable energies. Moreover, the Lithuanian TPP, Vilnius CHP and Kaunas CHP cannot rely only on one type of fuel — orimulsion, thus they will also consume some natural gas. This would further increase the share of natural gas. Therefore natural gas is the main fuel for scenario 1 (construction of the new CCGT) and constitutes more than 50% of the total fuels consumed for electricity and heat generation. The whole system of power and heat supply then depends heavily on natural gas, which is supplied from a single foreign source — the Russian Federation.

In the case when Ignalina NPP is replaced by the Lithuanian TPP (scenario 2) orimulsion is the predominant fuel (see Fig. 5.12), which is used not only by the Lithuanian TPP but also by the Vilnius CHP and Kaunas CHP. At the end of the study period natural gas and fuel oil correspondingly share about 36% and 9% of the total fuel consumption and orimulsion takes a share of about 47%. As in scenario 1, the share of natural gas may increase and may surpass 40% of the total fuel consumption once SO_2 emission constraints are applied to all boiler-houses. Some orimulsion may also be replaced by natural gas at the Vilnius and Kaunas CHPs as well as at the Lithuanian TPP because of reliability of fuel supply. However, this scenario will be less dependent on natural gas supply because most capacity can be switched from natural gas to orimulsion or oil and vice versa. The Lithuanian TPP will be able to use orimulsion, natural gas or heavy fuel oil at any proportion, while the new CCGT in scenario 1 can be fired only with natural gas.

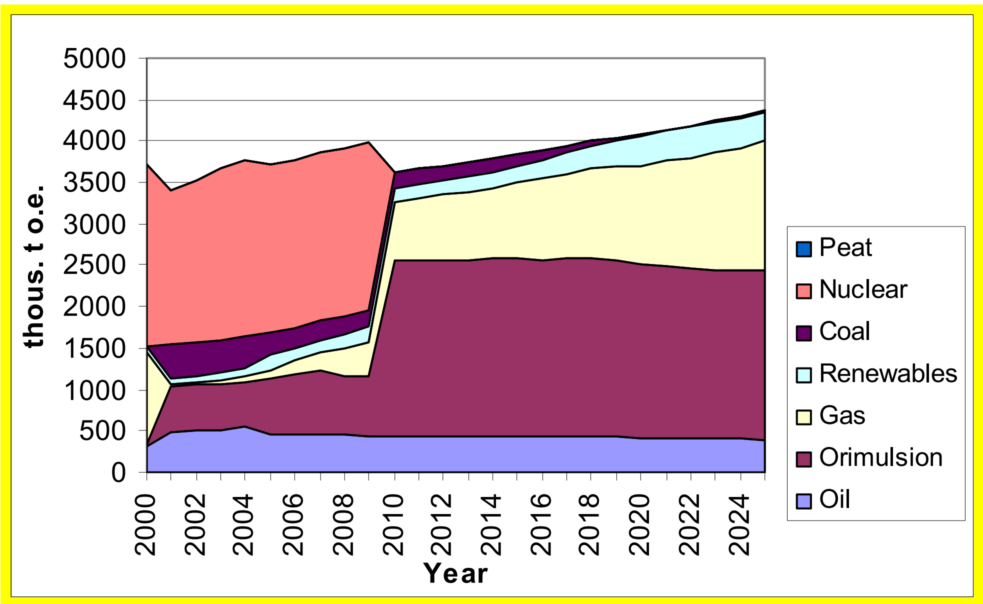


Figure 5.12. Fuel Consumption for Electricity and Heat Generation, Scenario 2.

Fuel consumption for electricity and heat generation in scenario 3 is shown in Fig. 5.13. With some exceptions for the time period 2010–2014 this figure can represent the dynamics of fuel consumption for nuclear scenarios 3–5, and for scenario 6 in which part of the gas consumption is replaced by orimulsion because of its higher utilization at the Lithuanian TPP. Despite the higher fuel diversity in all nuclear scenarios it should be noted that power plants are more tightly linked to one or another fuel type in comparison with scenario 2. This means that they have less space for maneuver in selecting fuel types, suppliers and for negotiation of fuel prices. Fuel consumptions for electricity and heat generation of all scenarios analyzed in this study are documented in Appendix II.

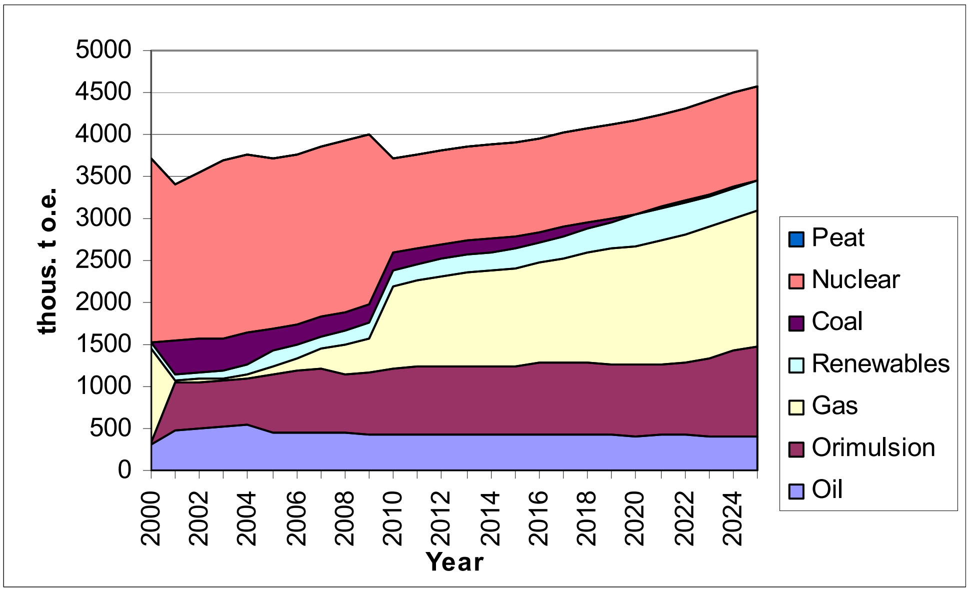


Figure 5.13. Fuel Consumption for Electricity and Heat Generation, Scenario 3.

5.6. Total Primary Energy Requirement and Energy Export

Oil (including oil products) and natural gas dominate the total primary energy requirement of Lithuania in all analyzed scenarios. The share of oil and its products in the total country primary energy requirement grows slightly from 33% in 2000 to 35% in 2025. Oil consumption for heat and electricity production might have been lower if limits on the SO_2 emissions were to be applied to all boiler-houses. In this study SO_2 emission constraints were imposed only on power plants.

In the year 2000, 14% of the total primary energy was supplied by natural gas. Out of this amount, 44% of the total gas supply was consumed directly in various sectors of the national economy, while the remaining 56% was used for production of electricity and heat. The share of natural gas in the total primary energy supply is within the range 14%–19% with the Ignalina NPP in operation. After the closure of Ignalina unit 2 the share of natural gas in the total primary energy requirements increases to 24%–32% depending on the scenarios and remains more or less stable at that level until the end of study period.

The highest consumption of orimulsion takes place in scenario 2 and scenario 6 where the highest contribution for electricity production comes from the Lithuanian TPP. The share of orimulsion for those scenarios would be in the range 25%–26% in 2010 and 18%–21% in 2025. This decreasing trend is due to the fact that fewer existing power plants will be converted into orimulsion firing plants during such time. In contrast, scenario 1 exhibits a growing share (even in the absolute value of orimulsion consumption) because of higher utilization of the Lithuanian TPP, which in that scenario runs on orimulsion. The contribution of orimulsion to the total primary energy requirement for nuclear scenarios (except scenario 6) is in the range 10.3%–15.7%. Consumption of natural gas and orimulsion in the case of scenario 1 and scenario 2 is shown in Table 5.4.

Table 5.4. Consumption of Natural Gas and Orimulsion in the 1 and the 2 Scenarios, ktoe

Scenario and fuel type	2000	2005	2010	2015	2020	2025
Scenario 1						
Gas	2065.2	1183.3	2316.6	2578.1	2734.2	2847.0
Orimulsion	15.7	692.1	1380.6	1397.5	1381.7	1729.1
Scenario 2						
Gas	2065.2	1182.5	1661.6	1941.0	2162.0	2535.9
Orimulsion	15.7	692.1	2363.3	2369.4	2240.9	2208.8

Renewable energies will also increase their contribution in the country's primary energy supply. Their shares increase slowly from 9% in 2000 to 12%–12.5% in 2025. The higher value corresponds to the scenario 2 and scenario 1 when bigger changes occur in Lithuanian power and district heating sector in respect of technological changes. The lower value corresponds to scenario 6 when new nuclear power plant in combination with the modernized Lithuanian TPP replaces the Ignalina NPP.

The dynamics of total primary energy requirements are shown for scenario 2 (fossil fuel based) in Fig. 5.14 and for scenario 3 (immediate nuclear scenario) in Fig. 5.15 correspondingly.

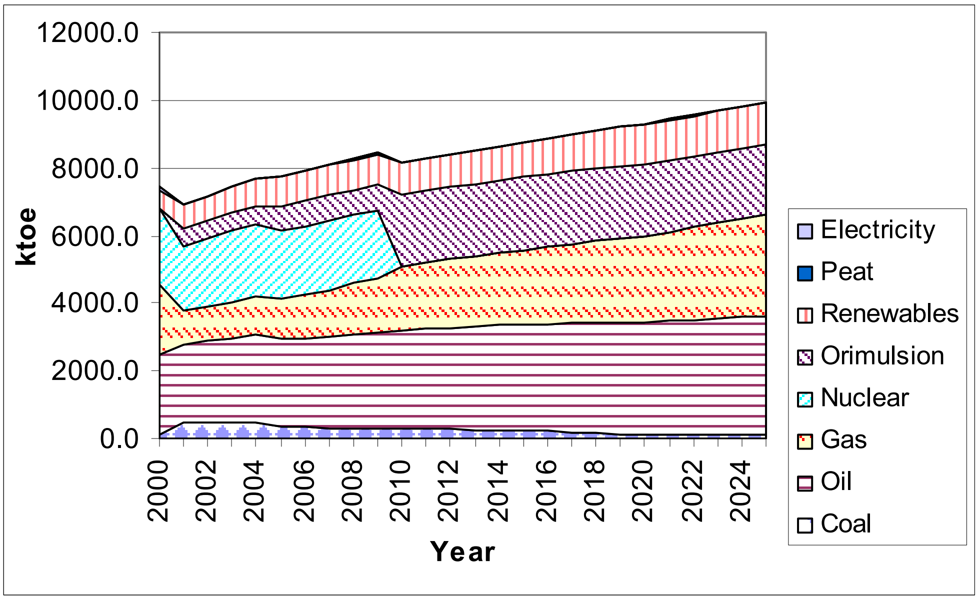


Figure 5.14. Total Primary Energy Requirement in Scenario 2.

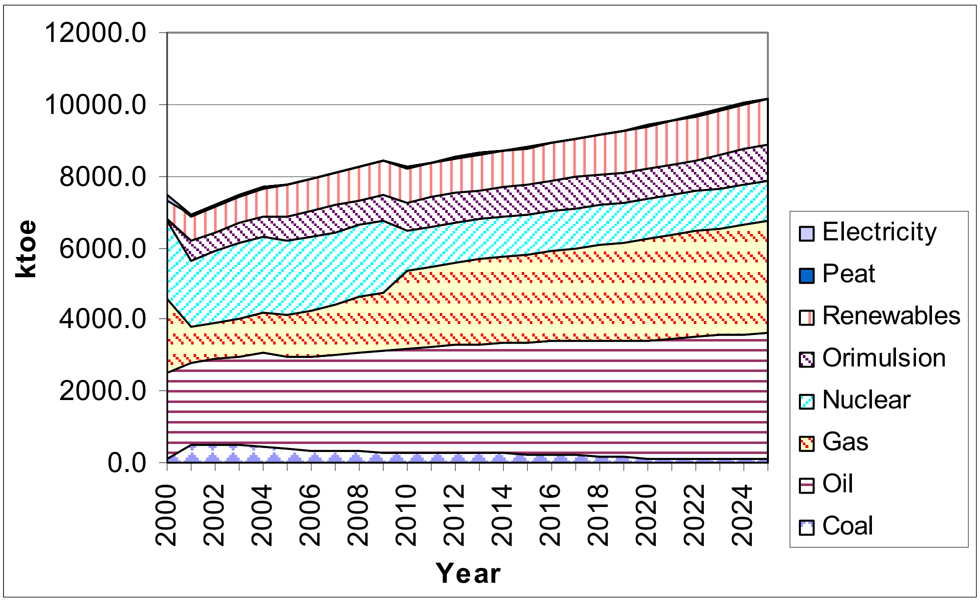


Figure 5.15. Total Primary Energy Requirement in Scenario 3.

The fuel mix of the primary energy supply is more diverse in the case when new a nuclear power plant is built in place of the closure of the Ignalina NPP (nuclear scenarios). Diversity of fuel supply is an important factor in enhancing the reliability of energy supply for Lithuania. Nuclear fuel has an additional very important advantage owing to its immense energy content and may be stored at the power plant. In nuclear scenarios, gas, orimulsion, renewables and nuclear fuel have approximately similar shares and all together account for about 30% of the total primary energy requirement. The total primary energy requirements associated with each scenario analyzed in this study are given in Appendix III.

Lithuania is exporting oil products from the Mazeikiai Refinery. Export of light distillates more than doubles during the study period and in 2025 reaches 3.2–3.3 Mtoe. Export of medium distillates decreases to 300 ktoe (less than 50% of the 2000's level) in 2025. Export of heavy fuel oil will be around 650 ktoe in 2025. The export of oil products together with increasing internal consumption necessitates a growing utilization of capacities of the Mazeikiai Refinery that already in 2012–2013 reaches 8 Mtoe.

5.7. Air Pollution from Energy Supply Sector

To formulate national energy strategies, along with the economic aspect and energy balance considerations, the associated environmental emissions have to be taken into consideration as well. For such a purpose in this study the evolution of CO_2, SO_2 and NO_x emissions was determined in each scenario. No limits have been imposed on emissions of CO_2 and NO_x, but SO_2 emissions have been subjected to limits established in Chapter 4, Section 4.5.4.

Total CO_2 emission is shown in Fig. 5.16. The Figure also depicts the CO_2 emission limit mandated by the Kyoto Protocol, related to the fuel combustion. The Kyoto limit was determined by subtracting 8% from the emission release value for 1990.

It can be seen clearly from Fig. 5.16 that the CO_2 emissions in all scenarios do not violate the requirement of the Kyoto Protocol throughout the entire study period. Moreover, there is a "reserve" of 9.7–13.8 million tons of CO_2 at the end of the study period. Higher CO_2 reserve naturally belongs to the nuclear scenarios and without large involvement of the Lithuanian TPP in electricity production. On the other hand, after the decommissioning of Ignalina unit 2 CO_2 emissions go up by 4.0 million tons in scenario 1 (if the new CCGT power plant is built) or by 5.5 million tons in scenario 2 (if the Lithuanian power plant is operated). If the new nuclear power plant starts operation immediately after closure of the Ignalina NPP the increase of CO_2 emissions will be only 1.7 million tons.

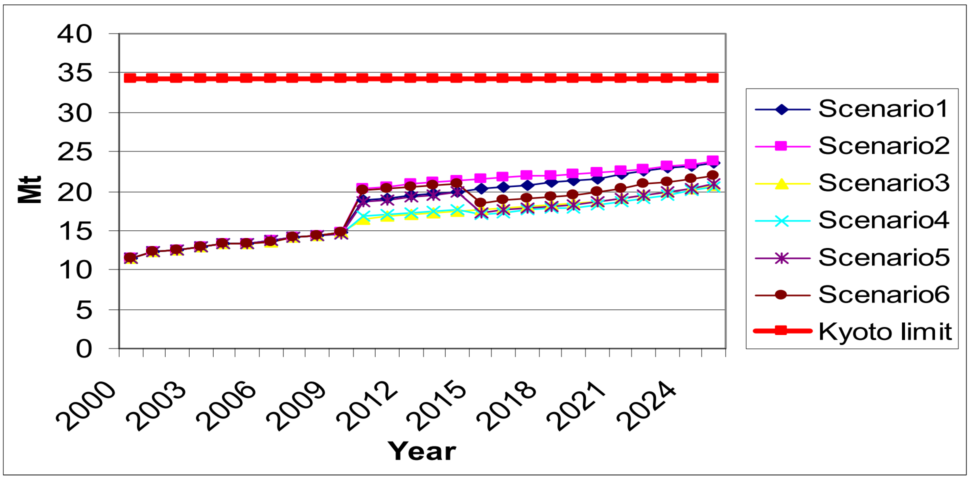


Figure 5.16. CO_2 Emissions Related to Fuel Combustion Processes.

Fig. 5.17 presents the dynamics of SO_2 emissions over the period of 25 years. SO_2 emissions are more or less stable in all scenarios. A small peak of SO_2 emissions recorded at the beginning of the study period is caused by switching from a more expensive natural gas to a less expensive fuel, namely heavy fuel oil and orimulsion. The similar rise in SO_2 emissions was observed during 1995–1999 when heavy fuel oil was cheaper than natural gas.

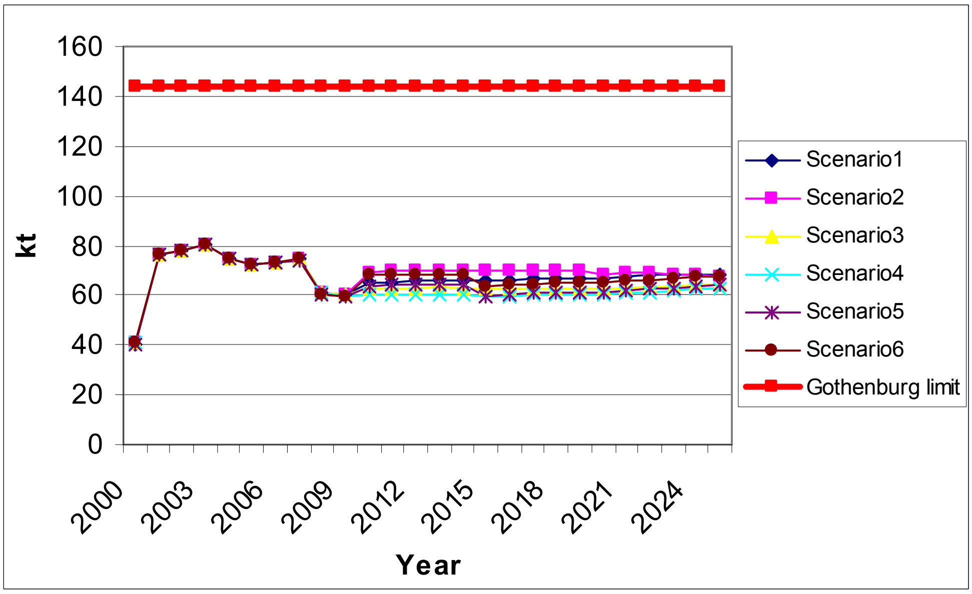


Figure 5.17. SO_2 Emissions Related to Fuel Combustion Processes.

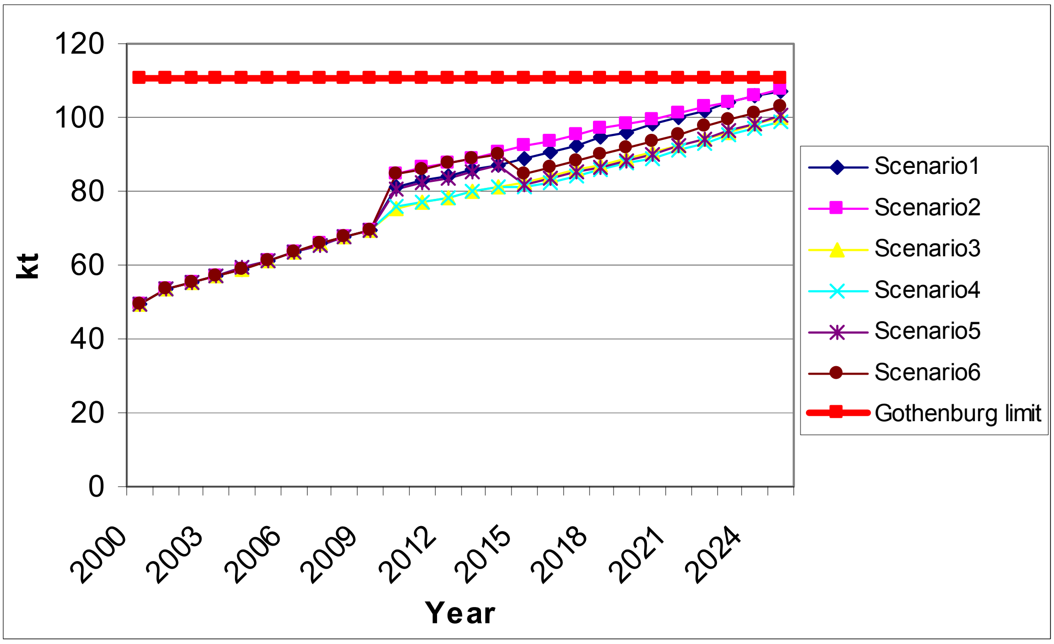


Figure 5.18. NOx Emissions Related to Fuel Combustion Processes.

The total volume of SO_2 emissions is practically independent of the future development path chosen for the Lithuanian power sector: whether it is based on fossil fuel or with continuation of nuclear energy. The major determinant for this trajectory of SO_2 emissions is the provisions of EU Directive 2001/80/EC. All power plants are obliged to install flue gas desulphurization equipment or switch to natural gas. Likewise, if a scenario includes a "segment" of successive nuclear development, the SO_2 emissions release does not expand as well. Thereby, stabilization of SO_2 emission levels could be achieved either by installation of flue gas cleaning technologies, or by successive extension of nuclear energy or by the extension of dependence on natural gas.

The NO_x emission profile displays an increasing trend over the study period (See Fig. 5.18). Despite the expected increase by more than 2 times, the total emissions in all scenarios remain below the requirement of the Gothenburg protocol that corresponds to the 70% of the emission level in 1990. However, at the end of study period NO_x emissions approach that limit. However it is important to point out that the NO_x emissions shown in the Fig 5.18 are likely to be higher than in the real situation because the study did not reflect the introduction of low NO_x burners, which eventually reduce NO_x emissions.

5.8. Electricity Production Cost

The dynamics of the average production cost of electricity for all six scenarios are presented in Fig. 5.19. This average production cost represents the sum of the annual fixed and variable O&M cost; fuel cost and annualized investment cost calculated for 1 kW·h of electricity sold from power plants. Costs related to heat production at CHPs are separated from the cost of electricity production by subtracting the revenue earned by heat sale from the total annual cost of all power plants assuming a heat price of 6 Lct/kW·h.

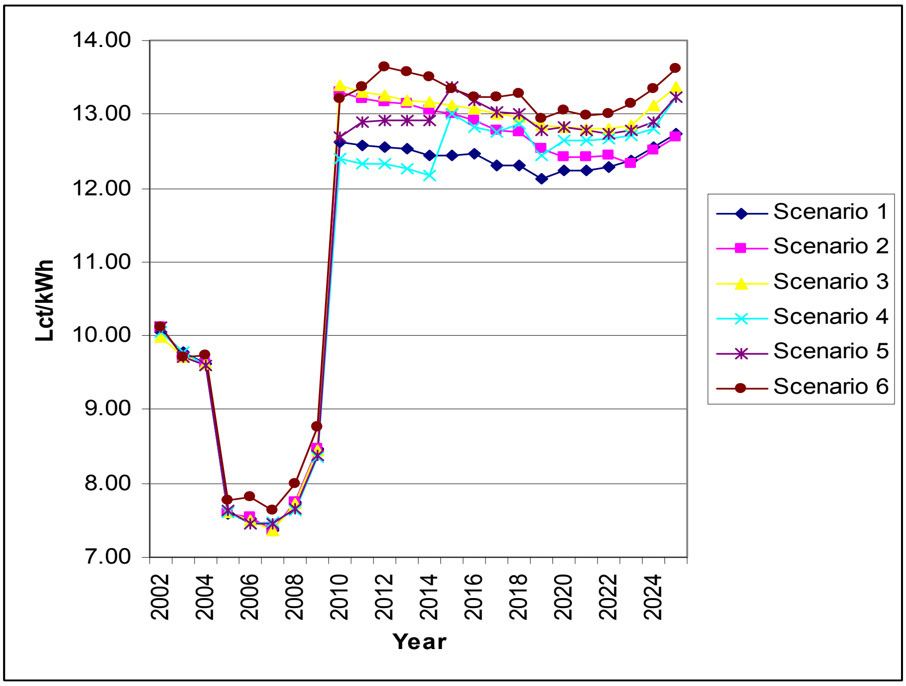


Figure 5.19. Average Electricity Production Cost in All Scenarios.

The electricity production cost decreases after the closure of Ignalina unit 1 by about 2.5 Lct/kW·h. It is clear that this cost reduction could be materialized only if the decommissioning costs of Ignalina unit 1 are covered from sources other than the collection of levies included in the electricity tariff. In addition, the fixed cost of the Ignalina NPP reduces by half after the closure of unit 1. The closure of old units at the Klaipeda CHP, the Petrasiunai CHP and other plants also leads to a reduction in production costs of electricity during this early period because their closure reduces the O&M cost. Such a reduction of electricity production cost is possible only because of the current excess capacity in the existing Lithuanian power system. Only because of that, closure of the first unit of the Ignalina NPP reduces overcapacity and the O&M cost.

After closure of the second unit of the Ignalina NPP the average electricity production cost rises 4–4.5 Lct/kW·h compared with that in the year 2009 or by 2.5–3.5 Lct/kW·h compared with the year 2002. The lowest electricity production cost is observed in scenario 1, when new CCGT units are constructed at the site of the Lithuanian TPP. Electricity production cost is in the range 12.1–12.7 Lct/kW·h. Low electricity production cost in this scenario is related to the low investment cost and high efficiency of the new CCGT and CHPs, as well as to the high utilization rate of those power plants (including existing CHPs) producing the major part of electricity and securing a comparatively low O&M cost.

During 2010–2015 the cost of electricity production in scenario 2, in which the modernized Lithuanian TPP becomes the main electricity producer, is 0.66–0.57 Lct/kW·h higher than in scenario 1. In the following years this difference decreases. Despite higher electricity production cost, operation of the Lithuanian TPP guarantees higher reliability of energy supply by ensuring a higher degree of fuel diversification. Another advantage of scenario 2 is that the modernization of the Lithuanian TPP will likely be partly financed by the EU in the form of a grant. That would ease the capital requirements.

The average electricity production cost of the Lithuanian power system after the commissioning of the new nuclear power plant tends to be higher in comparison with those in fossil fuel scenarios. After 2010, the electricity production cost in scenario 3 is 0.46–0.76 Lct/kW·h higher than in scenario 1.

The comparatively small difference in average electricity production costs between scenarios can be explained by the modest share of nuclear electricity (only 600 MW is considered). If the capacity of the new nuclear power plant were to be bigger the difference in costs would have been higher.

6. SENSITIVITY ANALYSIS

6.1. The Timing of the Closure of the Ignalina NPP

According to the Lithuanian National Energy Strategy the first unit of the Ignalina NPP will be closed at the end of 2004 and the second unit at the end of 2009. However, the real lifetime of existing fuel channels of the second unit may reach 2018 [56, 57]. This means that the real lifetime of the second unit may be extended until the end of 2017. Later fuel channels could be replaced and the unit may be in operation for an additional 15–20 years. In this study the consequences of replacement of fuel channels are not analyzed because there is insufficient information in Lithuania on the necessary investments for long term safety upgrade or modernization of the unit due to the aging problems. Nevertheless, operation of the unit until the end of 2017 does not require any special investments in modernization or safety upgrade. This issue is a subject for investigation, especially as it allows the estimation of the economic losses that Lithuania would have to incur due to the early closure of the Ignalina NPP.

In order to evaluate the economic consequences of the closure by 2009 of the second unit of the Ignalina NPP an additional scenario 7 was modeled in which Ignalina unit 2 is assumed to remain in operation until the end of its normal lifetime i.e., the end of 2017. All other inputs to the model are exactly the same as in the scenario 1 (in effect, scenario 7 is scenario 1 plus the operation of Ignalina unit 2 till 2017). The analysis of this study shows that continued operation of Ignalina unit 2 until the end of 2017 allows a saving of the total discounted cost of US$ 378 million in comparison with scenario 1 and US$ 390 million in comparison with scenario 2 respectively. Such a saving is equivalent to 3% of the total discounted system cost over the 25-year period.

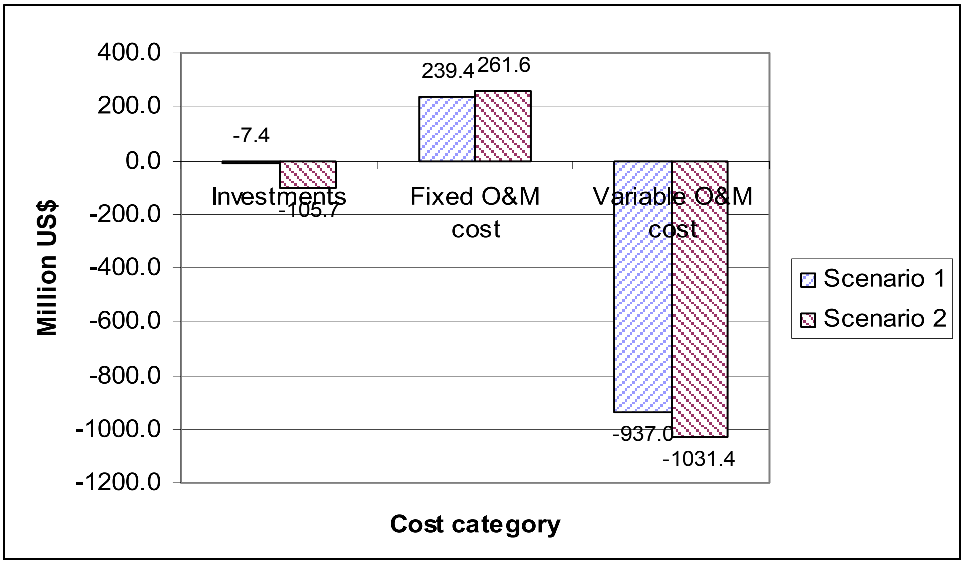


Figure 6.1. Comparison of Undiscounted Cost of Scenario 1 and 2 Relative to Scenario 7.

The highest saving, expressed in terms of undiscounted costs, is in the variable O&M cost. The cost differences between scenario 7 and scenarios 1 or 2 are shown in Fig. 6.1. The variable O&M cost for scenario 7 is US$ 937 million lower than for scenario 1 and US$ 1031 million lower in comparison with scenario 2. The cost saving takes place during the time period 2010–2017.

The lowest saving is in the investment requirements because the second unit of the Ignalina NPP would still have to be closed within the study period. All necessary changes in the structure of generating capacities in scenario 7 are exactly the same as in scenario 1 or scenario 2. The only noticeable impact is that a large portion of the investments can be postponed for 8 years.

One of the important aspects of the closing down of Ignalina NPP is the issue of a decommissioning fund. Early closure of unit 2 at the end of 2009 precludes the power plant from the possibility of accumulating necessary financial means for its decommissioning. To investigate this issue, the formation of a special fund from the net revenue based on the electricity sale was analyzed for three possible future electricity prices. The first (marked — price projection 1) corresponds to the electricity price that is simply marginal production cost, derived directly from the system optimization. The second (price projection 2) corresponds to the marginal cost based electricity price (the same as the first one) but adjusted to include the fixed cost of the existing capacities. The actual marginal electricity production cost does not include the fixed costs of the existing units. However, the power sector has to pay for these fixed O&M costs. Taking this into account, the fixed costs of existing units were added to the marginal electricity production cost. The third one (at current price) foresees stable electricity sale price during the whole study period and is assumed to be the same as in 2001.

The accumulation of a decommissioning fund calculated for the three price possibilities as described above is shown in Fig. 6.2 for scenario 1 where the first unit of the Ignalina NPP is closed at the end of 2004 and unit 2 at the end of 2009. Figure 6.3 shows the accumulation of a decommissioning fund for the case when the first unit of the Ignalina NPP is closed at the end of 2004 and unit 2 at the end of 2017.

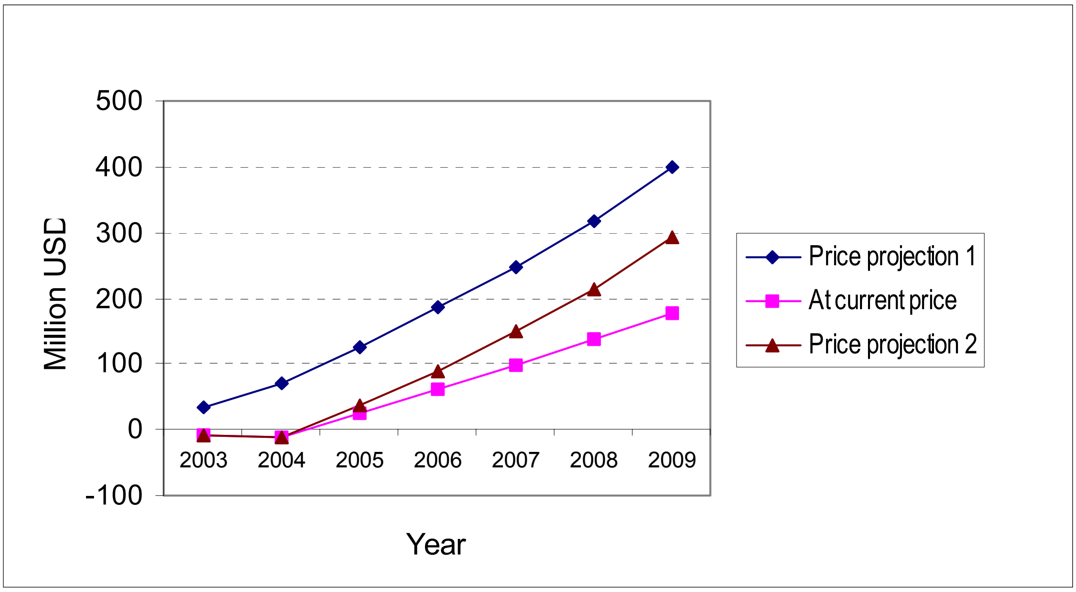


Figure 6.2. Accumulation of Decommissioning Fund in the Case when the Unit 2 of the Ignalina NPP is Closed at the End of 2009.

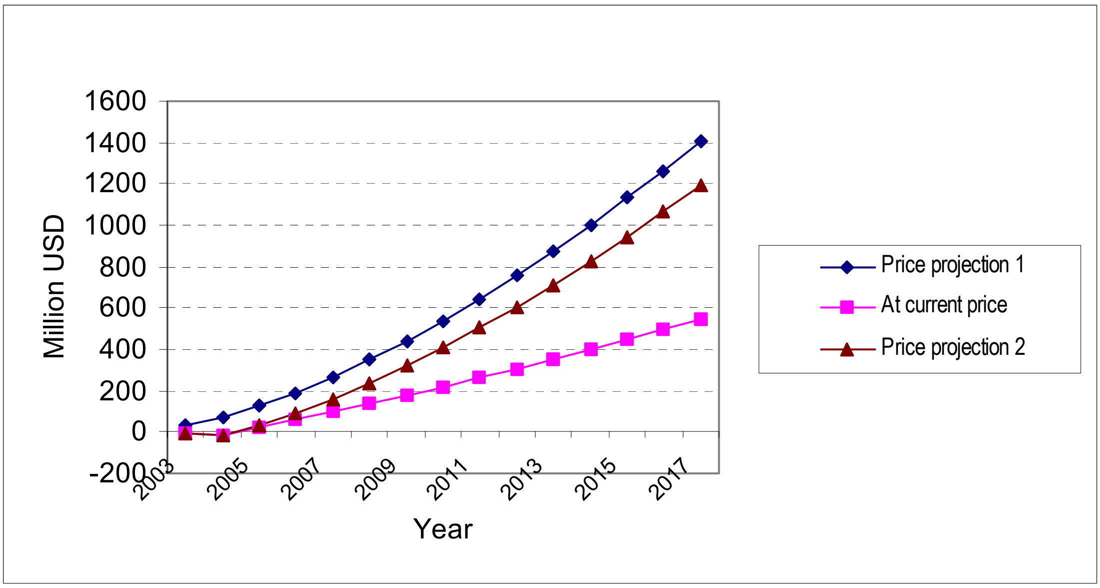


Figure 6.3. Accumulation of Decommissioning Fund in the Case when the Unit 2 of the Ignalina NPP is Closed at the End of 2017.

Given that a total of about US$ 1 billion will be necessary for decommissioning of the Ignalina NPP, the fund accumulated from electricity revenues generated by Ignalina NPP itself is not sufficient and additional financial resources will be necessary in order to fund all decommissioning projects. The range of the additional decommissioning fund is depicted in Fig. 6.4 which shows that an additional fund of US$ 600–822 million, depending on the price projections, will be required if unit 2 is to be closed at the end of 2009. Should the second unit of the Ignalina NPP remain in operation until the end of 2017 the power plant would be able to collect all necessary financial means for its decommissioning.

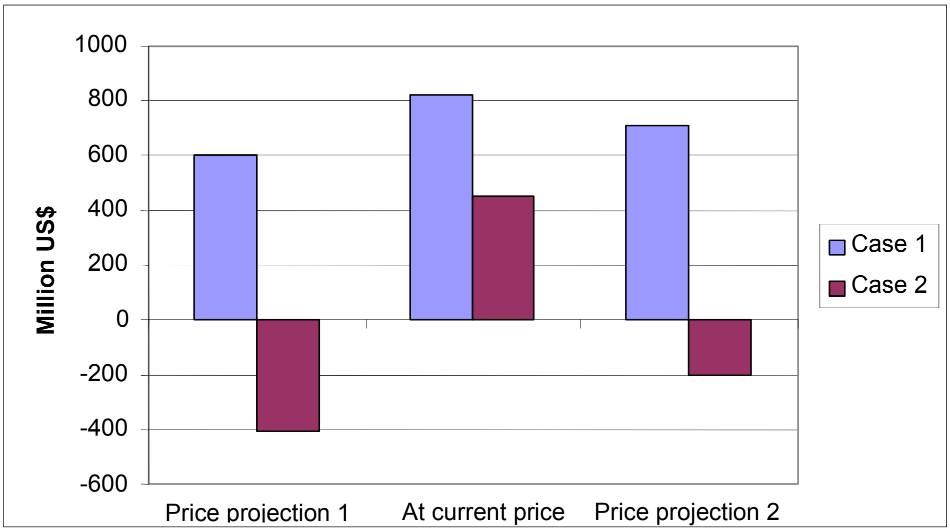


Figure 6.4. Additional Fund Required. (Case 1: The Unit 1 of the Ignalina NPP is closed at the End of 2004 and Unit 2 at the End of 2009; Case 2: The Unit 1 of the Ignalina NPP is closed at the End of 2004 and Unit 2 at the End of 2017).

Changes in electricity production mix and capacity structure of the whole system in scenario 7 are very similar to the ones in scenarios 1 and 2. The only difference is that those changes occur 8 years later as Ignalina unit 2 remains in operation till 2017. In scenario 7, nuclear fuel plays a dominant role in the total fuel structure for electricity and heat production until 2018. After 2018 the fuel mix of the scenario 7 resembles the fuel mix of the fossil fuel scenarios 1 and 2.

6.2. Impact of NPP Investment Cost on Its Economic Effectiveness

Sensitivity analysis of the investment cost for new nuclear power plant was carried out using 1500 US$/kW and 1000 US$/kW values of overnight investment cost and 600 MW capacity. All other inputs for modelling remain exactly as for scenario 3. Two values of discount rates were used in the analysis, namely 10% and 6%. The economic effectiveness of the new nuclear power plant was measured in terms of the total discounted costs of the whole energy system. The basis for comparison is the discounted costs of the system in scenario 1. If the total discounted system cost of a nuclear scenario is higher in comparison with scenario 1, it is considered to entail an "economic loss". Vice versa, if the total discounted system cost in the scenario with the new nuclear plant is lower in comparison with scenario 1, it is considered to entail an "economic gain".

Using this approach it was found that in the case of a 10% discount rate and 1500 US$/kW of investment cost for the new nuclear power plant, the Lithuanian energy system would bear a loss of approximately US$ 170.5 million. If the investment cost were equal to 1000 US$/kW the loss is reduced to US$ 45.8 million. In the case of a 6% of discounting factor and 1500 US$/kW of investment cost for new nuclear power plant, the total loss of the Lithuanian energy system is approximately US$ 161.2 million. Using an investment cost of 1000 US$/kW then construction of new nuclear power plant would bring a total gain of US$ 29 million. Thus, the effectiveness of a new nuclear power plant depends on the investment cost and discount rate (see Fig. 6.5).

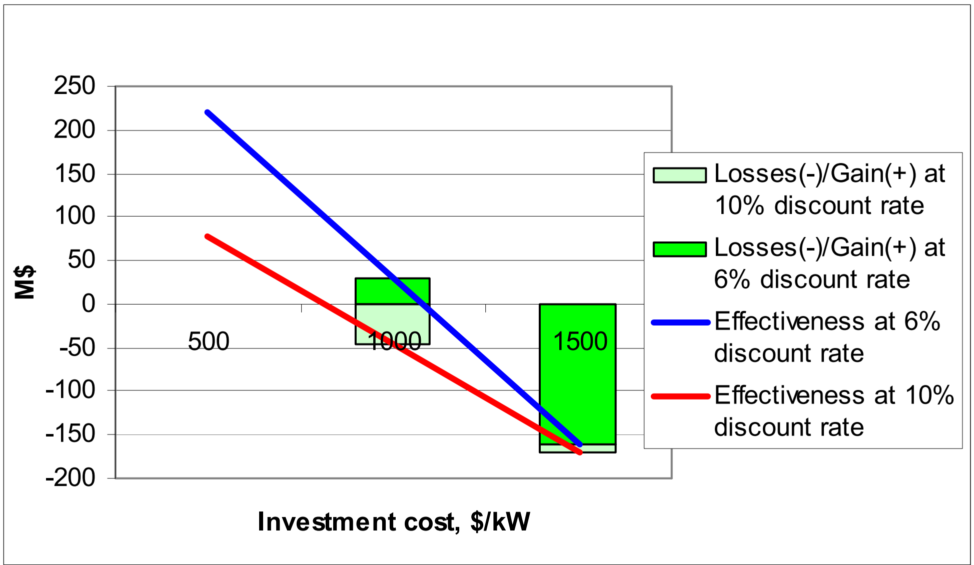


Figure 6.5. Effectiveness of New Nuclear Power Plant in Lithuanian Energy System.

As can be seen from Fig. 6.5 the construction of a new nuclear power plant is an economically attractive option if the investment cost is below 816 US$/kW in the case of a 10% discount rate or 1076 US$/kW in the case of a 6% discount rate.

6.3. Impact of Unit Size of New NPP

In order to estimate the impact of unit size of the new nuclear power plant on the future development of the Lithuanian power system scenario 8 was analyzed. All modelling inputs in scenario 8 are the same as in scenario 3 except for the capacity of the new nuclear power plant, which is now assumed to be 1000 MW, and thus a higher required reserve capacity is also taken into consideration. The existence of such a large nuclear unit induces significant changes in the structure of electricity production (Fig. 6.6).

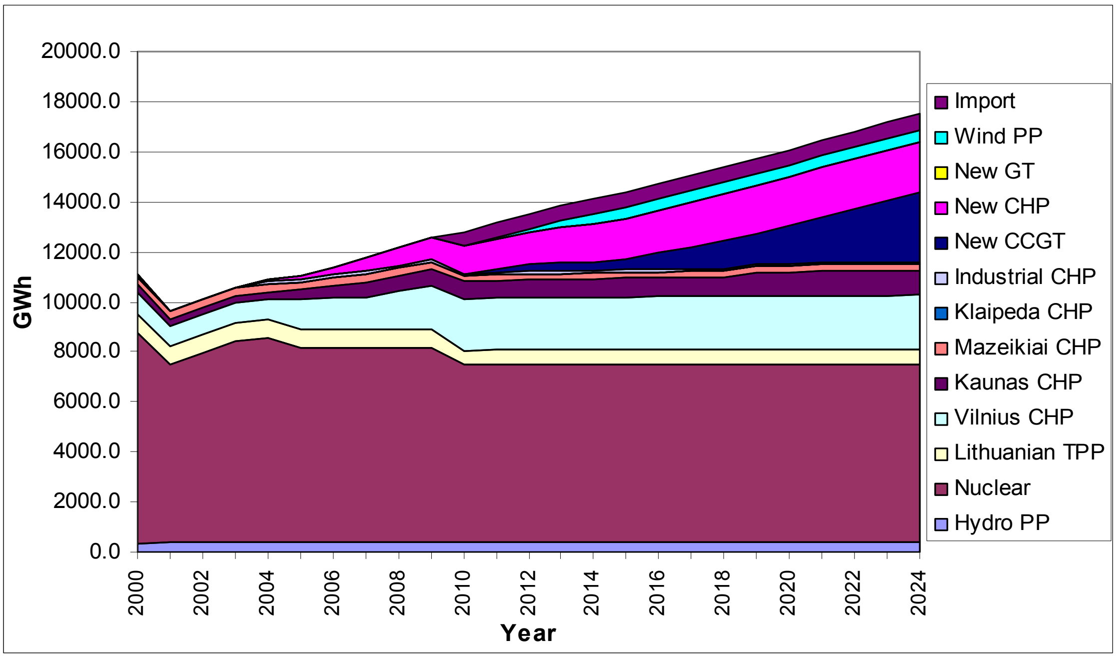


Figure 6.6. Electricity Production Mix in the Case of 1000 MW New Nuclear Power Plant.

Fig. 6.6 shows clearly that the new 1000 MW nuclear unit covers 55% of total electricity production in 2010 and 40% in 2025. The remaining part of the total electrical load is met by existing and new CHPs. Contribution of the new CCGT is visible only after 2017–2018 when its share grows from 5% to 17% in 2025. Electricity production at the Lithuanian TPP is limited by the heat demand of the Electrenai town. Only one combined heat and electricity production unit of 150 MW is used in CHP mode at this power plant and not at full capacity.

6.4. Impact of Demand

Two more scenarios were developed to probe the impact of higher electricity demand on the future development of the Lithuanian energy system. These were named scenarios 9 and 10. All modeling inputs in scenario 9 were the same as in scenario 1, except that energy demand for all energy forms is taken from a higher demand scenario (Chapter 3). Scenario 10 is scenario 9 without the construction of a new CCGT at the site of the Lithuanian TPP. The dynamics of electricity generation mix for scenario 9 are presented in Fig. 6.7 and for scenario 10 — in Fig. 6.8.

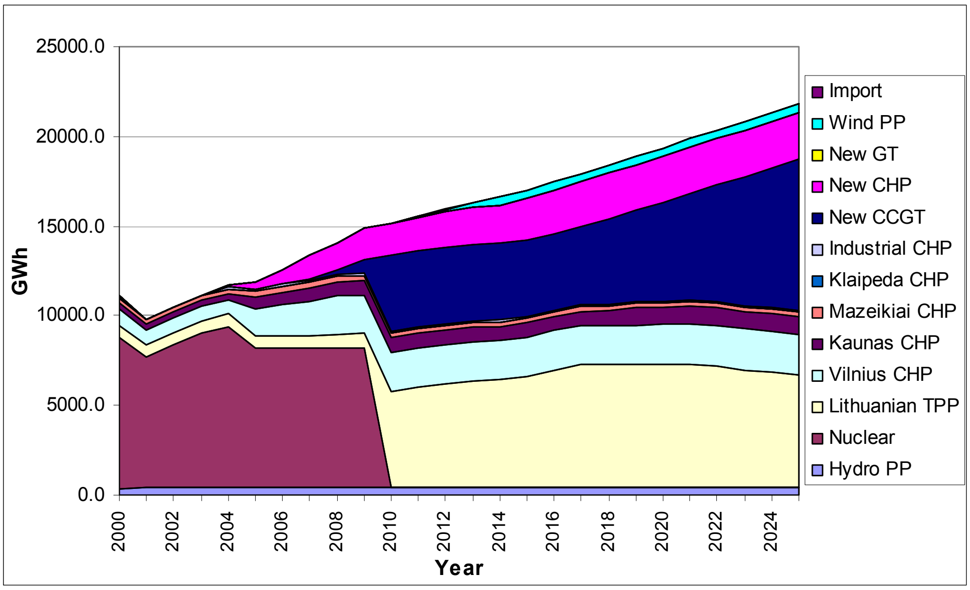


Figure 6.7. Electricity Production Mix in Scenario 9.

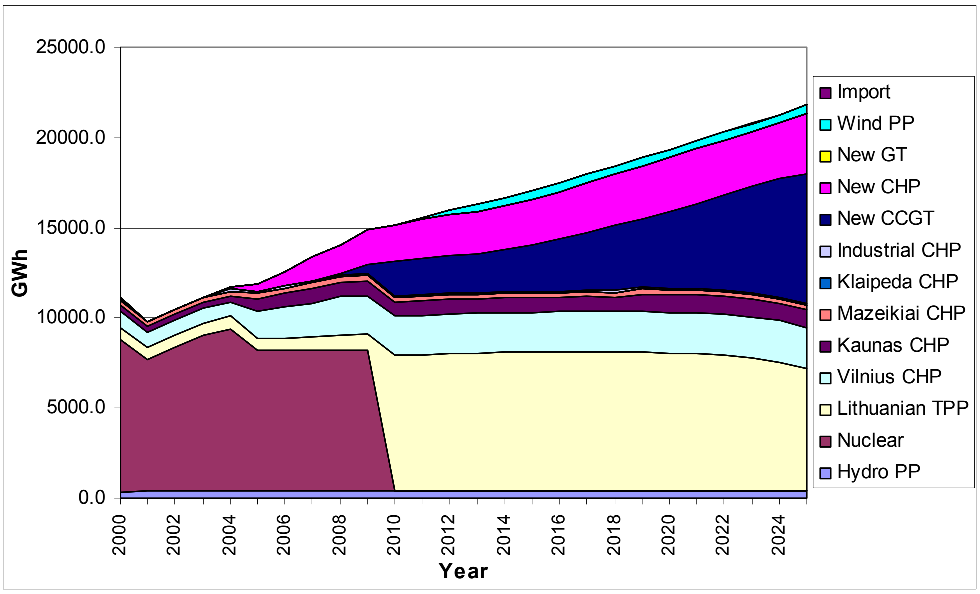


Figure 6.8. Electricity Production Mix in Scenario 10.

High electricity demand impacts mainly on the operation of the Lithuanian TPP if a new CCGT at the site of the Lithuanian TPP is built. In addition, another CCGT is built at the site of the Ignalina NPP. Its operation starts in 2017–2018 and in 2025 electricity production reaches the value of the CCGT at the site of the Lithuanian TPP. This means that two new CCGT power plants would need to be constructed at existing sites in order to cover the internal Lithuanian electricity demand during the study period. The third difference between scenario 9 and scenario 1 is a faster development of the new CHPs in the time period 2005–2009. New CHPs are a more economically attractive option in comparison with the Lithuanian TPP and their contribution grows alongside demand growth.

If the construction of new CCGT units is not allowed at the site of the Lithuanian TPP then new CCGT units will be constructed at the site of the Ignalina NPP instead. When the new CCGT at the Ignalina NPP site reaches its capacity limit of 600 MW a new CCGT must be built at a new site in order to meet the total electricity demand. Finally, after the closure of the Ignalina NPP the following technologies should be operating to produce enough electricity for Lithuania (in order of their economic attractiveness):

- Existing CHPs in combined heat and electricity production mode;
- New CHPs in combined heat and electricity production mode;
- New CCGT units at the site of the Lithuanian TPP;
- Modernized 300 MW units at the Lithuanian TPP;
- New CCGT units at the site of the Ignalina NPP;
- New CCGT units at new site.

This ranking of power plants is based solely on their economic merits. No other criteria such as reliability of energy supply were considered.

6.5. Impact of Discount Rate on the Future Structure of Electricity Production

In order to estimate the impact of discount rate on the future structure of electricity generation capacity, electricity production or economic effectiveness of various power plants, an additional scenario (scenario 11) was modelled. Scenario 11 has the same inputs as scenario 1 except for the discount rate, which is set to 6%. As expected, a lower discount rate favours new investments, in particular in this case the construction of the new CCGT units. New CCGT units, having a higher efficiency and a lower O&M and fuel cost in comparison with the O&M and fuel cost of the Lithuanian TPP are the optimum choice. In this regard, new CCGT units at the site of the Ignalina NPP become more attractive than the modernization of the Lithuanian TPP. This is the main difference from scenario 1.

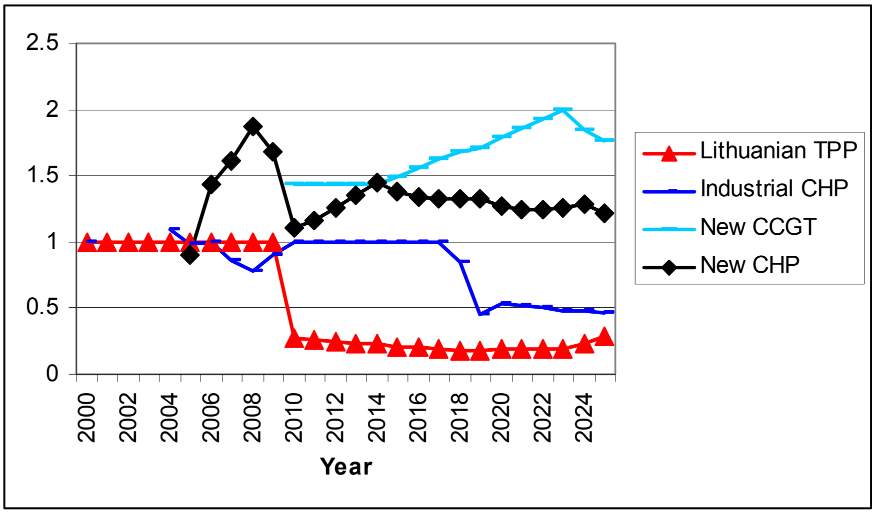


Figure 6.9. Differences of Electricity Production at Various Power Plants in Scenario 11 in Comparison with Scenario 1.

Figure 6.9 displays the differences of electricity production by various power plants in scenario 11 in comparison with scenario 1. The vertical axis shows the ratio of the production levels of a particular power plant between scenario 11 and that of scenario 1. Fig. 6.9 clearly demonstrates that new CCGT plants become major electricity producers after the closure of the Ignalina NPP. Their electricity productions in scenario 11 are by to 1.4 – 1.9 times higher than in scenario 1 (the discount rate of scenario 1 was 10%). High capacities and productions at new CCGT plants make Lithuanian electricity and district heating sector very dependent on natural gas. The share of natural gas in the total fuel consumption for electricity and heat generation rises to 53%–61% after 2015, depending on the year.

A lower discount rate also favours new CHP units. Electricity output from the new CHP units is generally about 1.2–1.3 times higher than in scenario 1 but occasionally it is as high as 1.6–1.9 times. Higher effectiveness of the new CCGT units leads to much lower utilization of the Lithuanian TPP in comparison with scenario 1. After 2009, electricity production at the Lithuanian TPP in scenario 11 makes up only 18%–28% of the electricity production in scenario 1 where the value of the discount rate was 10%. Utilization of the Lithuanian TPP is mainly related to the heat supply to Elektrenai town and the related electricity output from combined heat and electricity production units. Electricity production at condensing units is very low.

From 2017 onward a lower electricity output is observed also from industrial CHPs because when the discount rate is equal to 6% industrial CHPs are less efficient in comparison with new CHP units. The lower O&M cost of new CHP units outweigh the investment cost, their capacity increases and electricity production at existing industrial CHP units is reduced. The lowest electricity production at an existing industrial CHP units starts in 2019 and makes up only 50% of the value in scenario 1.

A decrease of the discounting factor from 10% until 6% is not enough to make a new nuclear power plant an economically attractive option in comparison with new CCGT units or modernized Lithuanian TPP if the investment cost for a new nuclear power plant is 1500 US$/kW. As already shown in section 6.2, in order to make a new nuclear power plant economically attractive it is necessary to reduce its investment cost.

6.6. Impact of Fuel Prices on Economic Effectiveness of Various Power Plants

The impact of fuel prices on the future structure of electricity generation and the comparative effectiveness of power plants was evaluated with the help of scenario 12. This scenario uses all the modeling inputs in scenario 1 except that the high fuel price scenario as given in Table 4.13 is assumed. High fuel prices favors the operation of the Lithuanian TPP, which uses orimulsion — a comparatively cheap fuel. A comparison of electricity production by power plants between scenarios 12 and 1 is presented in Fig. 6.10.

As explained above, higher fuel prices give preference to the Lithuanian TPP. The modernized Lithuanian TPP becomes the main electricity producer in Lithuania after the closure of the Ignalina NPP. Starting from 2010 it produces about 1.5–2.5 times more electricity than in scenario 1. Higher electricity production at the Lithuania TPP diminishes the outputs of new CHPs running on natural gas. High fuel prices also facilitate the stronger penetration of wind power plants. In this regard, wind powered generation reaches its maximal capacity very soon after the closure of the Ignalina NPP. Wind power in 2010 produces twice as much as in scenario 1. The import of electricity depends on the market price of electricity and may become an attractive option after productions at domestic power plants reach their limit or especially when neighbouring countries have overcapacities, or when fuel prices in the Russian Federation remain lower than in Lithuania.

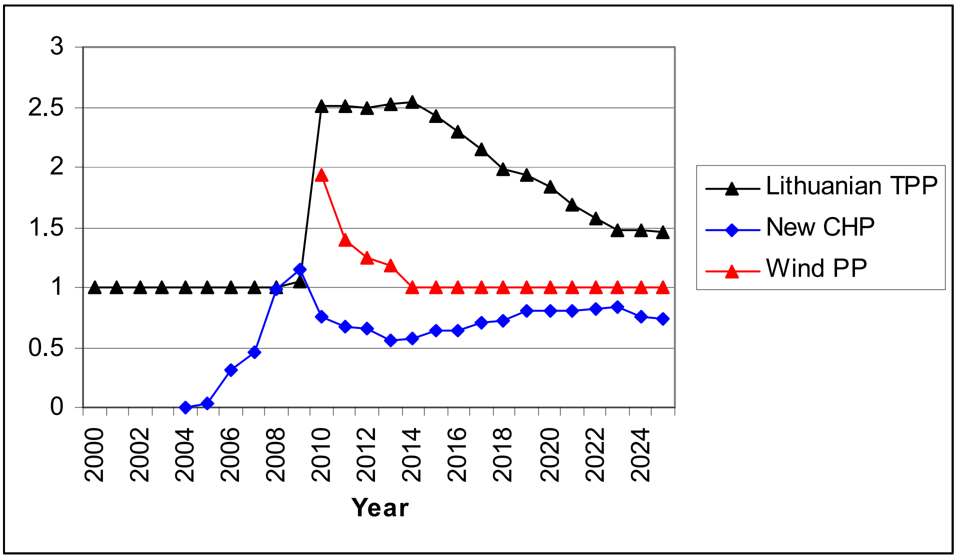


Figure 6.10. Electricity Production of Selected Power Plants in Scenario 12 (High Fuel Prices) in Comparison with Scenario 1.

Electricity and heat production in the case of high fuel prices will have a tendency to rely on orimulsion. However, this does not imply a strong dependency on one fuel type and one fuel supplier because orimulsion can be substituted by oil or natural gas. Thus, diversification of fuel supply is ensured but with a higher cost of electricity and heat production.

7. CONCLUSIONS

After a deep recession at the start of Lithuania's transition to a free market economy, in 1995, the economy began a gradual recovery. GDP grew at a modest rate of 3.4% per year during 1995–2000, and then jumped to an average rate of 5.9% in 2001 and 2002. Recent forecasts predict similar growth for the near future. During the period 1995–2000, demand for final energy and electricity decreased at an average rate of 4.4% and 2.3% respectively. In 2001 and 2002, however, annual electricity consumption grew by almost 4% and final energy demand by 3%. Future stable economic growth is expected to result in a continued increase in final energy and particularly electricity demand.

Some important features of the Lithuanian energy sector are the following:

- High dependence (over 85%) on imports from a single country for primary energy supply;
- Excess electricity generating capacity (installed capacity is almost 3 times higher than actual peak demand);
- Absence of interconnections with Western energy systems;
- Growing consumption of indigenous energy resources (their share in the primary energy balance increased from 2.4% in 1990 to 9% in 2000);
- Increasing extraction of local oil (its share in the country's balance of petroleum products is more than 15%);
- High percentage (about 75%) of residential heating demand in towns being supplied by district heating systems; and
- Significant increase of energy efficiency during the period 1994–2001.

At present energy intensity, i.e. the ratio of final energy consumption per unit of GDP using estimates of Purchasing Power Parity, in Lithuania is about 1.5 times higher than the average energy intensity of the European Union. During 1994–2001, Lithuania has seen a 38% reduction in the value of final energy intensity, which provides evidence of the substantial progress the country has made in improving energy efficiency.

It is very difficult to forecast precise rates of economic growth for countries in transition, particularly for the EU accession countries. Therefore this study took a similar scenario approach as was adopted for the Lithuanian National Energy Strategy approved in 2002, namely to analyze the following three scenarios of economic development:

- Fast economic growth scenario (7% per annum till the year 2010 and 3% in the period 2011–2025 or on average by 4.6% per annum in the period 2000–2025);
- Basic or moderate economic growth scenario (4.7% per annum until the year 2010 and 3% in the period 2011–2020 or on average by 3.7% per annum in the period 2000–2025); and
- Slow economic growth scenario (2% per annum until the year 2010 and 3% in the period 2011–2020 or on average by 2.6% per annum in the period 2000–2025).

Future final energy demand for Lithuania was projected based on an accurate determination of energy consumption for various branches of the economy in the reference year (2000), identification of the relationships between factors influencing such consumption and presumptions as to tendencies of their long term development. Based on these assumptions the modern and widely verified model for analysis of energy demand (MAED) was applied to develop a forecast of final energy demand. Experience accumulated shows that the new version of the MAED model, prepared in cooperation with the IAEA and IIASA in 2000, is one of the most suitable modeling tools, particularly for countries in transition.

Study results indicate that final energy demand in Lithuania during the period 2000–2025 will grow at an average rate of 2.3% per annum under the assumptions of the basic scenario and by 2.9% in the case of the fast economic growth scenario. At the same time electricity demand in Lithuania will grow faster — by 2.9% per annum for the basic scenario and 3.7% in the case of the fast economic growth scenario. In the latter case electricity consumption will increase by 2.5 times over the study period and, by 2025, per capita electricity use will be similar to the present average per capita level in the European Union.

The whole Lithuanian energy system was analyzed using the MESSAGE mathematical model; however, primary attention was paid to the economic analysis of power system development during the study period until 2025, taking into account earlier closure of the Ignalina NPP.

The analysis of future energy system development in Lithuania considered a set of possible technological options, including:

- Modernization of Lithuanian TPP and existing CHP including flue gas desulphurization measures;
- Construction of a new nuclear power plant or new CCGT units at different sites (at site of the Lithuanian TPP or the Ignalina NPP, as well as at a new site);
- Construction of new middle and small scale CHPs operating on natural gas and renewable energy sources;
- Conversion of boiler-houses into CHP;
- Construction of new hydro power plants on the Nemunas and Neris rivers, new gas turbines and wind power plants;
- Changing of fuel type in boiler-houses and power plants;
- Replacement of district heating systems by decentralized heating systems based on individual gas fired boilers; and
- Import, extraction, processing, transmission and distribution of various forms or primary energy resources and secondary energy.

For the most part, constant fuel prices in Lithuania at the level of 2000 were applied in the analysis of energy supply development scenarios.

Three groups of energy system development scenarios were analyzed: fossil fuel scenarios — where the Ignalina NPP is replaced by fossil fuel power plants; the nuclear scenario — representing development of the electricity sector with the immediate commissioning of a new nuclear power plant after shut down of the second unit of Ignalina NPP; postponed nuclear scenarios — representing development of the electricity sector with postponed commissioning of a new NPP till 2015. The capacity of the candidate nuclear power plant was assumed to be 600 MW for the major part of scenarios analyzed.

Looking purely from an economic point of view, the most rational option for Lithuania would be continued operation of the 2nd unit of Ignalina NPP until the end of its technical lifetime with existing fuel channels and, if necessary, with their subsequent replacement. However, closure of the plant by the end of 2009 is already stated in the National Energy Strategy and agreed with the EC during accession negotiation.

In order to meet the growing electricity demand in Lithuania and replace lost generating capacity associated with early closure of the Ignalina NPP, relative economics point to the use of:

- Existing CHPs in combined heat and electricity production mode;
- New CHPs in combined heat and electricity production mode;
- New CCGT units at the site of the Lithuanian TPP;
- Modernized 300 MW units at the Lithuanian TPP;
- New CCGT units at the site of the Ignalina NPP;
- New CCGT units at a new site
- New nuclear units.

The future generation mix in the country is not only dependent on the price of alternative expansion options, but also final energy demand growth, and energy policy options to promote security of energy supply. Table 7.1 shows the structure of new generating capacity necessary to meet electricity demand in Lithuania up to 2025, under assumptions of the basic demand scenario, constant fuel prices and a 10% discount factor.

When evaluating alternative replacement capacity for the Ignalina NPP, the options of constructing new CCGT units and modernizing the existing 300 MW units at the Lithuanian TPP have similar economics. While CCGT units produce lower levels of atmospheric emissions, this option significantly increases dependence on natural gas. The option to modernize the Lithuanian TPP leads to considerably improved diversity of fuel supply and suppliers, and thus greater fuel price security.

Table 7.1: Necessary power plant capacities utilization

	Fossil fuels (MW)	Nuclear (MW)	Delayed nuclear (MW)
Lithuanian TPP	1500	1370	900–1800
Existing CHP	800–820	790	700–790
New CHP	400–450	390	340–370
New CCGT	600–680	600	160–600
New nuclear PP	0	600	600
Hydro & HPSPP	914	914	914
Wind PP	180	180	180
Import		0	0–580
Total	4474–4464	4844	4814

A low discount rate (5–6%) creates more favourable economic conditions for new units (CCGT, CHP and others), while increasing the price of natural gas or higher discount rates (over 10%) lead to higher economic attractiveness of modernizing the Lithuanian TPP due to lower investment cost and possibility of burning comparatively cheep fuel — orimulsion.

Replacement of the Ignalina NPP by a new nuclear power plant would result in a higher cost of the Lithuanian energy system operation and development among all scenarios analyzed. Total discounted cost in comparison with fossil fuel scenarios would be US$ 158–170 million higher if a new nuclear power plant would start operation immediately after closure of the second unit of the Ignalina NPP (under basic demand growth scenario, assuming an investment cost for new nuclear of 1500 US$/kW and applying a 10% discount rate). In the case of commissioning of the new nuclear power plant in 2015, the discounted cost of energy system operation and development will exceed the cost of scenarios based on fossil fuel utilization by US$ 60–84 million. The decommissioning cost and insurance of the nuclear power plant, which are not included in this analysis, would further worsen the economic competitiveness of the new nuclear option.

Results of sensitivity analyses indicate that construction of a new nuclear power plant would be an economically attractive option in Lithuania if the investment cost is below 800 US$/kW with a discount rate of 10% or below 1100 US$/kW with a rate of 6%. Only in the case of a discount rate of 6% is building a new nuclear power plant after closure of the Ignalina NPP more economically attractive than power system development based on fossil fuel power plants.

In the case of the basic demand scenario, a new 1000 MW nuclear unit would provide 55% of the total electricity production in Lithuania in 2010 and 40% in 2025. Remaining electricity would be produced by existing and new CHPs. In this case, construction of a new CCGT would only be needed after 2017 when its share will grow from 5% to 17% in 2025. As in the case of further operation of the Lithuanian TPP, construction of a new nuclear unit would also lead to diversification of primary energy requirements. However, power plants used for electricity generation would be more tightly linked to a specific fuel type in comparison with the scenario where the Lithuanian TPP is modernized. As a result, there would be less space to maneuver in selecting fuel types and suppliers and for negotiating fuel prices.

The average electricity production cost for the Lithuanian power system could decrease after closure of the first unit of Ignalina NPP if fixed O&M cost related to that unit can be avoided. After closure of the second unit of the Ignalina NPP, however, the average electricity production cost increases by 2.5–3.5 Lct/kW·h in comparison with the year 2002. The lowest rise in electricity production cost is in the case when new CCGT units are constructed at the site of the Lithuanian TPP, while the highest rise in cost is associated with construction of a new nuclear unit. The average electricity production cost after closure of the Ignalina NPP is in the range 12.1–12.7 Lct/kW·h assuming the basic electricity demand scenario, 10% of discount rate and constant fuel prices throughout the study period.

High electricity demand leads to much higher electricity production at the Lithuanian TPP. It also favours development of new CHPs (about 240 MW) in the period 2005–2009. In addition, it would be necessary to construct two new 600 MW CCGT power plants at existing sites (one in 2010, another during 2018–2020) in order to meet electricity demand in Lithuania during the analyzed time period. Availability of electricity in a market at a price below 13–13.5 Lct/kW·h would promote electricity imports and postpone investments in new capacity.

Major changes are foreseen in the structure of heat production with the growth of CHP in district heating systems that do not yet utilize this technology. The fastest growth is expected from new CHPs based on renewables and from new small CHPs operating on natural gas. For scenarios of basic economic growth, the corresponding installed electrical capacity of CHP based on renewables is 90 MW and on natural gas is 110–140 MW. A significant amount of heat production comes from boiler-houses converted into CHPs through the installation of steam turbines after the steam boilers or additional gas turbines in front of the boilers. The installed electrical capacity of such units is in the range 70–160 MW. The decision on which development path is chosen for the Lithuanian power sector (fossil fuel or nuclear) will not have a significant impact on the operation of existing CHPs. Existing CHPs become economically competitive upon closure of the first unit of Ignalina NPP. Prior to closure of the second nuclear unit the existing capacity of CHPs will be utilized at 75–80%.

After decommissioning the second unit of Ignalina NPP, emissions of CO_2 (in the case of basic economic growth scenarios) in Lithuania increase by 4.0 million tons in the case where replacement capacity comes from a new CCGT or by 5.5 million tons if from modernization of the Lithuanian TPP. If a new nuclear power plant begins operation immediately upon closure of Ignalina NPP, CO_2 emissions will only increase by 1.7 million tons. Due to installation of flue gas desulphurization equipment the amount of SO_2 emissions is practically the same for each power sector development path – based on fossil fuel or with continuation of nuclear energy. However, emissions of NO_x during the study period increase 2 times in the fossil fuel scenario. Still, the requirements of the Kyoto and Gothenburg protocols for the electricity and district heating sectors, as well as for the whole Lithuanian energy sector will be not neither for CO_2, SO_2 or NO_x.

APPENDIX I. RESULTS OF THE ENERGY DEMAND PROJECTION

Slow economic growth scenario

Table I.1. Fuel Demand in the Industrial Sector

	2000	2005	2010	2015	2020	2025
MWa						
Motor fuel	46.20	52.36	55.89	62.64	70.21	78.68
Coal	17,79	16,86	16,48	16,79	16,99	17,03
Peat	2,52	3,09	3,76	4,55	5,46	6,41
Wood	39,30	43,02	48,20	56,45	66,03	77,07
Natural gas	1005,97	1038,39	1074,90	1135,61	1205,65	1285,76
Fuel oil	354.89	345.02	346.58	354.28	360.50	364.58
Total	1466.68	1498.74	1545.80	1630.33	1724.83	1829.52
Shares from total demand						
Motor fuel	0.03150	0.03493	0.03616	0.03842	0.04070	0.04301
Coal	0.01213	0.01125	0.01066	0.01030	0.00985	0.00931
Peat	0.00172	0.00206	0.00243	0.00279	0.00317	0.00350
Wood	0.02679	0.02871	0.03118	0.03462	0.03828	0.04212
Natural gas	0.68589	0.69284	0.69537	0.69655	0.69899	0.70278
Fuel oil	0.24197	0.23021	0.22420	0.21731	0.20900	0.19927

Table I.2. Fuel Demand in the Services Sector

	2000	2005	2010	2015	2020	2025
MWar						
Motor fuel	16,86	16,86	16,86	16,86	16,86	16,86
Coal	71,16	72,18	72,92	73,79	74,25	74,30
Peat	0,66	1,06	1,46	1,90	2,39	2,65
Wood	58,02	62,62	67,53	73,31	79,28	85,71
Natural gas	41,29	47,76	55,53	64,03	73,12	81,46
Fuel oil	29,08	28,66	26,92	24,99	22,65	21,23
Total	217.07	229.15	241.22	254.89	268.56	282.22
Shares from total demand						
Motor fuel	0,07768	0,07358	0,06990	0,06615	0,06278	0,05975
Coal	0,32783	0,31498	0,30228	0,28949	0,27648	0,26327
Peat	0,00306	0,00463	0,00605	0,00747	0,00890	0,00940
Wood	0,26728	0,27329	0,27996	0,28763	0,29522	0,30370
Natural gas	0,19021	0,20844	0,23020	0,25121	0,27226	0,28866
Fuel oil	0,13394	0,12507	0,11161	0,09805	0,08435	0,07522

Table I.3. Fuel Demand in the Transport Sector

	2000	2005	2010	2015	2020	2025
MWa						
Motor fuel	1387.28	1485.92	1609.35	1784.68	1962.47	2146.59
Fuel oil	0.13	0.13	0.12	0.11	0.11	0.10
Total	1387.41	1486.05	1609.47	1784.80	1962.58	2146.69
Shares from total demand						
Motor fuel	0.99990	0.99992	0.99992	0.99994	0.99995	0.99995
Fuel oil	0.00010	0.00008	0.00008	0.00006	0.00005	0.00005

Table I.4. Fuel Demand in the Agriculture

	2000	2005	2010	2015	2020	2025
MWa						
Motor fuel	47.80	61.30	65.05	72.81	81.50	91.22
Coal	0.53	0.57	0.59	0.66	0.72	0.80
Peat	0.00	0.10	0.16	0.24	0.33	0.45
Wood	8.63	9.61	10.51	12.12	13.97	16.09
Natural gas	32.66	35.44	37.71	42.32	47.50	53.30
Fuel oil	3.45	3.55	3.57	3.78	3.99	4.19
Total	93.07	110.56	117.59	131.93	148.01	166.05
Shares from total demand						
Motor fuel	0.51355	0.55445	0.55318	0.55190	0.55063	0.54936
Coal	0.00571	0.00512	0.00505	0.00497	0.00490	0.00482
Peat	0.00000	0.00089	0.00134	0.00179	0.00225	0.00270
Wood	0.09272	0.08688	0.08936	0.09186	0.09437	0.09689
Natural gas	0.35093	0.32058	0.32069	0.32079	0.32089	0.32099
Fuel oil	0.03709	0.03208	0.03038	0.02868	0.02696	0.02524

Table I.5. Fuel Demand in the Household Sector

	2000	2005	2010	2015	2020	2025
MWa						
Motor fuel	100.90	99.58	97.60	96.00	94.44	92.90
Coal	18.06	19.38	19.05	19.05	18.72	18.29
Peat	8.76	11.63	13.61	15.19	16.80	17.94
Wood	678.97	782.08	787.33	798.85	809.51	820.30
Natural gas	138.08	154.38	150.40	145.81	142.22	138.86
Fuel oil	1.46	1.65	1.62	1.61	1.59	1.57
Total	946.23	1068.69	1069.61	1076.51	1083.29	1089.86
Shares from total demand						
Motor fuel	0.10664	0.09318	0.09124	0.08918	0.08718	0.08524
Coal	0.01908	0.01814	0.01781	0.01770	0.01728	0.01678
Peat	0.00926	0.01088	0.01272	0.01411	0.01551	0.01646
Wood	0.71755	0.73181	0.73609	0.74207	0.74727	0.75266
Natural gas	0.14592	0.14446	0.14061	0.13545	0.13129	0.12741
Fuel oil	0.00154	0.00154	0.00152	0.00149	0.00147	0.00144

Basic scenario

Table I.6. Fuel Demand in the Industrial Sector

	2000	2005	2010	2015	2020	2025
MWa						
Motor fuel	46.20	60.15	73.52	82.81	93.19	104.89
Coal	17.79	25.79	27.30	26.92	26.86	26.58
Peat	2.52	4.06	5.28	6.38	7.70	9.11
Wood	39.30	64.25	78.25	89.13	103.11	119.19
Natural gas	1005.97	1207.84	1314.51	1393.44	1495.00	1611.34
Fuel oil	354.89	430.88	447.97	446.74	447.73	445.71
Total	1466.68	1792.97	1946.82	2045.41	2173.59	2316.82
Shares from total demand						
Motor fuel	0.03150	0.03355	0.03776	0.04048	0.04287	0.04527
Coal	0.01213	0.01439	0.01402	0.01316	0.01236	0.01147
Peat	0.00172	0.00226	0.00271	0.00312	0.00354	0.00393
Wood	0.02679	0.03583	0.04020	0.04357	0.04744	0.05145
Natural gas	0.68589	0.67365	0.67521	0.68125	0.68780	0.69550
Fuel oil	0.24197	0.24031	0.23010	0.21841	0.20599	0.19238

Table I.7. Fuel Demand in the Services Sector

	2000	2005	2010	2015	2020	2025
MWa						
Motor fuel	16.86	16.86	16.86	16.86	16.86	16.86
Coal	71.16	75.42	79.50	81.05	82.21	82.25
Peat	0.66	1.11	1.59	2.09	2.65	2.94
Wood	58.02	65.44	73.63	80.53	87.79	94.89
Natural gas	41.29	49.91	60.54	70.33	80.96	90.19
Fuel oil	29.08	29.95	29.35	27.45	25.08	23.50
Total	217.07	238.69	261.47	278.33	295.55	310.62
Shares from total demand						
Motor fuel	0.07768	0.07064	0.06449	0.06058	0.05705	0.05428
Coal	0.32783	0.31598	0.30404	0.29122	0.27817	0.26480
Peat	0.00306	0.00465	0.00608	0.00752	0.00896	0.00946
Wood	0.26728	0.27416	0.28159	0.28934	0.29703	0.30547
Natural gas	0.19021	0.20911	0.23154	0.25270	0.27393	0.29034
Fuel oil	0.13394	0.12546	0.11226	0.09864	0.08487	0.07566

Table I.8. Fuel Demand in the Transport Sector

	2000	2005	2010	2015	2020	2025
MWa						
Motor fuel	1387.28	1649.06	1918.24	2133.34	2353.44	2584.85
Fuel oil	0.13	0.13	0.12	0.11	0.11	0.10
Total	1387.41	1649.19	1918.36	2133.45	2353.54	2584.95
Shares from total demand						
Motor fuel	0.99990	0.99992	0.99994	0.99995	0.99996	0.99996
Fuel oil	0.00010	0.00008	0.00006	0.00005	0.00004	0.00004

Table I.9. Fuel Demand in the Agriculture

	2000	2005	2010	2015	2020	2025
MWa						
Motor fuel	47.80	67.95	80.60	88.89	97.01	106.89
Coal	0.53	0.62	0.71	0.76	0.81	0.87
Peat	0.00	0.11	0.19	0.28	0.37	0.49
Wood	8.63	10.48	12.62	14.12	15.63	17.45
Natural gas	32.66	38.68	45.30	49.32	53.14	57.80
Fuel oil	3.45	3.87	4.29	4.41	4.46	4.54
Total	93.07	121.71	143.71	157.78	171.43	188.03
Shares from total demand						
Motor fuel	0.51355	0.55827	0.56083	0.56338	0.56593	0.56847
Coal	0.00571	0.00508	0.00496	0.00485	0.00473	0.00462
Peat	0.00000	0.00088	0.00132	0.00175	0.00217	0.00259
Wood	0.09272	0.08614	0.08783	0.08951	0.09116	0.09278
Natural gas	0.35093	0.31782	0.31519	0.31258	0.30997	0.30738
Fuel oil	0.03709	0.03180	0.02986	0.02794	0.02604	0.02417

Table I.10. Fuel Demand in the Household Sector

	2000	2005	2010	2015	2020	2025
MWa						
Motor fuel	100.90	100.09	98.92	98.35	97.93	97.61
Coal	18.06	19.98	20.25	20.25	20.53	20.55
Peat	8.76	11.99	14.47	16.66	18.88	20.68
Wood	678.97	806.15	836.95	875.85	909.67	945.76
Natural gas	138.08	159.13	159.88	159.87	159.82	160.10
Fuel oil	1.46	1.70	1.73	1.76	1.79	1.82
Total	946.23	1099.04	1132.18	1172.75	1208.62	1246.51
Shares from total demand						
Motor fuel	0.10664	0.09107	0.08737	0.08387	0.08103	0.07830
Coal	0.01908	0.01818	0.01789	0.01727	0.01698	0.01648
Peat	0.00926	0.01091	0.01278	0.01420	0.01562	0.01659
Wood	0.71755	0.73351	0.73923	0.74684	0.75265	0.75872
Natural gas	0.14592	0.14479	0.14121	0.13632	0.13223	0.12844
Fuel oil	0.00154	0.00155	0.00152	0.00150	0.00148	0.00146

Fast economic growth scenario

Table I.11. Fuel Demand in the Industrial Sector

	2000	2005	2010	2015	2020	2025
MWa						
Motor fuel	46.20	66.62	91.22	103.14	115.59	129.52
Coal	17.79	27.99	32.58	32.24	32.21	31.89
Peat	2.52	4.28	5.97	7.25	8.81	10.49
Wood	39.30	68.83	91.19	102.07	115.93	130.30
Natural gas	1005.97	1255.50	1443.99	1545.46	1674.19	1822.90
Fuel oil	354.89	451.76	497.08	494.85	494.55	490.32
Total	1466.68	1874.99	2162.03	2285.01	2441.29	2615.42
Shares from total demand						
Motor fuel	0.03150	0.03553	0.04219	0.04514	0.04735	0.04952
Coal	0.01213	0.01493	0.01507	0.01411	0.01319	0.01219
Peat	0.00172	0.00229	0.00276	0.00318	0.00361	0.00401
Wood	0.02679	0.03671	0.04218	0.04467	0.04749	0.04982
Natural gas	0.68589	0.66960	0.66789	0.67635	0.68578	0.69698
Fuel oil	0.24197	0.24094	0.22991	0.21656	0.20258	0.18747

Table I.12. Fuel Demand in the Services Sector

	2000	2005	2010	2015	2020	2025
MWa						
Motor fuel	16.86	16.86	16.86	16.86	16.86	16.86
Coal	71.16	78.71	86.16	91.02	93.99	95.24
Peat	0.66	1.16	1.72	2.35	3.03	3.40
Wood	58.02	68.07	79.00	88.67	97.82	106.13
Natural gas	41.29	52.32	66.41	80.74	95.11	108.17
Fuel oil	29.08	31.25	31.81	30.83	28.68	27.21
Total	217.07	248.38	281.97	310.47	335.49	357.02
Shares from total demand						
Motor fuel	0.07768	0.06789	0.05980	0.05431	0.05026	0.04723
Coal	0.32783	0.31692	0.30557	0.29316	0.28017	0.26678
Peat	0.00306	0.00466	0.00611	0.00757	0.00902	0.00953
Wood	0.26728	0.27404	0.28018	0.28560	0.29157	0.29726
Natural gas	0.19021	0.21066	0.23552	0.26007	0.28350	0.30298
Fuel oil	0.13394	0.12584	0.11282	0.09930	0.08548	0.07622

Table I.13. Fuel Demand in the Transport Sector

	2000	2005	2010	2015	2020	2025
MWa						
Motor fuel	1387.28	1754.27	2172.08	2431.13	2699.18	2990.27
Fuel oil	0.13	0.13	0.12	0.11	0.11	0.10
Total	1387.41	1754.40	2172.20	2431.24	2699.28	2990.36
Shares from total demand						
Motor fuel	0.99990	0.99993	0.99994	0.99995	0.99996	0.99997
Fuel oil	0.00010	0.00007	0.00006	0.00005	0.00004	0.00003

Table I.14. Fuel Demand in the Agriculture

	2000	2005	2010	2015	2020	2025
MWa						
Motor fuel	47.80	73.31	95.35	102.75	110.38	118.20
Coal	0.53	0.66	0.83	0.86	0.89	0.91
Peat	0.00	0.11	0.22	0.31	0.41	0.51
Wood	8.63	11.20	14.63	15.83	17.07	18.33
Natural gas	32.66	41.31	52.50	55.28	58.03	60.72
Fuel oil	3.45	4.13	4.97	4.94	4.88	4.77
Total	93.07	130.72	168.51	179.96	191.65	203.44
Shares from total demand						
Motor fuel	0.51355	0.56080	0.56587	0.57093	0.57597	0.58100
Coal	0.00571	0.00505	0.00491	0.00476	0.00462	0.00448
Peat	0.00000	0.00088	0.00130	0.00172	0.00212	0.00251
Wood	0.09272	0.08564	0.08683	0.08796	0.08905	0.09008
Natural gas	0.35093	0.31600	0.31157	0.30717	0.30280	0.29845
Fuel oil	0.03709	0.03162	0.02952	0.02746	0.02544	0.02346

Table I.15. Fuel Demand in the Household Sector

	2000	2005	2010	2015	2020	2025
MWa						
Motor fuel	100.90	100.54	99.54	98.69	97.97	97.40
Coal	18.06	19.93	20.20	20.20	20.46	20.65
Peat	8.76	11.96	14.43	16.61	18.98	20.98
Wood	678.97	795.19	817.39	844.29	874.03	906.90
Natural gas	138.08	167.71	177.01	188.32	200.80	214.86
Fuel oil	1.46	1.69	1.72	1.76	1.80	1.84
Total	946.23	1097.02	1130.29	1169.86	1214.04	1262.64
Shares from total demand						
Motor fuel	0.10664	0.09165	0.08807	0.08436	0.08070	0.07714
Coal	0.01908	0.01817	0.01787	0.01727	0.01686	0.01636
Peat	0.00926	0.01090	0.01277	0.01420	0.01563	0.01662
Wood	0.71755	0.72487	0.72316	0.72170	0.71993	0.71826
Natural gas	0.14592	0.15288	0.15661	0.16097	0.16540	0.17017
Fuel oil	0.00154	0.00154	0.00152	0.00150	0.00148	0.00146

Slow economic growth scenario

Table I.16. Electricity Demand in Branches of Economy, TWh

	2000	2005	2010	2015	2020	2025
Industry	2.188	2.389	2.654	2.934	3.332	3.784
Construction	0.130	0.123	0.135	0.149	0.168	0.189
Agriculture	0.188	0.239	0.263	0.289	0.327	0.370
Transport	0.076	0.131	0.164	0.185	0.212	0.239
Household	1.767	2.047	2.380	2.655	3.038	3.433
Services	1.848	2.014	2.258	2.442	2.696	2.962
Energy sector	0.921	0.818	0.827	0.836	0.849	0.862
Losses	1.281	1.368	1.492	1.604	1.757	1.916
Total	8.399	9.129	10.173	11.095	12.379	13.755

Basic scenario

Table I.17. Electricity Demand in Branches of Economy, TWh

	2000	2005	2010	2015	2020	2025
Industry	2.188	2.787	3.539	3.930	4.479	5.103
Construction	0.130	0.139	0.177	0.196	0.224	0.256
Agriculture	0.188	0.264	0.324	0.353	0.389	0.433
Transport	0.076	0.125	0.156	0.171	0.190	0.208
Household	1.767	2.323	2.983	3.392	3.917	4.462
Services	1.848	2.144	2.554	2.786	3.110	3.419
Energy sector	0.921	0.849	0.886	0.900	0.921	0.941
Losses	1.281	1.507	1.784	1.921	2.095	2.268
Total	8.399	10.138	12.402	13.650	15.325	17.089

Fast economic growth scenario

Table I.18. Electricity Demand in Branches of Economy, TWh

	2000	2005	2010	2015	2020	2025
Industry	2.188	3.160	4.537	5.062	5.817	6.679
Construction	0.130	0.152	0.216	0.240	0.270	0.304
Agriculture	0.188	0.279	0.378	0.404	0.440	0.477
Transport	0.076	0.134	0.169	0.190	0.212	0.231
Household	1.767	2.461	3.347	3.916	4.679	5.503
Services	1.848	2.278	2.876	3.235	3.670	4.078
Energy sector	0.921	0.849	0.886	0.900	0.921	0.941
Losses	1.281	1.608	2.033	2.207	2.418	2.619
Total	8.399	10.922	14.442	16.154	18.425	20.831

Slow economic growth scenario

Table I.19. District Heat Supplied to Consumers by Regions, TWh

	2000	2005	2010	2015	2020	2025
Vilnius	2.075	2.494	2.541	2.618	2.699	2.785
Kaunas	1.283	1.527	1.556	1.603	1.653	1.705
Klaipeda	0.858	1.021	1.041	1.072	1.105	1.140
Mazeikiai	0.142	0.165	0.168	0.173	0.178	0.184
Elektrenai	0.157	0.182	0.186	0.191	0.197	0.204
Other cities	3.924	4.411	4.496	4.631	4.774	4.927
Total	8.438	9.800	9.988	10.289	10.607	10.945

Basic scenario

Table I.20. District Heat Supplied to Consumers by Regions, TWh

	2000	2005	2010	2015	2020	2025
Vilnius	2.075	2.536	2.780	2.957	3.129	3.304
Kaunas	1.283	1.529	1.688	1.808	1.926	2.047
Klaipeda	0.858	1.026	1.111	1.168	1.223	1.278
Mazeikiai	0.142	0.166	0.177	0.183	0.188	0.193
Elektrenai	0.157	0.179	0.185	0.193	0.201	0.209
Other cities	3.924	4.605	5.023	5.299	5.562	5.828
Total	8.438	10.042	10.965	11.609	12.230	12.860

Fast economic growth scenario

Table I.21. District Heat Supplied to Consumers by Regions, TWh

	2000	2005	2010	2015	2020	2025
Vilnius	2.075	2.622	2.973	3.208	3.450	3.702
Kaunas	1.283	1.624	1.854	2.013	2.178	2.349
Klaipeda	0.858	1.062	1.186	1.262	1.339	1.419
Mazeikiai	0.142	0.173	0.190	0.199	0.208	0.217
Elektrenai	0.157	0.186	0.194	0.209	0.224	0.240
Other cities	3.924	4.876	5.505	5.879	6.260	6.651
Total	8.438	10.543	11.903	12.770	13.659	14.579

APPENDIX II. FUTURE INVESTMENT COSTS AND FUEL CONSUMPTION

Table II.1. Investment Cost for Scenario 1, million US$

No	Measures	Before 2006	2006-2010	2011-2015	2016-2020	2021-2025	Total
1	Existing CHP	2.6	37.1	4.6	25.1	8.6	77.9
2	Existing TPP		13.1	4.7	19.2	6.2	43.2
3	Hydro	6.2	6.2				12.3
4	Heat only boilers	5.0	45.5	10.8	0.3	10.3	72.0
5	including HOB based on renewables						
6	including HOB conversion to CHP		39.0	9.4			48.4
7	including distributed heat generation system	5.0	6.5	1.4	0.3	9.5	22.7
8	New CHP	10.5	59.9	52.8	64.2	46.3	233.7
9	including CHP based on renewables	0.5	10.9	27.8	49.2	1.0	89.4
10	New TPP		240.0			31.8	271.8
11	Power Plants on renewables		4.4	141.5			146.0
12	Environmental measures	58.0	94.9	20.0	41.7	41.5	256.2
13	Oil supply system						
14	Gas supply system	5.5	10.8	8.2	1.7	13.2	39.4
15	Other						
	Total	87.9	511.9	242.5	152.2	157.8	1152.4

Table II.2. Investment Cost for Scenario 2, million US$

No	Measures	Before 2006	2006-2010	2011-2015	2016-2020	2021-2025	Total
1	Existing CHP	2.6	36.4	5.3	32.3	3.0	79.7
2	Existing TPP		31.9	1.9	9.4		43.2
3	Hydro	6.2	6.2				12.3
4	Heat only boilers	5.0	48.2	13.6	0.3	18.7	85.8
5	including HOB based on renewables						
6	including HOB conversion to CHP		42.1	12.2		8.5	62.8
7	including distributed heat generation system	5.0	6.1	1.4	0.3	9.4	22.2
8	New CHP	10.5	61.1	52.8	67.9	50.2	242.4
9	including CHP based on renewables	0.5	10.9	27.8	49.1	1.2	89.4
10	New TPP		30.5	26.1	70.0	113.3	240.0
11	Power Plants on renewables		12.9	134.9			147.7
12	Environmental measures	58.1	203.5	6.8	8.4	10.5	287.3
13	Oil supply system						
14	Gas supply system	5.5	21.1	17.2	27.0	41.3	112.2
15	Other						
	Total	88.0	451.8	258.5	215.3	237.1	1250.7

Table II.3. Investment Cost for Scenario 3, million US$

No	Measures	Before 2006	2006-2010	2011-2015	2016-2020	2021-2025	Total
1	Existing CHP	2.7	37.3	8.0	24.0	5.1	77.1
2	Existing TPP		14.9	0.9	2.6	8.4	26.9
3	Hydro	6.2	6.2				12.3
4	Heat only boilers	5.0	44.1	10.2	0.4	10.7	70.4
5	including HOB based on renewables						
6	including HOB conversion to CHP		37.6	8.8			46.4
7	including distributed heat generation system	5.0	6.5	1.3	0.4	9.4	22.7
8	New CHP	10.5	40.6	52.8	71.8	49.9	225.6
9	including HOB based on renewables	0.5	10.9	27.8	49.2	0.9	89.3
10	New TPP		1038.9	27.4	50.1	23.5	1139.9
11	Power Plants on renewables			142.8			142.8
12	Environmental measures	57.9	34.6	12.5	8.7	32.5	146.3
13	Oil supply system						
14	Gas supply system	5.5	10.8	8.2	4.0	2.2	30.6
15	Other						
	Total	87.8	1227.4	262.7	161.6	132.4	1871.9

Table II.4. Investment Cost for Scenario 4, million US$

No	Measures	Before 2006	2006-2010	2011-2015	2016-2020	2021-2025	Total
1	Existing CHP	2.3	36.1	4.3	23.4	3.2	69.3
2	Existing TPP		2.0		0.1	7.8	10.0
3	Hydro	6.2	6.2				12.3
4	Heat only boilers	5.0	26.2	3.0	0.4	16.4	50.9
5	including HOB based on renewables						
6	including HOB conversion to CHP		19.6	1.7		5.1	26.4
7	including distributed heat generation system	5.0	6.5	1.3	0.4	9.2	22.5
8	New CHP	10.5	88.5	47.8	65.9	26.0	238.6
9	including CHP based on renewables	0.5	10.9	27.8	49.2	1.0	89.4
10	New TPP		225.8	899.9	13.5	0.6	1139.9
11	Power Plants on renewables		40.2	110.6			150.8
12	Environmental measures	58.1	34.6	6.7	4.5	51.6	155.5
13	Oil supply system						
14	Gas supply system	5.5	10.8	6.7	2.2	2.1	27.2
15	Other						
	Total	87.5	470.3	1078.8	110.2	107.7	1854.5

Table II.5. Investment Cost for Scenario 5, million US$

No	Measures	Before 2006	2006-2010	2011-2015	2016-2020	2021-2025	Total
1	Existing CHP	2.3	46.7	4.5	23.2	3.5	80.2
2	Existing TPP		12.0	1.9	1.9	11.8	27.5
3	Hydro	6.2	6.2				12.3
4	Heat only boilers	5.0	30.9	5.7	0.4	13.1	55.1
5	including HOB based on renewables						
6	including HOB conversion to CHP		24.3	4.4		1.4	30.1
7	including distributed heat generation system	5.0	6.5	1.3	0.4	9.4	22.7
8	New CHP	10.5	92.7	47.8	59.2	30.2	240.4
9	including CHP based on renewables	0.5	10.9	27.8	49.2	1.1	89.5
10	New TPP		233.4	899.9			1133.3
11	Power Plants on renewables		40.2	110.6			150.8
12	Environmental measures	58.1	89.4	6.7	4.5	5.2	163.9
13	Oil supply system						
14	Gas supply system	5.5	10.8	6.6	0.2	2.2	25.3
15	Other						
	Total	87.6	562.1	1083.7	89.4	66.0	1888.8

Table II.6. Investment Cost for Scenario 6, million US$

No	Measures	Before 2006	2006-2010	2011-2015	2016-2020	2021-2025	Total
1	Existing CHP	2.6	36.6	3.8	25.9	8.8	77.6
2	Existing TPP				35.0	8.2	43.2
3	Hydro	6.2	6.2				12.3
4	Heat only boilers	5.0	32.6	3.7	0.4	19.2	61.0
5	including HOB based on renewables						
6	including HOB conversion to CHP		26.1	2.4		8.5	37.0
7	including distributed heat generation system	5.0	6.5	1.3	0.4	9.4	22.7
8	New CHP	10.5	73.7	54.0	64.6	35.7	238.6
9	including CHP based on renewables	0.5	10.9	27.8	49.2	0.8	89.2
10	New TPP		52.7	904.3		8.3	965.3
11	Power Plants on renewables		17.1	131.3			148.4
12	Environmental measures	58.3	192.9	7.0	4.0	12.8	274.9
13	Oil supply system						
14	Gas supply system	5.5	10.8	7.1	1.8	2.2	27.4
15	Other						
	Total	88.1	422.5	1111.1	131.8	95.2	1848.7

Table II.7. Fuel Consumption for Electricity and Heat Generation in Lithuania for Scenario 1, ktoe

Fuel type	Until 2005	2006-2010	2011-2015	2016-2020	2021-2025
Oil	2817.9	2227.8	2166.3	2132.5	2089.3
Orimulsion	2908.9	4214.3	6750.2	7883.7	9293.8
Gas	1372.8	2431.0	6901.0	7318.1	7734.3
Renewables	602.5	832.1	935.4	1451.3	1820.3
Coal	1835.1	1094.7	828.8	344.2	91.7
Nuclear	12285.5	8119.9	0.0	0.0	0.0
Peat	2.2	0.0	0.0	0.0	0.0
Total	21825.1	18919.6	17581.7	19129.8	21029.4

Table II.8. Fuel Consumption for Electricity and Heat Generation in Lithuania for Scenario 2, ktoe

Fuel type	Until 2005	2006-2010	2011-2015	2016-2020	2021-2025
Oil	2816.3	2235.8	2199.5	2146.2	2044.7
Orimulsion	2909.8	5043.5	10648.7	10664.2	10247.8
Gas	1372.7	1843.7	4149.1	5399.7	7044.9
Renewables	602.5	826.7	906.4	1441.8	1820.5
Coal	1836.0	1100.6	826.6	316.0	71.4
Nuclear	12285.5	8119.9	0.0	0.0	0.0
Peat	2.2	0.0	0.0	0.0	0.0
Total	21825.0	19170.1	18730.4	19968.0	21229.3

TableII.9. Fuel Consumption for Electricity and Heat Generation in Lithuania for Scenario 3, ktoe

Fuel type	Until 2005	2006-2010	2011-2015	2016-2020	2021-2025
Oil	2818.6	2226.1	2162.3	2121.4	2082.6
Orimulsion	2908.5	3716.6	4058.8	4223.3	4678.3
Gas	1371.3	2120.2	5515.4	6572.9	7797.4
Renewables	602.7	858.6	1054.5	1469.3	1821.9
Coal	1837.3	1094.2	834.1	368.2	89.9
Nuclear	12284.5	9235.9	5580.4	5580.4	5580.4
Peat	2.2	0.0	0.0	0.0	3.3
Total	21825.2	19251.6	19205.4	20335.4	22053.8

Table II.10. Fuel Consumption for Electricity and Heat Generation in Lithuania for Scenario 4, ktoe

Fuel type	Until 2005	2006-2010	2011-2015	2016-2020	2021-2025
Oil	2825.9	2195.3	1996.1	1973.9	1978.8
Orimulsion	2909.3	3709.7	4096.2	3940.4	5271.0
Gas	1363.8	2258.7	5753.5	6193.0	6600.5
Renewables	602.5	760.0	994.8	1476.1	1820.7
Coal	1844.2	1146.0	832.7	390.1	113.1
Nuclear	12276.3	8119.9	1116.1	5580.4	5580.4
Peat	2.2	0.0	0.0	0.0	5.1
Total	21824.4	18189.6	14789.3	19553.9	21369.6

Table II.11. Fuel Consumption for Electricity and Heat Generation in Lithuania for Scenario 5, ktoe

Fuel type	Until 2005	2006-2010	2011-2015	2016-2020	2021-2025
Oil	2826.4	2193.7	2032.9	2000.3	1993.9
Orimulsion	2909.5	4088.6	5826.6	4064.7	5410.3
Gas	1364.6	2506.5	6849.8	6565.9	7184.7
Renewables	602.5	748.3	922.8	1494.6	1821.3
Coal	1842.6	1142.9	831.8	378.9	104.0
Nuclear	12276.5	8119.9	1116.1	5580.4	5580.4
Peat	2.2	0.0	0.0	0.0	5.1
Total	21824.3	18799.9	17580.1	20084.7	22099.8

Table II.12. Fuel Consumption for Electricity and Heat Generation in Lithuania for Scenario 6, ktoe

Fuel type	Until 2005	2006-2010	2011-2015	2016-2020	2021-2025
Oil	2816.6	2198.6	2050.1	2017.7	2006.2
Orimulsion	2911.3	4954.9	9613.2	7741.0	9034.4
Gas	1369.4	1912.0	4166.0	4051.6	4685.2
Renewables	602.7	839.5	968.2	1471.8	1821.3
Coal	1838.3	1095.7	834.1	384.0	96.3
Nuclear	12284.5	8119.9	1116.1	5580.4	5580.4
Peat	2.2	0.0	0.0	0.0	4.6
Total	21825.0	19120.6	18747.6	21246.6	23228.4

APPENDIX III. FUTURE PRIMARY ENERGY REQUIREMENT

Table III.1. Total Primary Energy Requirements in Lithuania for Scenario 1, ktoe

Fuel type	Until 2005	2006-2010	2011-2015	2016-2020	2021-2025
Coal	2355.2	1568.4	1314.4	834.9	584.2
Oil	14809.8	13812.9	15214.3	16210.6	17188.3
Gas	7488.7	8281.6	13203.9	14035.0	14927.5
Nuclear	12285.5	8119.9	0.0	0.0	0.0
Orimulsion	2908.9	4214.3	6750.2	7883.7	9293.8
Renewables	4523.0	4547.9	4871.8	5603.0	6195.2
Peat	68.3	74.7	89.8	105.2	119.7
Electricity	-114.9	0.1	0.5	0.5	0.6

Table III.2. Total Primary Energy Requirements in Lithuania for Scenario 2, ktoe

Fuel type	Until 2005	2006-2010	2011-2015	2016-2020	2021-2025
Coal	2356.0	1574.4	1312.2	806.8	564.0
Oil	14808.2	13820.9	15254.3	16229.4	17127.1
Gas	7488.5	7689.2	10429.4	12101.7	14231.7
Nuclear	12285.5	8119.9	0.0	0.0	0.0
Orimulsion	2909.8	5043.5	10648.7	10664.2	10247.8
Renewables	4523.0	4542.5	4842.8	5593.5	6195.4
Peat	68.3	74.7	89.8	105.2	119.7
Electricity	-114.9	0.1	0.5	0.5	0.9

Table III.3. Total Primary Energy Requirements in Lithuania for Scenario 3, ktoe

Fuel type	Until 2005	2006-2010	2011-2015	2016-2020	2021-2025
Coal	2357.4	1567.9	1319.7	859.0	582.5
Oil	14810.5	13811.2	15209.4	16195.4	17179.0
Gas	7487.1	7968.4	11806.5	13285.5	14996.7
Nuclear	12284.5	9235.9	5580.4	5580.4	5580.4
Orimulsion	2908.5	3716.6	4058.8	4223.3	4678.3
Renewables	4523.1	4574.4	4990.8	5621.0	6196.8
Peat	68.3	74.7	89.8	105.2	123.0
Electricity	-114.9	0.1	0.4	0.3	0.5

Table III.4. Total Primary Energy Requirements in Lithuania for Scenario 4, ktoe

Fuel type	Until 2005	2006-2010	2011-2015	2016-2020	2021-2025
Coal	2364.3	1619.8	1318.3	880.9	605.7
Oil	14817.8	13780.4	15003.6	15993.3	17036.9
Gas	7479.5	8105.4	12037.4	12889.8	13774.8
Nuclear	12276.3	8119.9	1116.1	5580.4	5580.4
Orimulsion	2909.3	3709.7	4096.2	3940.4	5271.0
Renewables	4523.0	4475.8	4931.1	5627.8	6195.6
Peat	68.3	74.7	89.8	105.2	124.8
Electricity	-114.9	234.5	1066.4	222.8	274.3

Table III.5. Total Primary Energy Requirements in Lithuania for Scenario 5, ktoe

Fuel type	Until 2005	2006-2010	2011-2015	2016-2020	2021-2025
Coal	2362.7	1616.6	1317.4	869.6	596.6
Oil	14818.3	13778.9	15048.4	16029.4	17057.5
Gas	7480.3	8356.6	13149.2	13265.7	14366.1
Nuclear	12276.5	8119.9	1116.1	5580.4	5580.4
Orimulsion	2909.5	4088.6	5826.6	4064.7	5410.3
Renewables	4522.9	4464.1	4859.2	5646.3	6196.2
Peat	68.3	74.7	89.8	105.2	124.8
Electricity	-114.9	0.0	0.0	0.0	0.0

Table III.6. Total Primary Energy Requirements in Lithuania for Scenario 6, ktoe

Fuel type	Until 2005	2006-2010	2011-2015	2016-2020	2021-2025
Coal	2358.4	1569.4	1319.7	874.8	588.8
Oil	14808.5	13783.8	15072.0	16053.3	17074.3
Gas	7485.2	7758.2	10444.5	10733.5	11849.2
Nuclear	12284.5	8119.9	1116.1	5580.4	5580.4
Orimulsion	2911.3	4954.9	9613.2	7741.0	9034.4
Renewables	4523.1	4555.3	4904.5	5623.6	6196.2
Peat	68.3	74.7	89.8	105.2	124.3
Electricity	-114.9	0.1	35.8	0.3	0.3

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ABBREVIATIONS

CCGT	Combined Cycle Gas Turbine
CHP	Combined Heat and Power plant
DHU	District Heating Utility
dol/1000 m^3	Dollars per Thousand Cubic Meters
DWT	Dead Weight in tonnes
EUR	Euro, Currency of the European Union
FCC	Fluid Catalytic Cracker
FGD	Flue Gas Desulphurisation
FGP	Flue Gas Purification
GDP	Gross Domestic Product
GW·h	million of Kilowatt hours
ha	Hectare
HFO	Heavy Fuel Oil
HPSPP	Hydro Pumped Storage Power Plant
HSC	High Sulphur Content
JSC	Joint Stock Company
ktoe	Kilotons of Oil Equivalent
kW·h	Kilowatt hours
kWa	8760 Kilowatt hours
LPG	Liquefied Petroleum Gas
LSC	Low Sulphur Content
LTL	Litas, Lithuanian Currency
Lct	cents, Lithuanian currency
MAED	Model for Analysis of the Energy Demand
MESSAGE	Model for Energy Supply Strategy Alternatives and their General Environmental Impact
mln.	Million
Mt	Million Metric Tons
Mtoe	Million Tons of Oil Equivalent
MW	Thousand Kilowatt
MW·h	Thousand Kilowatt hours
MWa	8760 000 Kilowatt hours
Nm^3	Normal Cubic Meters

NPP	Nuclear Power Plant
O&M	Operation and Maintenance Cost
PHARE	Programme of the European Communities
PPP	Purchasing Power Parity
SCR	Selective Catalytic Reduction
Seimas	Parliament of Lithuania
SSH	Saturday, Sunday and Holiday
t	Metric Tonnes
thous.	Thousands
toe	Tons of Oil Equivalent
TPP	Thermal Power Plant
TW·h	Billion Kilowatt hours
US $	Dollar, Currency of the United States of America
VOC	Volatile Organic Compounds
WD	Working Day

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