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Energy Demand Forecasting in Economies in Transition

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ABSTRACT

Countries in transition from centrally planned to free market economies face many fundamental transformations both in their economies and energy sectors. Deep economic decline is accompanied by a similar reduction in energy consumption. This paper considers the current situation in the Lithuanian economy, its development since 1990 and future outlook, and provides an analysis of changes in primary and final energy consumption as well as changes in energy intensity. It provides a comparison of the main indicators of energy consumption in Lithuania to those in other countries, such as primary energy per capita and the ratio of primary energy and final energy to Gross Domestic Product based on estimates of Purchasing Power Parity and electricity consumption per capita. Analysis of real trends of energy consumption by applying mathematical modeling, mathematical statistics and economics is rather complicated for countries in undergoing this kind of transition. Therefore the paper describes a methodology of energy demand forecasting based on the application of econometric and simulation models as well as on the comparative analysis of various indicators. The paper also presents forecasts of final energy and electricity demand in Lithuania through 2025.

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Introduction

Lithuania is the largest of the three Baltic States, with borders to the Republic of Latvia, the Republic of Belarus, the Republic of Poland and the Russian Federation (Kaliningrad region). The country is situated at the geographical center of the European continent, on the crossroads between Eastern and Western Europe. Its area is 65.3 thousand square kilometers, with a population of 3.5 million. For half a century the country was fully integrated into the Former Soviet Union (FSU). The Supreme Soviet of the Republic of Lithuania declared restitution of Lithuania's independence on March 11, 1990. The Lithuanian Government and Parliament have instituted reform policies in the economy and the energy sector since the first days of regained independence. However, despite the desire for a rapid transition, the country is still facing many complicated problems and in some cases unpredictable changes.

In any country energy planning should be based on consistent statistical information describing the relationships of energy systems and their relation to the national economy. However, the problem of energy statistics is rather complicated for countries in transition. It is related to a lack of necessary information, difficulties in data collection, as well as data presentation and interpretation in various statistical sources and publications. Thus, during periods of transition, the analysis of changes in energy consumption and economic and technical parameters requires much more effort and possibly even revision of existing information (using methodologies of international organizations.) The main objectives of the paper are: 1) to describe the current state of the Lithuanian economy and energy sector and changes in energy consumption during the past decade's transition period, 2) to provide analysis of energy consumption in Lithuania and other countries in transition, as well as in developed countries based on comparisons of the main energy indicators, 3) to describe the methodology of mathematical modeling appropriate for forecasting of energy demand in a case of sudden dramatic changes in energy consumption, 4) to discuss the main assumptions and to present a forecast of final energy demand and electricity demand in Lithuania through 2025.

1. Changes in economic development

All countries of the former Eastern Block could be characterized by: 1) a certain degree of integration within the common system of exchange of goods and energy resources; 2) dependency on imports of raw materials and primary energy from several republics of the FSU (mostly from Russia); 3) specialization in the production of goods for a specific area within these countries and the integration of industries; 4) low prices of primary energy resources and raw materials together

with comparatively low energy efficiency. Therefore, unsurprisingly, the transition to a free market economy led to a deep decline of the economies in these countries.

Assessment of this economic decline is rather complicated for several reasons: there are serious differences in methodologies of the statistics used in the former centrally planned economies and Western countries; there is a lack of adequate basic statistical data necessary for re-estimation of the indicators for the previous periods; accounting problems exist related to privatization and the increase of activities in small businesses; for all of these economies the relative size of the informal (shadow) economy is large. Estimates of economic indicators in countries of the former Eastern Block, presented in various sources and publications, are different. Nevertheless comparison of such indicators enables analysts to assess the similarities and differences of transition periods in various countries.

After the collapse of the FSU almost all countries that had had centrally planned economies experienced a large reduction in economic activities. However, countries in Central and Eastern Europe have been experimenting with market-oriented economic reforms for decades. Therefore the decline of the Gross Domestic Product (GDP) in these countries was comparatively low – to about 74-85% of the 1990 level (the lowest reduction of GDP was in the Slovak Republic and Poland – to 91 and 93% correspondingly). The period of economic slump was also shorter in these countries. In countries of the FSU the decline of the economy was much higher – for example in 1996, GDP dropped in Kazakhstan to 28.7%, in Moldova – to 35.8%, in Armenia – to 36.6% [1, 2], and in 1998 GDP dropped in Ukraine – to 36.1%, in Russia – to 57.7 % of the 1990 level [3,4].

The economic slump in the Baltic States was lower than in the majority of the FSU countries: at the end of 1994, the GDP dropped in Estonia to 66.5%, in Lithuania to 56.1%, and in Latvia to 49.9% of the 1990 level [5,6]. GDP began increasing in Lithuania only in 1995 (**Fig. 1**). In 1996, Lithuanian GDP increased by 4.7%, in 1997 by 7.3%, in 1998 by 5.1%. In 1999, the GDP decreased again by 3.9%. Since September 1998 the Lithuanian economy was negatively influenced by the financial and economic crisis in Russia. As a consequence of a sudden jump in inflation, exports to Russia in September and October of 1998 were only 30% of the exports at the same time in 1997. The reduction of exports and disturbed accounts has caused a decrease in economic activities in manufacturing, construction, and agriculture and finally a decrease in GDP. The continued influence of these factors on GDP growth was evident in 1999. Overall the decline of GDP was only mitigated by the rise of certain service activities (transport and communications, financial intermediation, real estate and other business). Information about the main economic indicators confirms that the country was able to get out of this crisis and in 2000 GDP increased by 3.8%; according to the most recent assessment in 2001 GDP

increased by 5.9%. At present the dependence of the Lithuanian economy on the status of the economy in Russia and Belarus is significantly reduced. In 1997 the share of export to and import from these countries was 34.8 and 27.6% respectively. In 2000 the share of export and import had changed to 12.0 and 29.2%, respectively. The same year, the share of the European Union (EU) in exports and imports was 47.9%, and 43.3%.

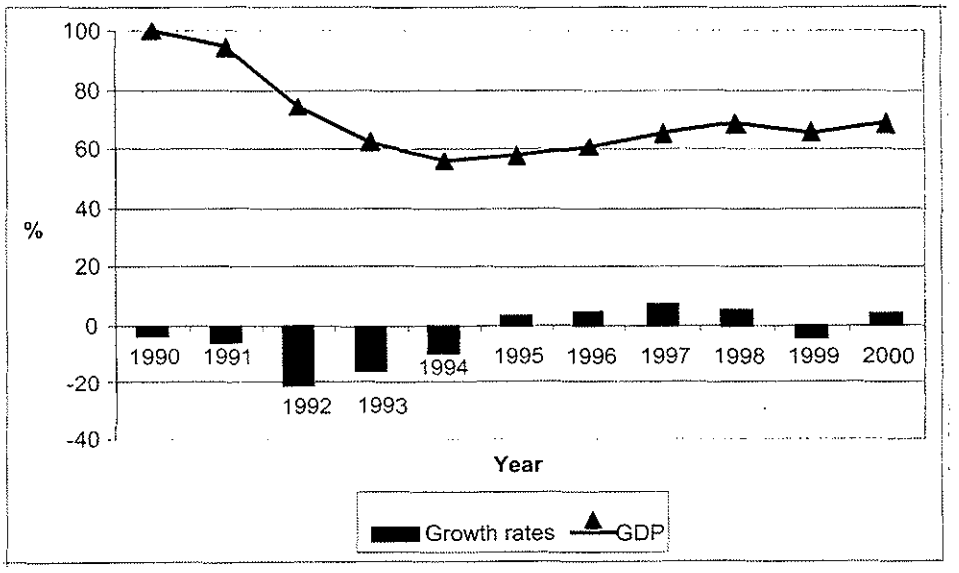

Figure 1. Annual Changes of GDP in Lithuania

2. Features of the Energy Sector and Changes in Energy Consumption

Lithuania inherited from its Soviet past a very powerful energy sector, which was created not only to meet local needs, but also to satisfy the requirements of the large FSU North-Western region (**Table 1**). The excess capacity is a result of the common central planning policy of the FSU trying to create a fully integrated energy sector and economy. The existing rather modern energy sector to some extent was helpful to the Lithuanian economy, mitigating problems at the beginning of the transition to a free market economy.

The existing overcapacities of the Lithuanian power sector could be also potentially advantageous for the recovery of the national economy in the future. However, at present it is rather difficult to efficiently use the surplus of electricity generating capacities because of the absence of transmission lines to Western countries. The export of electricity to Belarus is technically possible, but difficult to justify if Belarus still cannot pay its debts for 1998-1999.

Lithuania has an extensive gas distribution network which is based on the import of gas supplies from Russia. Due to the reduction of overall demand the meeting of peak winter load became easier. However, some share of the main lines was constructed in the sixties and is close to the limit of its technical lifetime. Therefore it is necessary to perform an audit of the integrity of older lines. It is possible that some of the main lines will need to be replaced.

All towns in Lithuania have district-heating networks. The existing combined heat and power plants are comparatively new, but the boiler houses are equipped with old equipment and some parts of their control systems are obsolete. Difficulties with heat transmission and distribution arise from reduced demand leading to underutilization of pipelines and from pipelines ageing. To ensure satisfactory performance, about 5% of the total pipe length needs to be replaced each year. Disconnection of industrial consumers, caused by comparatively high cost of heat, makes the efficiency of district heating systems even worse.

Table 1. Lithuanian Energy Sector

Sector	Unit	Potential	Used in 1990	Used in 1990 for domestic needs	Used in 2000
Installed power capacity	GW	6.2	5.1	3.1	2.4
Electricity production	TWh	35	28.1	16.4	11.4
Oil refining	Mt	12	9.6	6.4	5.0
Gas import by pipeline	bcm	8	6.2	6.0	3.0

Lithuania has almost no primary energy resources. In 2000 indigenous energy resources (wood, peat, hydro) represented about 9% of the primary energy balance (including the extraction of local oil increases the figure to about 13%). Their share during the period of 1990-2000 increased more than 4 times. Nevertheless the primary energy supply is still dominated by imports from Russia - all crude oil, natural gas and nuclear fuel are imported from this country. The development of total primary energy consumption (in million tonnes of oil equivalent) is shown in **Fig. 2.** During the transition period the share of nuclear, the cheapest imported fuel,

was rather high - it fluctuated from 24,7% in 1994 to 36,9% in 1996. In 2000 its share was 30.3%. The role of nuclear fuel is very important when seeking to increase the security of the primary energy supply, especially in the power sector. In principle oil products are the most important fuel in the Lithuanian energy balance – their share fluctuates around 40%. In 1996 the share of oil products was 33.2%, and in 2000 – only 30.8%. The share of natural gas, the most attractive fuel in the long-term perspective, was about 20% during this period. It decreased from 26,8% in 1990 to only 16.1% in 1993, but it increased again to 28.5% in 2000. The role of coal has decreased throughout the period– from 3.7% in 1990 to 1.2% in 2000.

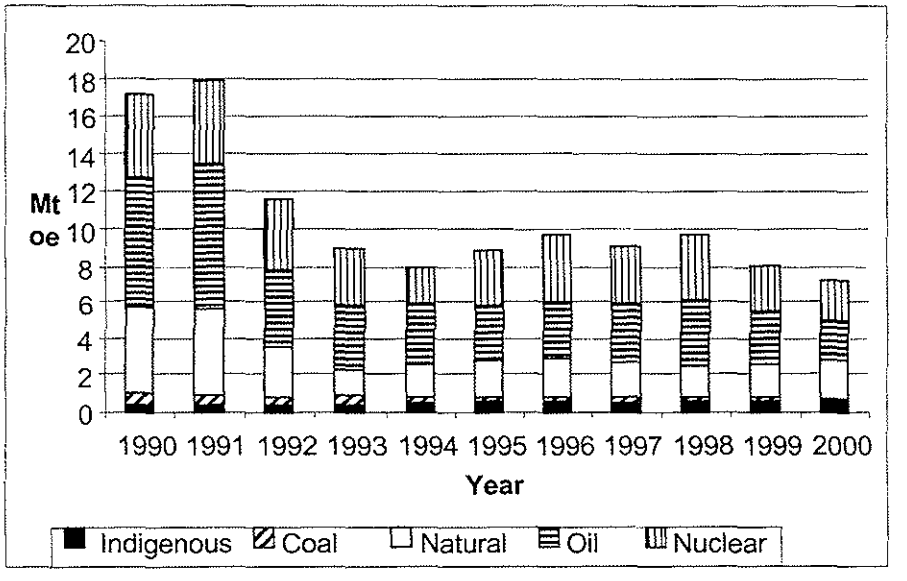

Figure 2. Primary Energy Consumption in Lithuania

The sharp decrease in primary energy consumption together with changes in its structure was an important factor that softened the economic and social problems of the transition period in Lithuania. However, the decrease of primary energy consumption at the beginning of the transition period and its recent changes were influenced not only by the decline of economic activities and the development of internal consumption in the country. Because of the existing overcapacities, the changes in primary energy demand in Lithuania are strongly related to energy consumption in the power sector and the Mazeikiai refinery that is dependent on

export of electricity and oil products. Lower primary energy demand in 1999-2000 was related to lower final energy consumption and to lower exports of electricity.

Consumption of natural gas following its sharp decrease in 1992-1993 has fluctuated around 2 billions of m^3 (**Fig.3**). The changes were related mostly to development of prices for heavy fuel oil and natural gas. Volumes of natural gas consumption for production of mineral fertilizers at present are comparatively stable and similar to the 1990 level.

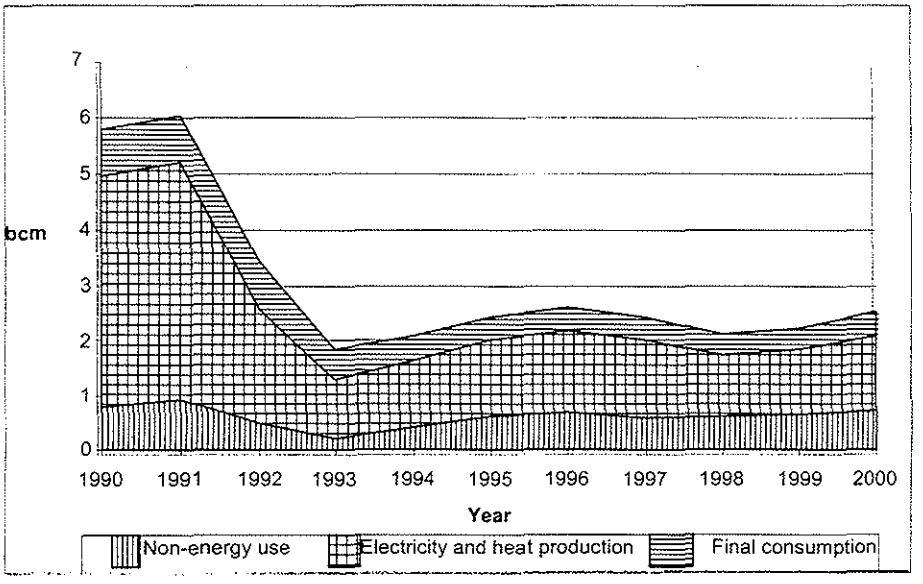

Figure 3. Dynamics of Natural Gas Consumption in Lithuania

The evolution of consumption of oil products in Lithuania during the transition period is shown in **Fig. 4**. The category "other oil products" represents the consumption of kerosene, petroleum coke,refinery gas, bitumen, etc. In 1990-1992 a portion of consumption was related to military use (mainly transportation and housing of troops) of the FSU. Because of increased prices the consumption of light fuel oil, which was a rather important fuel until 1992 in the household sector, has decreased sharply. According to the official energy balance the consumption of fuels for passenger and freight transportation (diesel oil, motor gasoline and liquefied gas) in 2000 was about 25% lower than in 1998. However, this decline was related not only to more efficient use but also to the increased role of the shadow economy in the oil market.

Total final energy consumption in Lithuania decreased from 8.7 mill. toe in 1990 to 3.8 mill. toe in 2000. Energy consumption decreased in all sectors of the national economy (**Fig. 5**). Analysis of the final energy demand by sectors shows a sharp decrease in the shares of agriculture, construction and industry. In 2000 final energy consumption in these sectors dropped respectively to 11, 23 and 25% of the 1990 value. At the same time the share of the trade and services sector decreased slightly. Energy demand in the household and transport sectors decreased during the transformation period respectively to 73 and 72% of the 1990 value. Therefore their shares increased significantly - from 21 and 17% in 1990 to 36 and 28% correspondingly in 2000.

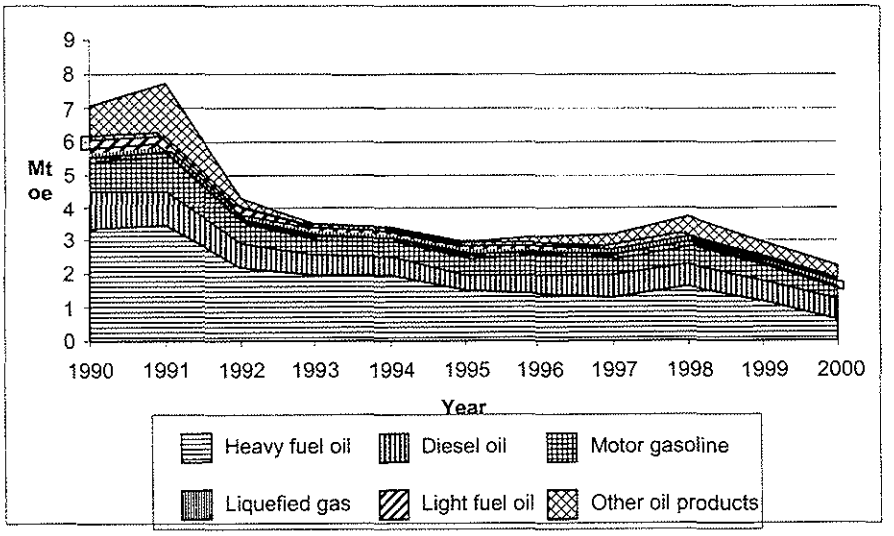

Figure 4. Consumption of Oil Products in Lithuania

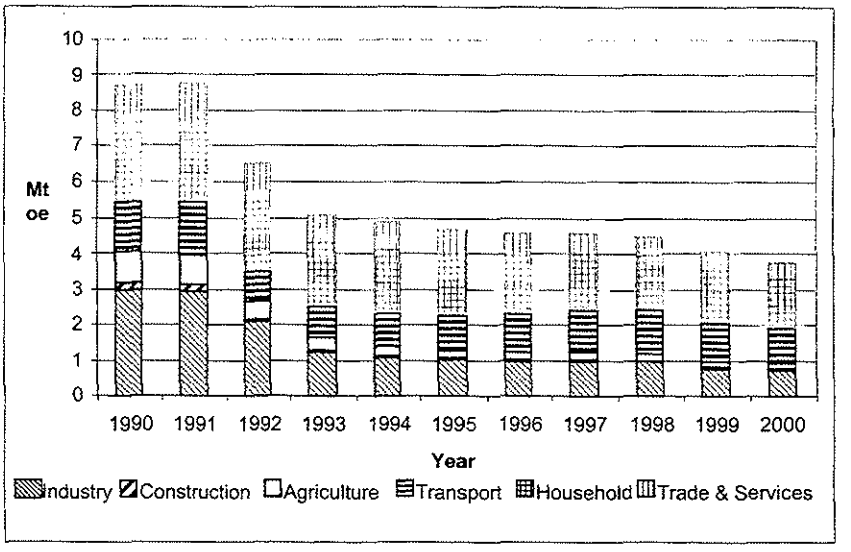

Figure 5. Final Energy Consumption in Lithuania

When analyzing the final consumption of different energy carriers (electricity, heat and fuel) one may notice that the final electricity consumption decreased from 12 TWh in 1990 to 6.2 TWh in 2000, district heat decreased during this transition period more than 3 times and was about 9.9 TWh in 2000, and final fuel consumption decreased from 5 mill. toe in 1990 to 2.4 mill. toe in 2000.

An increase of energy efficiency is one of the most important positive changes for the Lithuanian economy. Real changes of the final energy intensity in various branches of the economy are shown in **Fig. 6** using ratios of final energy, consumed in each sector, per its value added. Only in the transport and household sectors is energy intensity assessed as a classical ratio of energy consumption on total GDP. Indicators of energy intensity in the period 1990-1994 could be estimated, although with some uncertainty, because of price distortions as well as the different principles of GDP assessment in 1990 and 1995. The dynamics of energy intensity reflect significant changes of energy consumption per value added, especially in agriculture and industry. One can see from Fig. 6 that the energy intensity in agriculture in 2000 was only 25% of the 1990 level. This is related to rather important changes in the structure of activities and energy consumption in this sector. Energy intensity in manufacturing and construction decreased to 44 and 57% of their 1990 levels respectively. This huge reduction of specific energy consumption was related to the decrease of activities of energy-intensive industries and the implementation of new

technologies in modernized enterprises. Energy consumption in households decreased very slowly in 1990-1995. Therefore specific energy consumption in this sector per unit of total GDP increased. Since 1995 energy consumption in households decreased rather quickly and in 2000 its level was about 70 % of the 1990 level. This reduction of energy consumption is a result of the implementation of energy saving measures and the lower level of comfort, especially in families with low social maintenance. The reduction of energy intensity in the services sector, to 40% of the 1990 level, was related to significant changes in the structure of activities and the reduction of energy consumption in buildings related to education, health and social work.

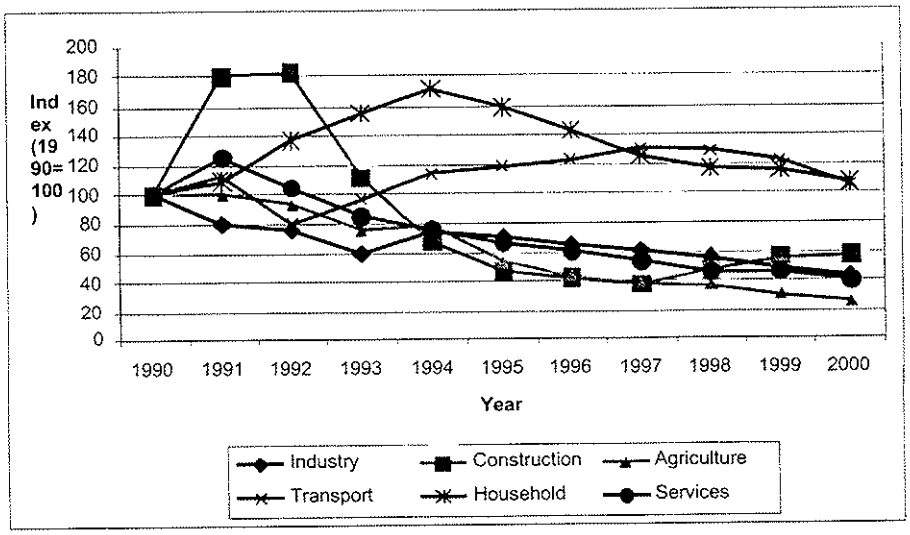

Figure 6. Changes of Energy Intensity in Different Branches of the Lithuanian Economy

3. Indicators of energy consumption

The comparison of energy consumption in various countries could be based on several indicators. One of the most popular indicators is primary energy consumption per capita. In principle the high level of energy consumption per capita in industrialized countries is related to high living standards in these countries. In 1990, this indicator in Lithuania was 4.6 toe or 1.3 times higher than the average for countries of the European Union. In 2000, primary energy consumption per capita in Lithuania was only 2.1 toe or about 50% of the present average of the European

Union. In Central and Eastern Europe this indicator is equal to 2.4-3.8 toe [2,7]. However, this aggregate indicator does not account for climatic conditions and the differences in averages of heating degree days in various countries, the role of personal cars in the country's transport system, efficiency of energy use, etc.

One of the most important indicators for the analysis of energy efficiency within each country is energy intensity. In the case of total energy efficiency this indicator is defined as a ratio of gross consumption of primary energy (or total supplied commercial primary energy) per unit of GDP. It is used in many studies prepared by the International Energy Agency (IEA), the European Commission [8,9] and various statistical publications. According to data, presented in [2], in 1999 energy intensity in the Czech Republic, Hungary, Poland and Slovakia was 3-5 times higher than the average of the EU countries and 2-3 times higher than in Canada and USA.

The indicator of primary energy consumption per unit of GDP using exchange rates does not fully reflect the real differences of energy efficiency in Western countries and countries of the former Eastern Block because high energy intensity in former centrally planned economies is determined also by the low level of GDP. It is caused principally by price distortions and the differences of the GDP evaluation. Therefore a method of Purchasing Power Parity (PPP) should be used when seeking to compare a level of GDP in developed countries and countries in transition. In this case the indicators of energy intensity in various countries could be assessed more accurately also. On the basis of data presented in [2] primary energy intensity in Hungary, Poland and the Czech Republic is only 1.3-1.7 times higher than the average of the EU countries and is similar to indicators of the USA and Canada.

Indicators of primary energy intensity are not fully correct for the comparison of energy efficiency in various countries for other reasons as well. On the basis of analysis of energy balances one can see that the structure of primary energy consumption (losses of primary energy in a transformation sector, own use of power plants, non-energy consumption, transmission and distribution losses, and final energy consumption) in different countries varies quite a bit. For example, according the IEA methodology output of the same amount of electricity from hydro power plants requires three times less primary energy than from nuclear power plants. Thus, primary energy consumption per unit of GDP depends very much on the structure of electricity generating capacities, on the importance of the energy sector for the country's economy in absolute terms of energy consumption, and on volumes of primary energy consumption for non-energy purposes, etc. In addition, the amount of primary energy consumption in Lithuania depends very much on the export of electricity and oil products because the capacity of the energy sector, constructed through 1990, considerably exceeds the requirements of the country. 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 the production of various goods and for the delivery of services.

Thus, seeking to compare more exactly the energy efficiency in various countries it is necessary to use the ratio of the final energy consumption and GDP using estimates of Purchasing Power Parity. As it is shown in **Fig. 7**, in 1999 this indicator in Lithuania was about 1.5 times higher than in Denmark and EU countries (at an average), 1.3 times higher than in Belgium and Netherlands and by 1.1 times higher than in the USA [2,7].

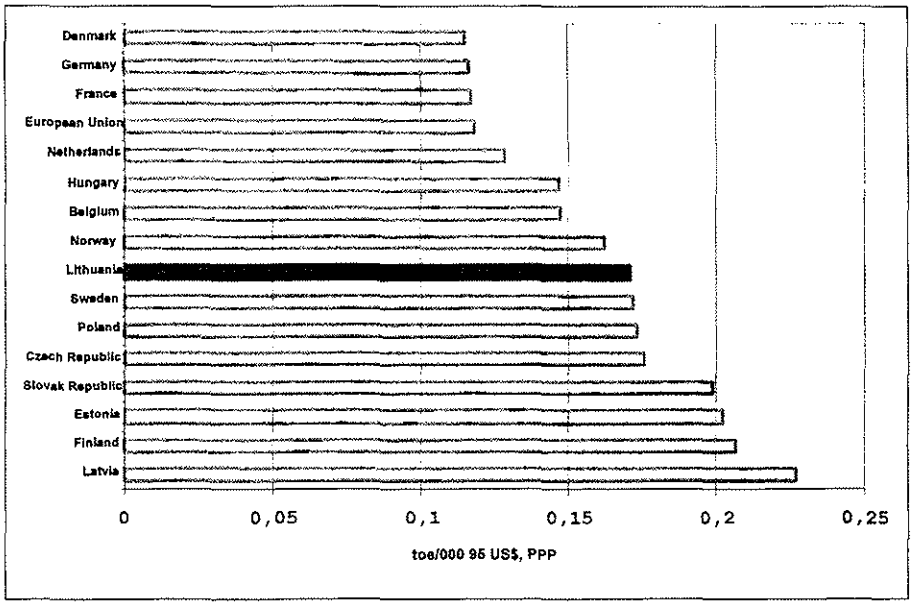

Fig. 7. Final Energy Intensity in 1999 (GDP is calculated in PPP)

Final energy intensity in Lithuania, as well as in other countries of Central and Eastern Europe, is higher than the average of energy intensity in the European Union. High energy intensity in countries of this region is caused by several reasons: the past existence of very low energy prices; old and inefficient equipment and technologies; low thermal performance of dwellings and public buildings; inadequate or even non-existent metering and control of energy consumption, etc. At the beginning of the transition period final energy intensity in Lithuania was increasing because of a decline in activity in all sectors of the economy and the significant share of the household and transport sectors in the total final energy demand. Their share increased from 38.1% in 1990 to 63.4% in 2000. However,

since 1994 final energy intensity in Lithuania has been decreasing, and in 2000 it was lower in comparison to the 1990 level by 35%.

Two other indicators – electricity's share in final energy consumption and electricity consumption per capita - are important for comparison of electricity's role in various countries. Electricity is the fastest growing component of the final energy demand in Lithuania – its share increased from 11.9% in 1990 to 13.8% in 1999. However, at present this indicator is much higher in many countries: in Norway 3.5 times, in Sweden 2.2 times, in France 1.5 times. In countries of the European Union (in average) this indicator is equal to 19.1% or 1.4 times higher than in Lithuania. Actual electricity consumption per capita in Lithuania is only 2570 kWh. Lithuania considerably lags behind the developed European countries and is behind the majority of the neighboring countries in terms of electricity consumption per capita **(Fig.8)**. This indicator in many countries is several times higher than in Lithuania: in Norway 9.7 times, in Finland 5.9 times, in the USA 5.2 times, in countries of the European Union (in average) 2.5 times, and in Estonia 1.7 times.

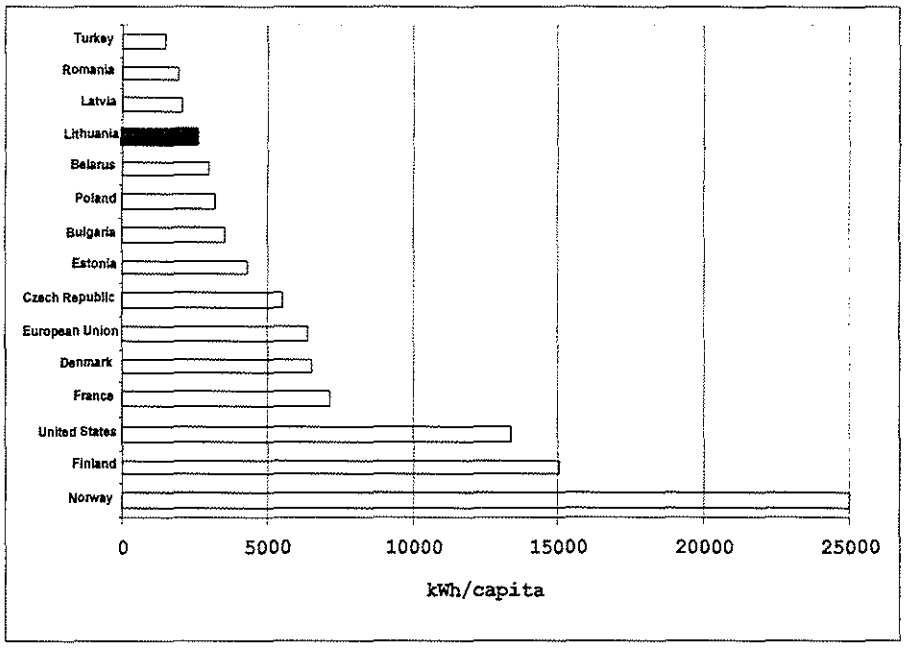

Figure 8. Electricity Consumption Per Capita in 1999

Based on the comparison of these indicators an assumption could be made about further growth of electricity penetration in all branches of the Lithuanian economy.

4. Methodology of energy demand forecasting and energy demand projections

The general concept of the complex analysis of energy systems includes the forecasting of energy demand as an important component of energy planning in each country. Forecasts of energy demand and its structure by energy forms (electricity, district heat, oil products, natural gas, etc.) play a crucial role in decision-making for further development of energy systems. Analysis of real trends in energy consumption by applying mathematical modeling, mathematical statistics and economics is rather complicated for countries in transition. In many countries with sudden steep changes of energy consumption description of its trends by the use of various time series methods is not possible and extrapolation of existing energy consumption trends cannot be applied.

In this case a concept of the final (useful) energy, i.e. energy consumed by final consumers, should be defined and justified as the basis for energy demand forecasting methodology. This concept allows for the inclusion of the main aspect of system analysis – substitution of energy resources at the consumer's side – and thus improves the reliability of the forecast. The concept of final energy is one of the main characteristics when making energy balances according to the standards of international statistics. Finally, modern mathematical models applied in Western countries for forecasting and for optimization of the energy sector development, are based on this concept.

Energy demand forecasts, prepared for the first Lithuanian National Energy Strategy in 1993 and several other studies, were based on the application of econometric models. Experience gained using this approach has shown that energy demand is determined by changes in the main macroeconomic indicators, characteristics of the development of various branches of the national economy, and by changes in fuel and energy prices. In general energy demand at any time could be described as a function of the preceding amount demanded, the relative change in income (or development of activity in a certain sector of economy) and energy prices, and the behavioral reactions of consumers to changes in income and prices, as well as additional energy saving [10]:

$$E_{ij}(t) = E_{ij}(t-1)[V_i(t)/V_i(t-1)]^{\alpha(ijl)} \times [P_{ij}(t)/P_{ij}(t-1)]^{\beta(ijl)} \times C_{ijl}$$

where i- index of the sector of the national economy, $i = 1,\ldots,m$; j- index of the energy form, $j = 1,\ldots,n$); l- index of the end-use appliance, $l = 1,\ldots,L$; t- time index, $t = 2000, 2005, 2010, 2015, \ldots$; E_{ij}- demand of energy form j in the sector i; Ai-

economic activity of the sector *i*; P_{ij}- price of energy form *j* in sector *i*; *a(ijl)*- income elasticity in sector *i* for fuel *j* and end use *l*; *ß(ijl)* – price elasticity in sector *i* for fuel *j* and end use *l*; C_{ijl} – factor of additional energy saving in sector *i* for fuel *j* and end use *l*.

The shortcoming of such an econometric model is related to the necessity to assess income and price elasticity. In practice indicators of elasticity in Lithuania were chosen in line with estimates in other Central and Eastern European countries in transition. Moreover, such elasticities have been calculated from past experience. Thus, their application to the future energy situation cannot be justified directly without analysis of additional factors.

When forecasting future energy demand it is necessary to evaluate many factors that determine the amount of energy consumed. Some of them reflect the state of the economy and GDP growth, as well as its structural changes, the dynamics of production in industrial branches, changes in living conditions, etc. Other factors assess the implementation of new technologies, the effect of substituting one energy form with another, and penetration of more efficient equipment. In the common case these factors may complement or counteract each other.

Due to the reasons mentioned above, final energy demand forecasts, prepared for the National Energy Strategy adopted by the Seimas of the Republic of Lithuania in 1999, were based on the application of the simulation model MAED (model for analysis of energy demand) [11]. The methodology of energy demand forecasting in this case is based on the most accurate determination of energy consumption in the base period and the mutual relationships between the factors influencing the consumption of their long-term development. The MAED model is widely applied in Western countries. Forecast of final energy and electricity demand, presented below, is based on a new version of this model [12]. It enables the determination of final energy consumption taking into consideration the impact of different factors.

The main steps of the MAED model are:

- Disaggregation of the total final energy demand into a large number of end-users (sectors of the economy);
- Identification of the social, economic and technological parameters which affect energy demand at final consumers;
- Establishment of the relationships between energy demand and the factors influencing this demand;
- Preparation of consistent scenarios including development of social, economic and technological indicators;
- Sensitivity analysis and evaluation of the energy demand resulting from each scenario.

One of the merits of the model is that energy demand of the final consumers could be calculated as useful (in terms of the services performed) or as final energy (amount of energy supplied). This differentiation allows the user to perform better analysis of the substitution between alternative energy forms, as well as the evolution of technological parameters of equipment and appliances at final consumers. The final energy demand is calculated as a function of social, economic and technological indicators (**Fig. 9**).

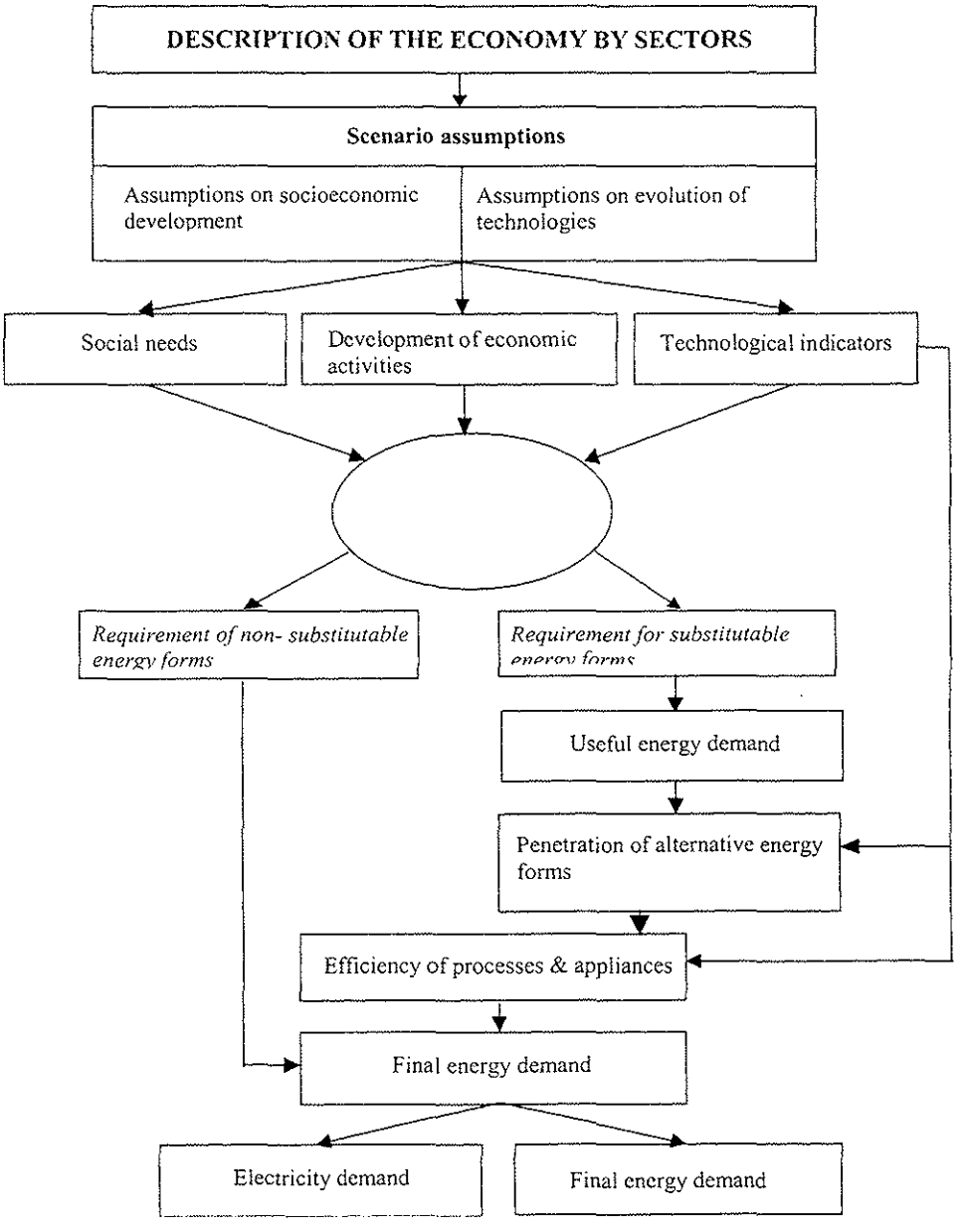

Figure 9. Aggregated Scheme of the MAED model

In the first stage the final energy consumption in the MAED model is specified by the economic sectors: industry and its sectors, construction, agriculture, transport, services sector and household. The main principle of detailed analysis of energy consumption in each sector (by the industrial processes, elements of the transport sector, social needs of the population, etc.) is related to the description of the most important factors influencing energy demand. The relationships between those factors and energy demand for each sector are modeled in separate spreadsheets using Microsoft Excel. In addition the user is supplied with a graphical representation of the input and output data. Experienced analysts having such a structure of the model can control efficiently all inputs, change the description of original relationships, and add new factors, etc.

In the second stage the future development of the most important indicators affecting energy demand in branches of the national economy should be determined. According to the MAED methodology such indicators 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. One of the common driving factors is the reduction of specific energy consumption per unit of activities in all sectors of the economy. Thus, particular attention should be focused on the evaluation of the energy saving possibilities, implementation of the new technologies and energy saving measures.

Finally, assumptions on the development of social, economic and technological indicators should be made, consistent scenarios of economic development should be prepared and sensitivity analysis should be performed. When forecasting the future energy demand it is very important to pay particular attention to those scenario parameters which could affect the final energy demand and final electricity demand the most. Thus, forecasting based on the MAED model requires the analyst to make a lot of effort at each stage but it allows the possibility of performing rather detailed analysis of energy demand development by economic sectors and by energy forms, including demand of total final energy, electricity, district heat, and motor fuels.

Energy demand forecasting in Lithuania is based on an accurate determination of energy consumption and the mutual relationships between the factors influencing such consumption for the period 1995-2000 (which was accepted as a reference period) and on assumptions about their development by 2025. Seeking to encompass the large range of possible long-term development paths it is assumed that the same three scenarios that have been chosen in the National Energy Strategy could be used for this study, extrapolating them until 2025: 1) fast economic growth scenario (7% per annum until the year 2010 and 3% in the period 2011-2025 or on average 4.6% per annum in the period 2000-2025), 2) basic scenario (moderate economic growth) reflecting the actual tendencies of GDP growth (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 3) slow economic growth scenario (2% per annum till the year 2010 and 3% in the period 2011-2020 or on average 2.6% per annum in the period 2000-2025).

Assessment of energy saving potential is based on the analysis presented in the National Energy Efficiency Programme approved by the Government of Lithuania in 1996 and updated in 2001 [13]. Assumptions on the development of other indicators are based on the analysis of their development during the transition period, compared to similar indicators in other countries and discussions with local and foreign experts.

The future final energy demand determined in accordance with the MAED methodology is presented in **Fig. 10**. Only in the case of a fast economic growth scenario would final energy consumption in Lithuania approach to the level of the year 1990.

The forecast of final electricity demand is the main outcome of the MAED model. Forecasting of electricity demand in this case was modified to take into account that model WASP (it has been used for analysis of the power sector development) requires "net generation" as input information. Therefore the forecast of electricity demand, presented in **Fig. 11**, includes (in addition to final electricity demand) distribution losses and electricity demand in the energy sector (i.e. it includes the needs of petroleum refinery, oil and gas transportation, heat plants and other needs of the energy sector).

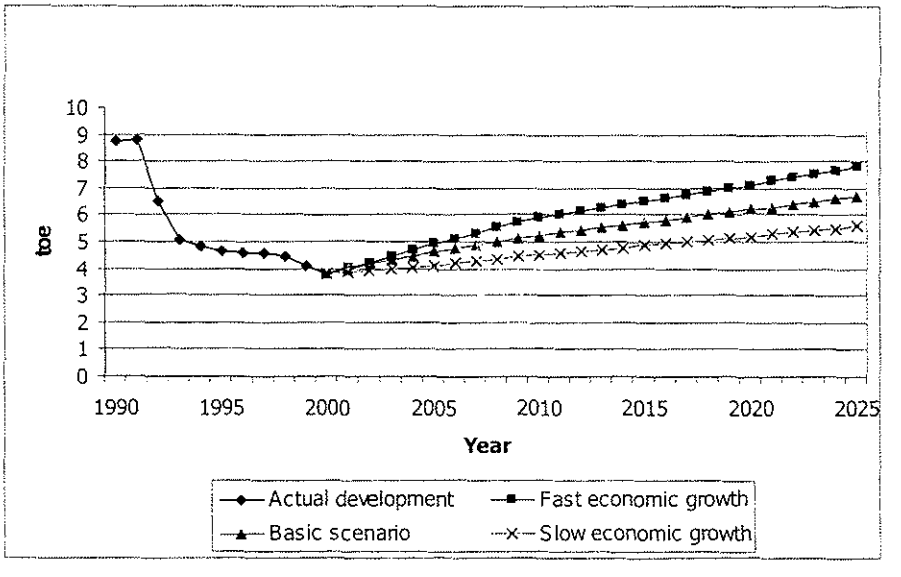

Figure 10. Final energy demand scenarios

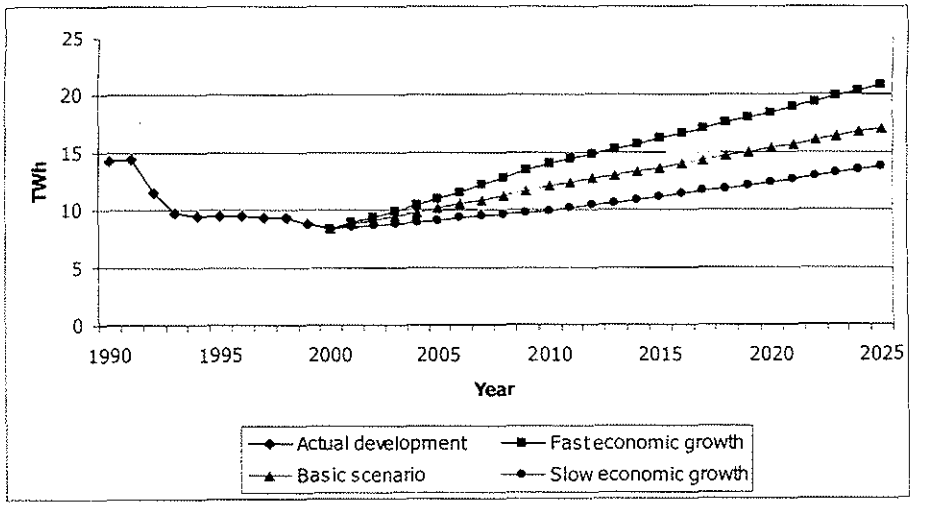

Figure 11. Electricity demand for the domestic needs

Taking into account the very low level of electricity consumption per capita an assumption was made about further penetration of electricity into all branches of the Lithuanian economy. As it is shown in Fig. 11, at the end of the planning period net electricity production could increase up to 2.5 times (in the fast economic growth scenario). In the case of the slow economic growth scenario, internal electricity demand at the end of the planning period will not exceed the 1990 level. Only in the case of the fast economic growth scenario will the level of electricity consumption per capita in Lithuania in 2025 be similar to this indicator in 1999 in Denmark, Germany or similar to the present average of the European Union. In the case of the basic scenario Lithuania would be able to reach the present level of electricity consumption per capita in the Czech Republic and Ireland in 2025. 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.

Conclusions

1. The deep decline in the economy (in 1994 the Lithuanian Gross Domestic Product dropped to 56% of 1990 level) and corresponding decrease in energy consumption were caused by a jump in prices of primary energy in 1990-1992, the loss of former Eastern markets together with other factors. The Lithuanian economy after the recession was able to get out of crisis and its future growth is related to increasing final energy and especially electricity demand.

2. The most important features of the Lithuanian energy sector are the following: excess capacity which could not be used efficiently during the transition period; absence of interconnections with Western energy systems; growing consumption of indigenous energy resources and increasing extraction of local oil; increase of energy efficiency.

3. The indicators of primary energy and especially electricity consumption per capita in Lithuania are much lower than in the EU and in many other Central and Eastern European countries. For comparison of energy efficiency in developed countries and countries in transition, the best indicator is a ratio of final energy intensity per unit of GDP using estimates of Purchasing Power Parity. Although at present this indicator in Lithuania is 1.5 times higher than the average energy intensity of the European Union, reduction of the final energy intensity in 1994-2000 by 35% confirms comparatively big progress in energy saving policy. Especially important changes have occurred in agriculture, industry and construction – final energy consumption per value added in 2000 was in agriculture 4 times, in industry 2.3 times and in construction 1.8 times lower than in 1990.

4. In Lithuania and other countries in transition experiencing sudden important changes in energy consumption a description of energy trends by using various time series methods is rather complicated and extrapolation of existing energy consumption trends cannot be applied for energy demand forecasting. Forecasting could be based on the application of the econometric or modern simulation models, applied to the analysis of energy demand development in many countries. Analysis performed in Lithuania has shown that a new version of the MAED model is a rather useful tool for energy demand forecasting and it could be applied to other countries in transition.

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