A thesis submitted to the Department of Environmental Sciences and Policy of Central European University in part fulfilment of the Degree of Master of Science

DEVELOPMENT OF THE UKRAINIAN ELECTRICITY SYSTEM: ADDRESSING ENVIRONMENTAL CONSIDERATIONS THRUOGH SCENARIO ANALYSIS

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:
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The main strategic features for the development of the electricity system in Ukraine are security, affordability and mitigation of environmental impacts. However, not all of them are equally addressed in the energy planning. The planning process is mainly based on economic and political considerations, while environmental issues are left outside the planning framework. Therefore this work is focused on the potential directions of the electricity sector development under the condition that environmental considerations are embedded in the planning. The research investigates possible paths for the system development through scenario analysis, which is rarely used approach in Ukraine. Three main scenarios have been elaborated based on the changes in crucial parameters of the system. The key strategic message that is derived from the analysis and comparison of the scenarios is that the development of the electricity system should be focused on energy efficiency of industry and households at the first place with the gradual transformation of supply system from fossil fuels to renewable sources of energy. The estimations show that the feasible decrease in energy intensity of two main electricity consuming sectors could bring savings of 91 TWh of electricity and decrease of CO_2 emissions in 50 million tonnes annually in 20 years.

Keywords: Electricity system, planning, scenario development and analysis, Ukraine.

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LIST OF ABBREVIATIONS

BAU	Business as usual (scenario)
CHPs	Combined heat and power plants
EUR	Euro
GDP	Gross domestic product
GHG	Greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
IPS/UPS	Integrated power system
kWh	Kilowatt hour
MW	Megawatt
NEC	National Energy Company
NERC	National Electricity Regulation Commission
NPPs	Nuclear power plants
toe	Tonnes of oil equivalent
TPPs	Thermal power plants
TWh	Terrawatt hour
UAH	Ukrainian hryvnia
UCTE	Union for the Coordination and Transmission of Electricity
USD	United States Dollar
WEC	World Energy Council
WEM	Wholesale electricity market

CHPTER 1. INTRODUCTION

1.1 Challenge of the energy planning in Ukraine

The key issues for the development of Ukraine's national energy system are security, affordability of energy supply, and mitigation of environmental impacts. Paying careful attention to these elements in the planning process is crucially important and should be adequately addressed in decision-making. However, in Ukraine's energy sector environmental considerations are not taken sufficiently into account when long-term targets are established. According to the National Energy Strategy (2006) these targets include doubling coal consumption and a threefold increase in the use of nuclear energy over the next twenty years. The Strategy also envisions a decrease in the use of natural gas and leaves the shares of hydropower and renewable energy as primary sources almost unchanged. These projections are based mainly on economic and political considerations such as availability of natural resources within the country and import dependence, growing demand in energy and price of primary sources. This research is aimed at the incorporation of environmental considerations into the energy planning through scenario analysis, which is a rarely used approach in Ukraine. The research explores the ways in which scenario analysis can help to formulate an energy development path and associated policy mechanisms for Ukraine that meet security, affordability and environmental safety criteria.

In the past practices economic and political issues had the predominant position in the decision-making process. In best cases environmental pressures were assessed as a side effect of the performance of energy sector. Such approach implies that environmental criteria and indicators could not influence the choice of primary energy sources or structure of energy market. For example, the main strategic document in the energy sector, the Ukrainian Energy Strategy (2006), proclaims environmental impacts of the energy sector as one of the special interest areas. It states the necessity for the ecologization of the energy sector, however it fails to provide concrete actions regarding how this could be achieved and quantitative indicators to measure the environmental performance of the sector. The Energy Strategy only contains an assessment of environmental pressure as part of the overview of the individual sectors, but no discussion of potential solutions or preventive measures. The necessity to account for the environmental criteria was raised numerous times by non-governmental and research organizations (MAMA-86 2006, NECU 2011). However, in practice, embedding environmental considerations in the planning process itself has not been made before at the national level. Currently, the Energy Strategy is under revision, which makes the discussion of the topic very timely.

The main reason why environmental considerations should be accounted for the planning process is severe environmental damage to the environment and public health which accompanies the performance of the energy sector. Energy production and consumption is accompanied with severe environmental degradation, direct and indirect effects of pollution on the natural systems and public health, and numerous negative externalities (Diak 2001). The energy sector is the main contributor to atmospheric pollution in Ukraine: it is responsible for 70% of the emissions of the greenhouse gases (GHG) (electricity and heat power plants along are responsible for 25% of the total CO_2 emissions), 75% of SO_2 emissions, 50% of the particle emissions and 45% of NO_x emissions (IEA 2006). The impacts on other components of the biosphere could be even more considerable taking into account that hydropower plants require significant land and change in the ecosystem dynamics, nuclear power plants are run under the constant radiation risks, thermal power stations are run on fossil fuels, whose extraction and utilization brings the major share of national emissions. For example, in 2010 coal extraction alone was responsible for the emission of 419 thousand tonnes of pollutants, the discharge of 380 million cubic meters of pumped mining water into the surface waters, the extraction of 20 million tonnes of waste rock, 18 million tonnes of which was stored in the spoil tips in Ukraine (MEP 2010, 2011). The environmental charges paid by energy companies in the majority of cases do not fully cover costs of pollution removal due to an inefficient environmental management. Apart from direct environmental costs, there are a number of serious negative environmental externalities that in aggregate could represent a significant cost to society (Greenpeace 2008).

An additional driver for the integration of environmental considerations into the planning process could be the orientation of Ukraine towards leading European practices and Ukrainian commitments under international agreements on energy and environment. The experience of developed countries like Great Britain, Germany, Sweden, Denmark, Norway, or the Czech Republic demonstrates that accounting for the environment in energy planning is beneficial not only for social and ecological reasons, but also advantageous for the energy security of the country (Coal Geology 2011). For example, the European Union is currently heading towards its 20/20/20 Energy Strategy (EC 2010). The EU Strategy has three main goals: security of supply, sustainability and competiveness, and five priority areas: achieving an energy efficient Europe, building an integrated European energy market, empowering consumers and achieving the highest level of safety and security, extending Europe's leadership in energy technology and innovation and strengthening the external dimension of the EU energy market. It is planned to achieve the stated goals through targets, one of which is 20% of GHG emission reduction compared to 2005, 20% increase in energy efficiency and 20% of renewables in the primary resource mix by 2020. Therefore, the Energy Strategy contributes to energy security by decreasing consumption and diversifying primary sources. Another target is 80-95% emission reduction in the EU by 2050. Head of the Delegation of the European Union to Ukraine, Jose Manuel Pinto Teixeira, highlighting the position of the EU on the Energy Day in Ukraine stated that "Energy is at the very edge of the EU-Ukraine relations. And we are calling our partners to join our efforts in this direction [direction toward energy efficiency and low carbon Europe]" (EUEA 2011).

Ukraine also has commitments regarding energy and environment under a number of international agreements. Ukraine is a party to the Charter Protocol on Energy Efficiency and Related Environmental Aspects and Energy Charter Treaty, Framework Convention on Climate Change and the Kyoto Protocol, Convention on Long-range Transboundary Air Pollution and the Montreal Protocol on Substances That Deplete the Ozone Layer. In 2011 Ukraine has joined the European Energy Community. Apart from economic benefits, this agreement also includes requirements to align the Ukrainian legislation with European legislation on a number of issues. Ukraine should implement the EU Directives 85/337/EEC on the assessment of the affects of certain public and private projects on the environment, Directive 2001/80/EC on the limitations of emissions of certain pollutants into the air from large combustion plants and plan for the implementation of the Directive 2001/77/EC on the promotion on electricity produced from renewable energy sources. In fact, accounting for the environmental considerations also became a question of reliability of Ukraine as a partner in the arena of international politics.

Once being included into planning, environmental considerations could catalyze transformations leading to more sustainable, diverse and therefore secure energy system. Therefore, this research looks at embedding environmental considerations into the energy planning process through scenario analysis, a practice with little tradition in Ukraine, but applied elsewhere around. The electricity sector was chosen as a specific example within the energy sector, because the electricity system is responsible for a major share of the primary resources consumption of the whole energy sector and it is the major emitter of greenhouse gases. The timeline was chosen until 2030 in accordance with current planning practices to ensure comparison with the existing Energy Strategy of Ukraine.

1.2 Project aims, research question and objectives

The aim of the research is to scope out an acceptable development pathway for the Ukrainian electricity system that accounts not only for energy security and economic sufficiency, but also takes into account mitigation of environmental impacts. The notion of energy security here is taken as a reference to the stable availability of natural resources for the supply of primary energy carriers that is essential for the national security. The main research question therefore is: How would the integration of environmental criteria into the planning process influence the development of Ukrainian's electricity sector in the future?

In accordance with the main aim and research question, the objectives of this research are:

1. Develop a model for the Ukrainian electricity supply system;
2. Elaborate several scenarios of the trends in the development of Ukrainian electricity system by 2030;
3. Evaluate the environmental performance associated with each scenario,
4. Define the priority scenario, acceptable according to the projected performance of associated security, economic and environment indicators and formulate key message for the decision-makers;
5. Analyze existing electricity sector-related policy mechanisms needed to facilitate system transformation;
6. Provide suggestions on policy development to ensure the sustainability of the electricity system in Ukraine.

1.3 Justification of the research approach

The research applies scenario development and analysis to exploring possible pathways for future supply in Ukraine. The construction of scenarios for examining alternative future developments based on assumptions has a long tradition in decision-making. Since the late twentieth century, scenario analysis has been actively used in environment and energy related policy assessment and strategy development (see Ito *et al.* 1997; Haldi 2000; Nakicenovic 2000; Oniszk-Poplawska *et al.* 2003; Ghanadan and Koombey 2005; Koskela *et al.* 2007). Environment and energy scenarios have been developed for different temporal and spatial scales, from the global to regional and local, both with a long-term, like Global Energy Perspectives developed (Nakicenovic 1998), Global world Scenarios (GSG 2010), or mid-term time horizon (Georgopoulou 1997). Over the years scenario building has become one of the main methods that is used to explore complexity and uncertainty associated with the long-term challenges, such as sustainable development (Kowalski *et al* 2009).

Scenario development is chosen as a tool for this research based on its potential to represent the alternative futures of complex systems under high uncertainty (Kowalski *et al* 2009). Ideally, data collection and modeling provide an opportunity to understand systems and determine possible states of the system over time. However, due to the complexity and uncertainty of some physical and socio-economic systems analytical work requires the use of heuristics approaches (Kowalski *et al* 2009). Through the combination of qualitative narratives concerning the future and quantitative analysis estimations, scenarios can help understand how the system works and may develop over time while making uncertainties, assumptions and their consequences explicit. Therefore, scenarios are useful tools for the exploration of complex systems and the formulation of policy-relevant messages for decision makers(Davis 1999).

Literature distinguishes different types of scenarios: normative scenarios, which are orientated towards certain milestones under the assumption that the future could be created to reach these milestones; and exploratory scenarios or descriptive, that describe how the future might unfold according to known processes of change or extrapolations of past trends (IPCC 2004). In the research there is applied exploratory scenario building. In exploratory scenarios, the future is seen as a social construct about which legitimately diverse opinions exist. This is important for exploring how the incorporation of new parameters, in case of this research environmental, could affect the development of the system. Generally, exploratory scenarios consist of a narrative storyline and quantitative indicators (Berkhout and Hertin 2002), which is done within the research.

Scenario development and analysis within this work combine qualitative and quantitative approaches. Qualitative methods involve interviews with experts, who have been invited to illustrate general trends in primary energy resource use for the future, evaluate the relevant importance of different energy sources in comparison to each other for the electricity system for selected timeline, develop the most probable scenario, the most sustainable favorable scenario (if different) and the most unfavorable one. On the basis of the collected data the qualitative scenarios are developed. Qualitative scenarios present the main trends in the demand for different primary energy resources. The quantitative approach is model-based. Projections for electricity use with the implementation of energy efficient technologies, as well as shares of energy carriers are to be modeled.

1.4 Thesis structure

The paper consists of five parts. The first chapter introduces the research problem. The second chapter presents the general review of the electricity sector in Ukraine and provides the basis for scenario development and estimations. The chapter consists of insights on the national context, within which the system operates, an overview of the installed capacities, production and consumption patterns, the analysis of the Ukrainian energy planning system, a brief review of Ukrainian Energy Strategy as the main strategic document and within that the planned development of the electricity system within it.

The third chapter provides information on research design and methodology. It is focused on the main methods and tools applied, such as literature review, interviews and model development. The chapter describes how scenarios have been elaborated and compared, and how policy analysis has been done. The chapter ends with the review of limitations.

In the fourth chapter the results of the research and their discussion are given. It is divided into three main parts. The first part is dedicated to the identification of key driving forces for the electricity system development that create a basis for the building of alternative scenarios. The second part is focused on scenario development and comparison based on the indicators presented in the methodology. It ends with the formulation of the strategic message for the decision-makers. The third part gives an overview of the possible policy mechanisms that are associated with the strategic message.

The concluding fifth chapter presents the summary of the results, recommendations and directions for the possible future research in the field.

CHPTER 2. ELECTRICITY SYSTEM IN UKRAINE: PAST AND PRESENT

This chapter provides overview of the Ukrainian electricity system and creates the background for the research. Firstly, this chapter highlights the national context within which the electricity system develops and operates. Secondly, the detailed information on Ukrainian electricity system is given: structure, supply and demand patterns, export potential. Finally, the planning practices in the electricity sector are presented.

2.1 National context

The organizational and operational structure of the electricity system is in many ways shaped by such national determinants as economic conditions within the country, natural resource availability and national interests.

2.1.1. Economic conditions

Being one of the largest countries in Europe, Ukraine so far has one of the lowest economic indicators in the world (Fisher 2011). Ukraine's dependence on imported energy carriers like gas and lack of fundamental structural reform have made Ukrainian economy vulnerable to external shocks. Nowadays political and economic situation in many cases shapes the future of Ukrainian energy sector.

In past Ukraine was one of the most important economic component of the former Soviet Union. It produced around four times the output in agriculture and heavy industry as the next-ranking republic (CIA 2011). After obtaining independence in 1991, the period of active reforms toward privatization began. However, widespread resistance to the reforms by the governmental bodies and the legislature soon affected the economic development. Production output in 1999 had fallen to less than 40% of the level of 1991. Later, Ukrainisn economic development started to stabilize even despite the political uncertainties of that time. In 2006-2007, Ukrainian real GDP growth was fueled by high global prices for steel growth and exceeded 7%. In 2007-2008 Ukraine experienced another economic crisis. The drop in steel prices and Ukraine's exposure to the global financial crisis lowered the growth in 2008 and the economy is now characterized as one the worst in the world. In 2010, the inflation was 10% and GDP per capita was USD 6700, which is behind other countries of the region, like Romania (USD 11600), Poland (USD 11800), Belarus (USD 13600) and Russia (USD 15900) (CIA 2011). However, experts indicate that external conditions are likely to facilitate efforts for economic recovery in 2011 (Ukraynska Pravda 2011).

The two main strategic economic sectors for Ukraine are agriculture and highly energy intense heavy industry. Not alike agriculture, industry is so far the largest electricity consumer, which in detail will be described in the following sections. During the Soviet times Ukrainian heavy industry provided the unique equipment (e.g, large diameter pipes) and raw materials to other parts of the former USSR. Ukrainian industry is still highly export-oriented with exports accounted to about 45% of Ukrainian GDP (SSCU 2009). Currently the industrial production is focused on coal, ferrous and nonferrous metals, machinery and transport equipment, chemicals and food processing (CIA 2011). The majority of these sectors require significant energy input. Energy-intensive metallurgical and machinery industries occupy the major shares in exports (respectively 40% and 16% of industrial export) (CIA 2011). So the most energy-intense production is prepared for the use outside the country. In fact, the orientation to the exports with the major share of highly energy-intense heavy industry is likely to remain important component in Ukrainian economic system. Therefore, electricity system should be ready to fuel industrial demand in energy. All in all, Ukrainian industrial enterprises consumed 71.5 TWh of electricity, or 48.5% of total electricity consumption in 2010, which among other is determined by the energy intensity, which is highest in Europe (Ukrenergo 2011). The energy intensity in Ukraine is 0.89 toe per dollar of GDP compared to European average 0.3 toe per dollar of GDP (SSCU 2009, IEA 2006).

2.1.2 Natural resource availability

The availability of natural resources within the country determines the choice of primary energy sources for the energy system. Currently, in order to fuel development Ukraine mainly uses nuclear energy and fossil fuels – domestic coal and imported oil, gas and nuclear fuel. Ukraine has to import around 30% of its annually oil, natural gas and nuclear fuel needs (Ukraine does not have full nuclear cycle) (IIIEE 2008). However, Ukraine has extensive domestic natural resources, especially coal, uranium, hydro power, that create the basis of the national electricity sector.

Ukraine has one of the vastest and valuable coal deposits in Europe, the Donetsk basin in the Eastern part of the country between the rivers Dniper and Don. The Donetsk basin provides the country with hard coal (UES 2006). There are also deposits of hard coal and lignite in the Lvivsko-Volynskyj basin and Dipro basin. Ukraine's proven coal reserves are estimated at 34,150 million tonnes, compared to European total of 312,680 million tonnes (WEC 2001). With the annual production of 72.3 million tonnes of coal in 2010, Ukraine was among ten biggest coal extractors in the world (WCA 2010).

Ukraine has also domestic oil and gas. There is 395 million barrels of proven oil deposits (around 170% of annual consumption) (WEC 2001) and currently, approximately 13% of crude oil for use is produced domestically (SSCU 2009). The proven gas reserves are 1.1 trillion cubic meters (around 1500% of annual consumption) (WEC 2001) and almost 25% of the natural gas for consumption is produced domestically (SSCU 2009). The gas extraction is mainly take place in the Dnipro-Prypyat region from over 120 oil and gas fields. The other strategic petroliferous regions include Carpathian, Volynsko-Podilskyj regions and Prychrnomorskyj regions, which is off-shore deposit. Theoretically, the sea bottom in the Northwest of the Black Sea close to the Danube delta could embed approximately 10 million tonnes of oil and 100 billion cubic meters of gas. This area was long time unexplored because of the border dispute between Ukraine and Romania. However, in 2009 the dispute was solved which opened the way for the resource exploration (IIIEE 2009).

Ukraine has also deposits of uranium, which are estimated to be 200,000 tonnes. (WEC 2001) With the extraction of 800 tonnes of uranium annually (2% of the world's total), Ukraine is included in the list of the largest producers of the world. Most of the uranium is produced in the Central Ukraine. Approximately 230 tonnes of uranium is exported annually (SSCU 2009).

Ukraine has high potential in hydropower and renewables. The overall potential of the Ukrainian rivers are assessed to be 45 TWh per annum (compared to current production of 13.9 TWh), among which 20-25 TWh per annum is considered to be economically and technically feasible (WEC 2001). Nowadays, the largest hydropower stations are situated on the Dnipro and Dnister rivers, which are the biggest rivers in Ukraine. The potential of small rivers is expected to be 12.5 TWh annually (currently the capacities of small hydropower account for 10 MW). The biggest potential for small hydro power plants has Western and Central Ukraine (WEC 2001, IIIEE 2009). Among the renewables, the biggest potential have biomass, wind and solar energy (IIIEE 2009, ECU 2006). According to the estimates, waste from agricultural activities and timber processing could substitute imported gas and cut the demand in this resource at least twice (IEA 2006). The potential for electricity production by waste utilization is expected to be around 15

TWh per annum. Ukraine has limited geothermal, wind and solar potential. The wind potential is assessed at the level of 5000 MW and is bound mainly to Crimea Region (IIIEE 2009). The Crimea region is also seen as potential are for the development of solar energy, which could substitute up to 3 million toe per annum of primary energy resources in the energy mix. Geothermal potential is accessed at the 200 GW level (MAMA-86 2006).

Ukraine also transports fossil fuels. The geographical location and transportation capacities made Ukraine the largest transporter of gas and oil through pipelines for Russia to Europe. More than 80% of Russian gas is going through Ukraine (IIIEE 2009). The Ukrainian gas transportation system could receive up to 290 billion cubic meters at the inlet and give up to 170 billion cubic meters of the natural gas at the outlet, including 140 billion cubic meters of direct transport to Europe. The capacity of oil transportation system is 114 million tonnes at the entry point and 56.3 million tonnes at the exit point. In 2010 the oil transit was 20.1 million tonnes of oil (IIIEE 2009).

2.1.3 National interests

The biggest threat to the Ukrainian energy security is dependency on the imported resources (Diak 2001). Ukraine depends on imported resources, especially gas because of the structure of te economy, low energy efficiency, primary energy resource mix with the high share of fossil fuels, lack of own gas deposits. Russian gas monopoly company, Gasprom, has continuously negotiated the increase of gas prices for Ukraine. The common position is that the increase in gas prices in the payback for Ukrainian government for the lack of loyalty to Russia after the political changes in Ukraine in 2004. Therefore, securing accessible, stable and affordable energy inflow is being the predominant national interest. In order to decrease the vulnerability of Ukrainian energy system, Ukraine is looking forward to reorient energy system toward domestic resources. This trend has been dominant in the energy sector development, including electricity system over the last decade.

2.2 General overview of the electricity system

The previous section gave the overview of the general conditions under which energy sector operates. This section is aimed to give particular description of Ukrainian electricity system. The section is focused on the three crucial components of national electricity balance such as production, or supply side, consumption, or demand side, and export. Firstly, the supply side is examined. It is given the description of installed capacities, production patterns and primary resource mix. Secondly, the demand side, which determines present and future electricity production, is described. In Ukraine electricity production overreach demand allowing export to the neighboring countries. So, thirdly, electricity export is analyzed. Finally, the summary of key challenges to be addressed in the planning is given.

2.2.1 Supply side

Ukrainian electricity sector has experienced major changes in market structure and ownership, fluctuations in supply and demand patterns since 1991. The total capacities of power plants are 53.1 GW (see Table 2.1) (Ukrenergo 2011), which is the 16th largest installed capacities for electricity production in the world (US EIA 2011). However, the actual electricity productio is lower than installed capacities. The electricity balance for the period 1996-2010 is presented in the Table 2.2.

The main types of generation facilities that operate in Ukraine are: nuclear power plants (NPP), thermal power plants (TPP), combined heat and power (CHP) plants and hydropower plants (HPPs). As for 2010, the majority of capacities are provided by thermal power plants (63.4%) with the shares of nuclear power plants (26.2%) and hydro (10.2%). There is also a small share of wind and helium plants that is gradually increasing (Ukrenergo 2010b). The differentiation of installed capacities according to the type of power plants is presented in the Table 2.1 and distribution of Ukrainian power networks is given in the Annex A.

Table 2.1 Installed capacities for the electricity production, 2010

Type of utilities	Installed capacities		Electricity production	
	GW	Percent	TWh	Percent
Thermal (TPPs and CHPs)	33.7	63.4	85.7	46.7
Nuclear	13.9	26.2	89.2	47.4
Hydropower	5.4	10.2	13.0	6.9
Renewable energy sources	0.1	0.2	0.0	0.0
Total	53.1	100.0	187.9	100.0

Data source: Ukrenergo 2011

Table 2.2 Electricity balance for the period 1996-2010, TWh

Electricity production/consumption, TWh	Year														
	1996[i]	1997[i]	1998[i]	1999[i]	2000[i]	2001[i]	2002[i]	2003[i]	2004[i]	2005[ii]	2006[ii]	2007[ii]	2008[ii]	2009[*]	2010*
Total electricity production	183	177	172	172	171	173	180	180	181	185	193	196	193	192	191
Fossil-fueled TPPs	77	71	63	69	66	67	66	67	59	60	na	na	na	62	60
Fossil-fueled CHPs	17	16	18	16	16	17	19	22	24	24	na	na	na	24	24
Total fossil	95	88	81	85	82	84	85	89	83	84	93	95	91	86	84
Hydro	9	10	16	15	11	12	10	9	12	12	12	12	12	13	13
Nuclear	80	80	75	72	77	76	78	81	87	89	88	89	90	90	90
Transmission losses	3	3	3	4	5	5	5	4	5	4	4	4	3	4	5
Total production net of losses	180	174	169	167	166	168	168	175	177	181	192	187	190	188	186
Consumption and losses by energy sector	15	18	15	12	10	11	10	12	14	15	29	29	26	19	16
Total production available for distribution	165	156	154	155	156	157	158	163	163	166	163	158	164	169	170
Electricity consumption															
Industry	74	73	69	66	69	70	70	74	78	78	67	72	67	69	71
Households and housing services	41	38	37	38	36	36	37	38	39	42	38	39	42	42	42
Other	25	23	23	21	19	17	17	18	18	19	24	15	26	23	22
Distributional losses	21	22	24	27	28	31	31	29	24	20	24	23	22	29	31
Net export	4	0	1	3	4	3	3	4	4	7	10	9	7	6	4
Total consumption including net export	165	156	154	155	156	157	158	163	163	166	163	158	164	169	170

Data sources: [i]- Tsarenko 2008; [ii] – IEA 2006, 2008; * - Ukrenergo 2010a, 2010b, 2011

Structure of electricity production differs from the structure of installed capacities. In 2010 it was produced 187.9 TWh by power plants, from which thermal power plants produced 46.7%, nuclear 47.4% and hydropower plants 6.9% (Ukrenergo 2011). The discrepancy between installed capacities and volumes of production appeare because of the difference in operation of different types of power plants (nuclear power plants should be run continuously, while thermal and hydro power plants are more flexible concerning the load factor). Moreover, the differences in price settings, level of equipment depreciation and low fuel quality produced within the country (like coal and gas) contribute a lot to the restricted use of thermal produced electricity (Tsarenko 2007). More detailed description of the electricity production by different sources, like nuclear energy, fossil fuels, hydropower and renewables is given below.

Nuclear energy

Currently, nuclear energy is the largest source of electricity in the country. In 2010 the electricity production on NPPs was 89.2 TWh, which accounts for 47.4% of total (Ukrenergo 2011). There are four nuclear power plants in Ukraine (Zhaporizka – 6000 MW, Pivdennoukrainska – 3000 MW, Rivnenska - 2880 MW and Khmelnytska – 2000 MW), with a total of 15 reactors. All nuclear power plants are owned and operated by the state through the state company Energoatom (established in 1996) (IEA 2006). Ukraine has used nuclear energy since 1970s, which is not surprisingly taking into account uranium deposits. So, it is likely, that share of nuclear energy will remain relatively high in the future (ESU 2006).

However, usae of nuclear energy in Ukraine is restricted by issues of nuclear fuel provision, fuel storage and public security (MAMA-86 2006). Only 30% of national demand in nuclear fuel is covered by domestic source, the rest is imported from Russia (MAMA-86 2006). Nevertheless Ukraine is one of the major world extractors of uranium, the country does not have the closed cycle of the nuclear fuel production. The introduction of full cycle has not been done because it requires significant investments. Moreover, Ukraine does not have technologies and capacities to store waste fuel and other types of radioactive waste. Another thread for the nuclear power use is connected to the nuclear safety. After Chernobyl disaster in 1986 the topic has been of the crucial importance for Ukraine, especially (IEA 2006). Therefore, the common critic of the increase of nuclear energy is that nuclear energy fails to meet the key national interest – provide import independence for electricity sector and safe energy for the population and natural environment (NECU 2011, MAMA-86 2006).

Fossil fuels

Fossil-fueled power plants account for 46.7% of electricity generation (Ukrenergo 2011). Nevertheless Ukrainian climate conditions create substantial demand in district heating, only 17% of fossil-fueled power plans are combined heat and power (in sum 32 CHPs, 1670 MW of installed capacities). There are 15 main TPPs with the capacities ranging from 800 MW to 3600 MW. They are operated by four state generation companies (Donbasenergo, Centrenergo, Zakhidenergo and Dniproenergo) and one private company Skhidenergo. There are about 30 large CHPs in Ukraine, 25 of which have capacities between 20 and 700 MW (Ukrenergo 2011, IEA 2006). The majority of CHPs are in the ownership of state or local communities, but approximately one third of them are operated by the private companies (Tsarenko 2008). The majority of CPPs and CHPs operate on coal, less – on natural gas and crude oil, and the smallest share utilizes biomass, the only CHP on methane gas is operates on the basis of Zasyadko coal mine (Ukrenergo 2011).

The use of fossil fuels for electricity production is restricted to the resource availability, environmental impacts and social considerations. As it was discussed earlier, Ukraine has limited proved oil and gas deposits that directed the electricity supply towards the use of domestic coal. However, Ukrainian coal is characterized by deep coal beds and low coal quality that results in severe environmental impacts during mining, processing and burning. The poor management of the coal sector could not properly address the question. For example, in Zhahtarsk, one of the many mining regions of Donetsk basin with 12 underground mines (six operating and six liquidated), 44.312 million tones of solid waste were accumulated up till now. Up to 98% of pumped mine water (14 million square meters) in the region is discharged into the surface waters without sufficient treatment, which bring about 16.7 thousand tonnes of pollutants into the surface water annually (MCI 2009). Moreover, approximately 5 thousand tonnes of methane is emitted annually contributing to the atmosphere pollution (MCI 2009).

However, the orientation of electricity system toward decrease of domestic coal use will put again the question of import dependency on the first place and also bring up social issues of development in mining regions. Coal sector plays significant role in the economic and social life of the mining regions. Most of the local work places are directly or indirectly connected to the mining (SSCU 2011). According to the National Statistic Report almost every third working position in the region is bond to the sector (including positions in control, research and health institutions). In fact, the need to close mines could threaten regional development by creating high unemployment rates, movement of labour forces, social perturbations and economic decrease in the areas (MCI 1998). So, the use of coal is bound to the question of finding delicate balance between energy security, environmental safety, regional development and stability of social indicators.

Hydropower

The country has nine hydropower facilities (that include both pure hydroelectric and hydroelectric accumulating plants) along the Dnipro, Dnistr, Pivdennyj Bug and smaller rivers. The four main hydro power stations, which are located along the Dnipro and Dnistr rivers, account for 3.3 GW of total 5.4 GW (Ukrenergo 2011). All large hydropower plants are owned and operated by the state company Ukrhidroenergo. In addition, there is up to 50 active and around 100 inactive small HPPs (with the capacity less than 10 MW) (Ukrenergo 2011). However, generally the small hydro is underdeveloped (IIIEE 2009).

Renewables

The share of renewabes in electricity productions is insignificant. Most of renewable energy capacities consentrate in biomass, wind and solar utilities. There are also several geothermal heating systems. Estimates made by International Energy Agency (2006) indicated that renewables have relatively high potential in Ukraine and can bring about 234.12 MWh of electricity per annum. However, significant initial costs and poor governmantal support slow down the wide use of renewable. In 2008 special green tariffs (in English terminology also referred as feed-in tariffs) were introduced to facilitate developmet of reneable sources. However, the share of reneables still increseas slowly (Ukrenergo 2010a, 2010b, IEA 2010a).

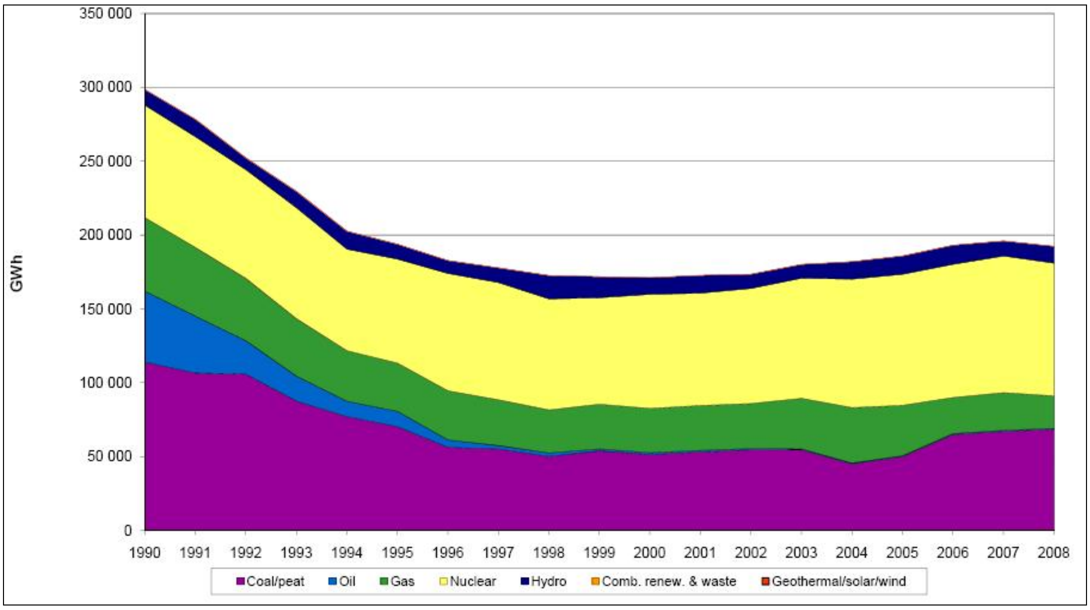

Fig. 2.1 Electricity generated by fuel in Ukraine (Source: IEA 2010b)

Going back to the review of the production pattern it is worth mentioning that currently Ukraine has significant excess capacities, which is the result of the past planning practices when rapid growth of the energy-intense industry should be fueled by cheap energy. Nowadays, these extreme capacities are in many ways outdated, but enable Ukraine to be net exporting country (latest will be discussed separately). According to estimates, 53.1 GW of installed capacities could have produced 371 TWh of electricity in 2010, which is enough to meet national demand up to the year 2015 (IEA 2010b). The actual production (see Table 2.2) is now at the 187.9 TWh (Ukrenergo 2011).

Load factor of installed capacities has experienced considerable fluctuations over the last twenty years (IEA 2006). At the beginning of 1990s electricity supply system had the load factor of 77%, ten years later, in 2000s, it has fallen to 54%. Now the system is 80% loaded. The figure 2.1 presents historical changes in the amount of electricity produced by different types of fuel in Ukraine for the period 1990-2008. A significant decline in the electricity production until 1998 emerged because of the economic crises. In 1998 total generation was 68% of generation in 1990. Later economic growth stabilized and demand in electricity was steadily growing until 2007-2008, when another economic crises stroke the country. During this period the shares of oil and gas as primary sources have decreased, while the share of coal has increased due to the policy direction towards the coal production.

One of the biggest technical problems of the sector is outdated production and distribution utilities. Over the period of exploitation, installed power plants have lost their functionality and tend to be quite inefficient as a result of both – their function and age (IEA 2006). According to the estimations of the World Bank, about one-third of thermal utilities are not available for use. In fact, eight out of 30 CHPs, which are still in operation, were built before 1940s, another eight were built between 1945 and 1960. The maximum exploitation period for the CHPs of these designs is 40 years, so around 50% of CHPs are reached their exploitation potential but still are in operation. The efficiency of the majority TPPs is around 25-28% and for CHP this indicator is 50-60%, which is five to ten percent less than planned efficiency. Moreover, Ukraine has one of the highest volume losses from power transmission in the world, that could reach 16% of electricity produced (Tsarenko 2008). Until 2005 transmission and distribution losses in the electricity supply sector were more than 18%. The losses dropped by 15% after joint actions taken by Ministry of Fuel and Energy and regional distribution companies in 2005. However, the losses remained on the relative high level compared to European practices (IEA 2006).

The technical and commercial challenge of high losses could have been solved through the investment inflow. However, small investments in the renovation and new capacities by private bodies are determined by low electricity price and strong state sectoral regulation (IEA 2006). Over the last ten years there were provided investments to build two nuclear reactors, renovate and increase capacities of two power plants and renovate hydropower plants (Ukrenergo 2011). However, inefficient power plants, transformation and distribution systems require much more financial inflow for capital renovation or replacement.

Another challenge of the electricity sector is severe environmental pollution that is associated with the sectoral performance. Generally, functioning of the electricity sector is associated with negative influence on the natural environment on the local and global level: atmosphere emissions, land degradation, water pollution and irreversible changes in ecosystems, externalities that are not covered by environmental payments from electricity producers (MEP 2010). However, due to environmental management practices these impacts are poorly addressed, monitored, reported and accounted in the planning process (MAMA-86 2006).

The energy sector is considered to be the main greenhouse gases (GHG) emitter on the national level. It contributes to the 69% of total emissions of Ukraine (IEA 2009). The combustion of fossil fuels brings around 57% of sectoral GHG emissions. TPPs and CHPs along are responsible for the 24% of total carbon dioxide emissions. In fact, Ukraine is considered to be in the top 20 countries with the highest carbon dioxide emissions from fuel combustion, and ranked as eighth in energy-related GHHG emissions. The historical trend in GHG emissions is presented on the Figure 2.2. The pattern of GHG emissions corresponds to those of economic development and electricity production for the period of 1990-2004. The figure shows that the energy sector was responsible for 700 million tonnes of CO_2eq emissions in 1990. Until 2004, the emissions dropped to 290 million tonnes of CO_2 equivalent per annum. In 2010, the overall emissions by energy sector was estimated on 275 million tonnes of carbon dioxide equivalent, among which electricity sector emitted 150 million tonnes of carbon dioxide equivalent (MEP 2011).

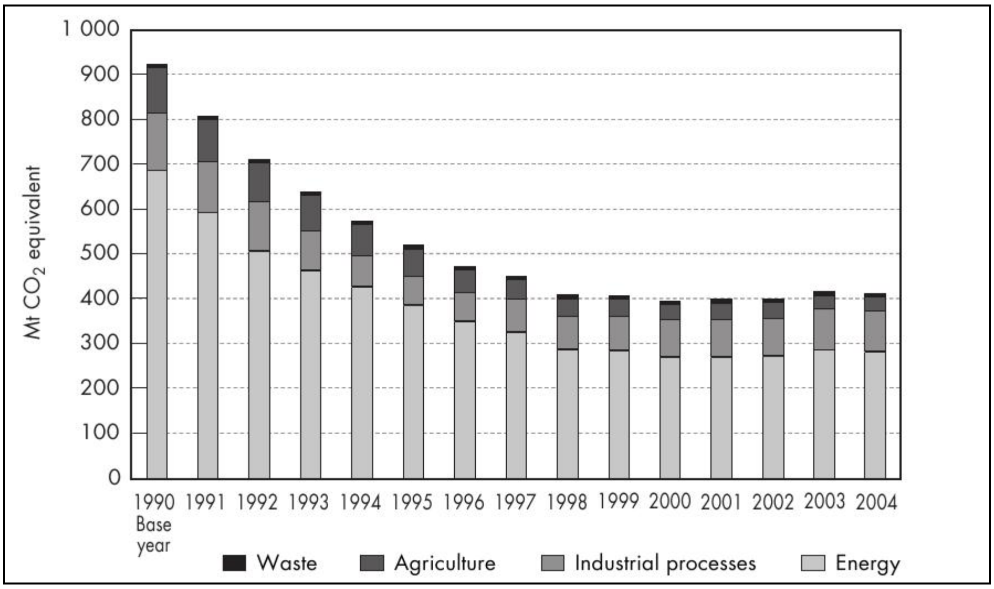

Fig. 2.2 Greenhouse gas emission in Ukraine, 1990-2004 (Source: IEA 2006)

Reduction of GHG emissions is currently considered as one of the priority areas for future development worldwide and Ukraine recognized this necessity by taking obligations under the UN Framework Convention on Climate Change and Kyoto protocol. However, without additional measures and technological improvements, the national GHG emission will continue to grow with the economic recovery and orientation on fossil fuels for electricity generation (IEA 2006). The increase in coal consumption for electricity production, which was discussed earlier, leads to the corresponding increase in GHG emissions (IPCC 2006). A strong influence on the amount of GHG emission has level of Ukrainian energy intensity. So far, Ukraine has the highest level of energy input per output of the economic activity (ESU 2006). So, if Ukraine is aiming to the mitigation of environmental impacts by the energy sector, environmental indicators should be among key parameters to be accounted in the choice of primary energy sources and overall planning in the electricity sector.

As for the organizational and ownership structure of the supply side, it is strictly state-controlled which in many ways defines the challenges in its management. In 1990s the sector was restructured and supply side was split into production, transmission and distribution (Tsarenko 2008). This was done to improve competition between electricity enterprises on the market. Generally, international advisory bodies see this as a positive change (Naumenko 2009c, IEA 2006). However, he potential for market development and improvements remains limited by the state dominant ownership and control over the entities (IEA 2006, Petrov 2010). In 1994 the presidential decree established state-controlled wholesale electricity market (WEM) (Tsarenko 2008). Mainly state-owned generating companies produce electricity and transmit it to Energorynok, state-owned company that is in charge for operating the WEM. Energorynok buys all the electricity which is produced from production companies and further sells it to 27 distributing companies. Transmission of electricity through the high-voltage network is operated by the state company Ukrenergo. Distribution through the low-voltage networks to the final users is operated by oblenergos, only 6 of 27 of them are privatized. There are also small share of independent distributors that pay for oblenergoes for utilization of low-voltage networks. They either sell purchased electricity to large industrial consumers or are industrial enterprises buying electricity for their own needs. The tariffs for the wholesale market, distribution and transmission are mainly established by National Electricity Regulation Commission (NERC). The generators market is divided into regulated (68% of market including all nuclear, hydro and wind PP, majority of CHPs) and competitive market (mainly TPPs and some CHPs that compete to sell electricity to Energorynok). NERC establishes tariffs on which it buys electricity from regulated producers, it also establishes fees from transmission and retail tariffs for the majority of distribution market. The organization structure of the electricity market is presented on the Figure 2.3.

The prices for electricity for final users are relatively small in Ukraine (IEA 2006). The tariff for residential users was 0.025 EUR/kWh and for industrial users was 0.036 EUR/kWh, so the cross-subsidising is taking place (Ukrenergo 2011). The tariffs are established by NERC on the basis of production and supply costs, losses, maintenance costs and rate of investment return. The price of electricity takes 77% of the tariffs, transmission and distribution costs – 13%, costs of losses –

9% (Tsarenko 2008). However, the Ministry of Fuel and Energy, as well as NERC admits that these tariffs cover only 36% of long-term production costs and could not stimulate to the developments in the sector. Low tariffs and cross-subsidizing not only undermine potential for renovations and developments of electricity utilities, but also provide poor incentives for population to reduce electricity consumption.

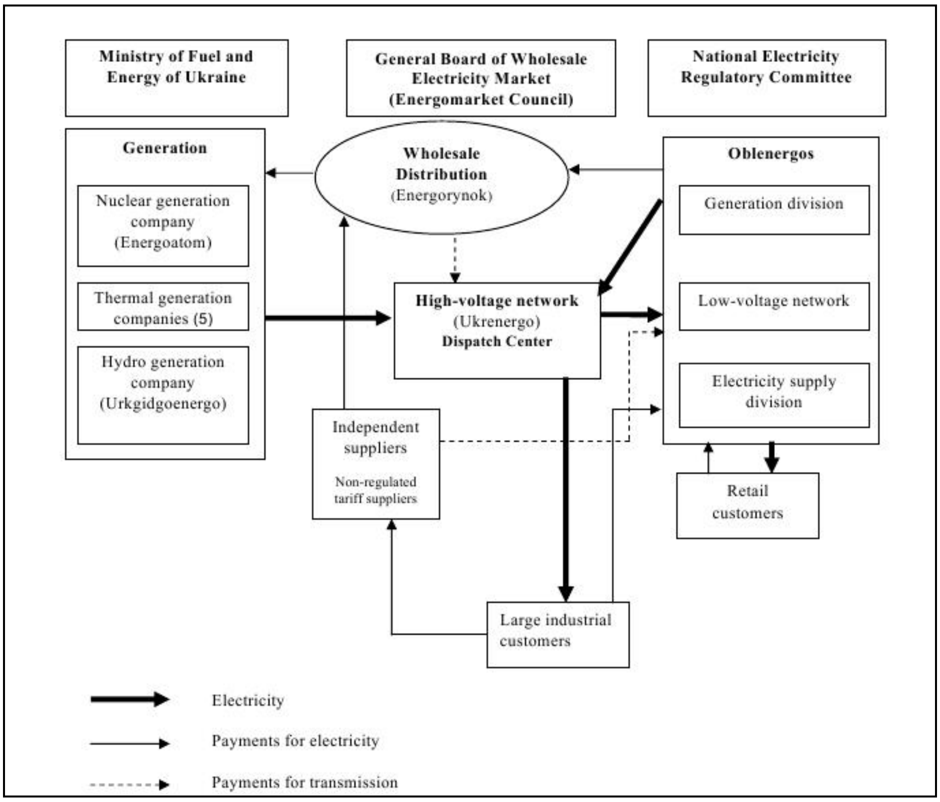

Fig. 2.3 Structure of the wholesale electricity market in Ukraine (Source: Tsarenko 2008)

From the positive side, the green tariffs (or feed-in tariffs in English terminology) were introduced in 2008 (Law on Green Tariffs 2008). The alternative sources, like solar, wind or biomass (excluding nuclear) have secured buyer for their electricity and higher price per kilowatt hour. The introduction of feed-in tariffs is aimed to increase the share of alternative primary energy sources at the national market. It will work for the next 10 years.

2.2.2 Domestic demand

Electricity demand in many ways shapes the supply pattern. Ukraine has excess capacities in electricity production inherited from past epoch of development when extreme quantities of energy were required to fuel the rapid increase of industrial production (IEA 2006). However, starting from early 1990s, economic growth falled down and stabilized only in ten years. Crisis period of early 1990s and after-crisis recovery resulted in the drop of electricity demand by 42% from 1992 to 2002 (see Figure 2.4). Since 2002 electricity consumption started to grow again and in 2008 reached 70% of the 1992 level. Currently, electricity produced within the country (183.9 TWh) is enough to satisfy domestic demand and also export electricity to the neighboring countries.

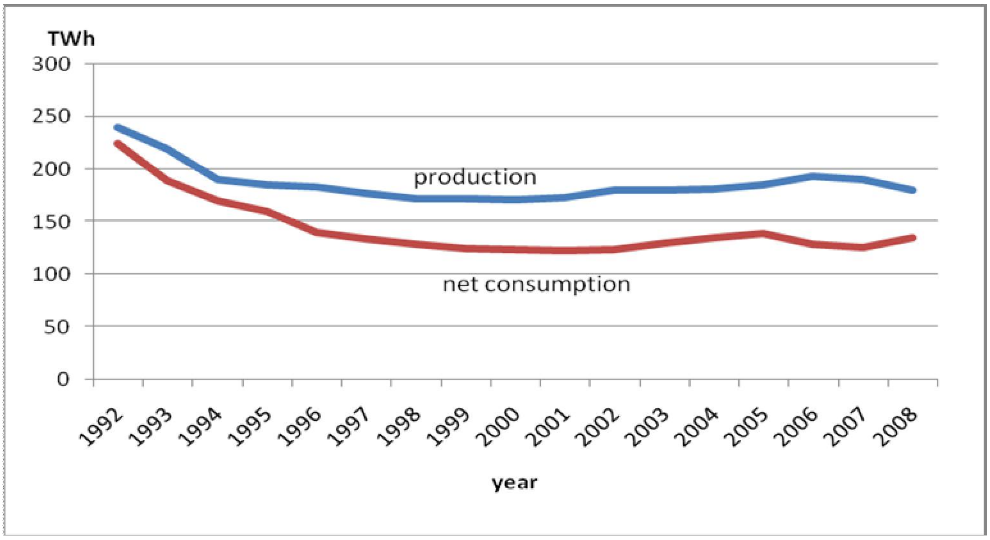

Fig.2.4 Electricity production and consumption over the period 1992-2008, TWh
(Source of initial data: Tsarenko 2008; IEA 2008, 2010b)

Industry and households are historically two largest consumers of electricity (see table 2.1) (Ukrenergo 2011; IEA 2006, 2008; Tsarenko 2008). The minor shares belongs to the commercial sector, agriculture, transport and other. Sectoral distribution of electricity consumption for 2010 is presented in the Figure 2.5 (Ukrenergo 2011). If to take industrial sector, the metallurgical branch was responsible for 38.4 TWh electricity consumed compared to total of 147.5 TWh, power sector has utilized 9,1 TWh, automobile – 5.9 TWh and chemical – 5.3 TWh. In the households, the biggest consumer group is the apartments in the multistory buildings.

One of the most striking problems of the demand side in 1990-2000 was debt and non-payment (IEA 2006). Before 2000, many consumers failed to pay bills or paid through barter. Consequently, the distribution companies could not provide finances to Energorynok for production and transmission services. For example, in 1996 the cash collection from final consumers covered only 1.1% of payments (Tsarenko 2008). After the restructuring process, the rate of payment collection significantly increased and in 2004 it reached 97.4%. In 2006 the payments covered 98.4% of services, which is considered to be good even by Western standards. However, Energprynok was left with the debt of UAH 877 million (USD 160 millions).

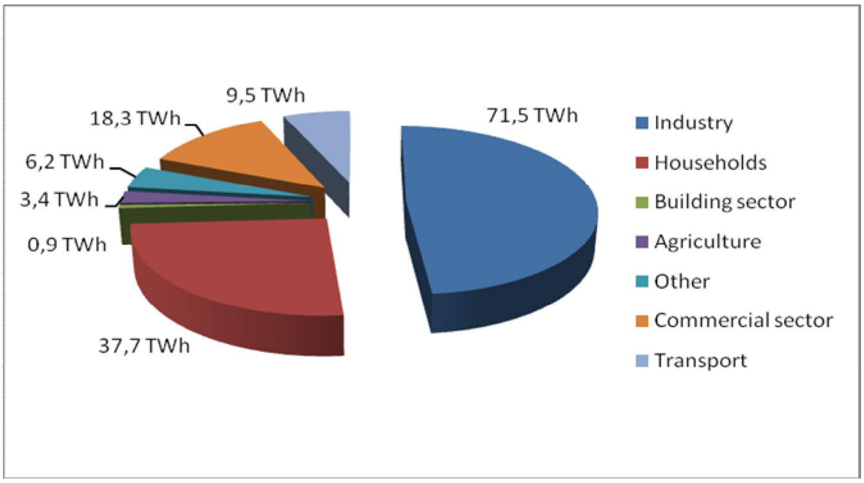

Fig.2.5 Electricity consumed per sector in 2010, TWh
(Source of data for the figure: Ukrenergo 2011)

Another challenge of demand side is inefficiency of electricity consumption by two major sectors – industry and households (ESU 2006; IEA 2006; Tsarenko 2008; MAMA-86 2006). Energy intensity of industry in Ukraine is 0.89 toe per dollar of GDP (ESU 2006). It is almost twice bigger than world average (0.34 toes per dollar of GDP) and four times bigger than in many developed countries like Germany, France, England and Denmark (see Figure 2.6). In fact, almost 60% of electricity consumed by industry is losst. The rate of losses in households is the same; approximately 65% of electricity consumption is not useful. The majority of electricity is wasted because of poor house insulation, inefficient appliance for heating, cooling and cooking, and traditional non-efficient use of the electricity.

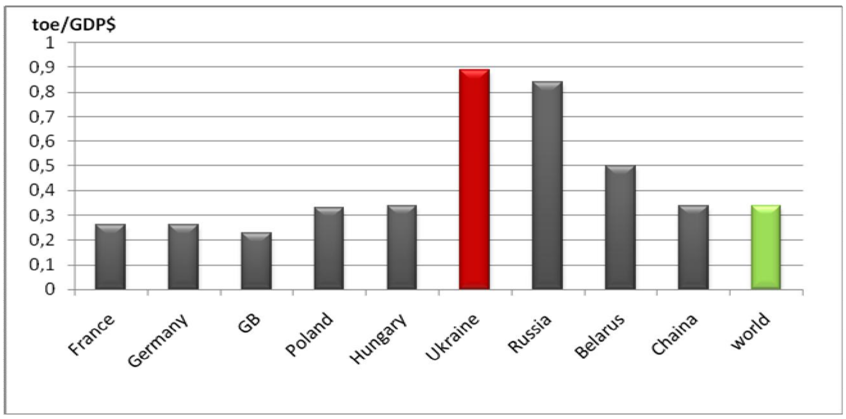

Fig.2.6 Industrial energy intensity, 2004
(Sourse of data for the figure: Energy Strategy of Ukraine 2006)

2.2.3 Export

Ukraine has electricity production surplus that enables Ukraine to export electricity in the neighboring countries. At the moment, government considers increasing export as the integral part of the system development (ESU 2006). In 2010 it was exported 4.2 TWh of electricity (Ukrenergo 2011). Over the last twenty years the dynamic of export experienced minor fluctuations (IEA 2006, 2008; Tsarenko 2006). During the period of 1995-2005 the average annual export was 3-4 TWh, in 2006-2007 there were a peak when export raised till 9 TWh per annum followed by decrease in 2008 (see Table 2.2). In 2010 electricity was exported to Belarus (69.7%), Hungary (14.4%), Slovakia (11.9%), and to less extend Russia (1.9), Romania (1.5%) and Moldova (0.6%) (Ukrenego 2011). The shares of country-importers changed over time which was determined by their demand, competition on the international electricity market, and abilities of Ukraine satisfy external demand.

The common trend since 1991 was export to the Commonwealth and Independent States, while more financial attractive European market was covered in the minor share due to technical barrier (Zhahmann and Naumenko 2009). Ukraine has limited ability to export electricity to the European countries because of the different types of high-voltage grids that are used by Ukraine and European countries (IEA 2006). Ukrainian high-voltage grid is connected to the integrated power system of the Commonwealth and Independent states (IPS/UPS) while European countries use different system under the Union of Coordination and Transmission of Electricity (UCTE). UCTE now connects 42 electricity transmission and operation systems from 34 countries. Synchronizing Ukrainian grid with UCTE is a challenging task because two systems have different technical background, organizational structure and legal regulations. Complete physical synchronization of two systems is technical impossible, so that electricity generated for UCTE system could not be used within Ukraine, only transferred to the UCTE system. The EU has provided Ukraine with assistance to synchronize two systems and increase export. However, according to the estimates of Ukrainian government it is required another seven years to complete the work. So far, only Burshtyn electricity island in Ukraine is synchronized with the UCTE system. The island was completely synchronized in 2003 and it consists of Burshtyn power plant, Kaluska combined heat and power plant and Tereblya-Rikska hydropower plant. The total installed capacities of the Byrshtyn island are 2.5 TWh, working capacities – 1.9 TWh (Ukrenergo 2010b). The island has connections with Hungary, Slovakia and Romania. It seems that new capacities for export to Europe will not be added soon (Naumenko 2009a).

Synchronizing IPS/UPS with European UCTE system is perceived as opportunity for Ukraine to increase electricity export (UES 2006). However, to benefit from this opportunity Ukraine needs well-functioning domestic market and elaborated national planning to find the balance between domestic energy security and export revenues (Zhahmann and Naumenko 2009). Ukraine also needs to upgrade transmission grids, invest in capacities and production of synchronized with UCTE utilities and keep in track EU regulations concerning electricity production. The last could become even more challenging than overcoming technical barriers. Countries within EU UCTE system are bound with obligations to minimize GHG emissions from electricity production. So far, Ukraine exports electricity to EU UCTE system, but is exempted from this obligations. However, in 2010 the country joined European Economic Community which means that now Ukraine also has obligations to adjust domestic electricity system to European standards. According to the estimates of national experts, financial inflows that are required to ensure implementation of new obligations could make European electricity market less attractive for Ukrainian export in the short-term perspective (Naumenko 2009a). However, this question will be examined more detailed further.

2.3 Key challenges

Ukraine has achieved significant progress in handling crisis in the electricity sector. In early 1990s electricity supply was quite unstable due to decrease in electricity consumption by industry, non-payments by final consumers, fuel shortage and fluctuations of fuel prices. The domestic market is much reliable now and excess capacities allow to export electricity surplus to the neighboring countries. However, if Ukraine is striving to develop secure system of electricity supply and strengthen position on the international market as country exporter, there are number of challenges to be addressed in the planning process. These challenges are presented in the above sections and this subsection gives a brief summary of main points.

The key topics for the future development of electricity system as they are presented in the literature review are:

1. Energy security and independence of the imported sources. The choice of primary energy sources is currently directed to minimize the use of imported gas. However, selection of sources

for energy mix has many uncertainties. Domestic coal as alternative fuel for the thermal power plants is of low quality, unprofitable in terms of mining operations and environmental unfriendly. On the other hand, decrease in domestic coal extraction could negatively affect development the mining regions in Dontesk basin, where economic and social life is closely bound to the mining industry. Nuclear energy has long-term traditions in Ukraine and significant potential. However, the use of nuclear energy as substitute for the gas is restricted by the issues of import of nuclear fuel, waste storage, nuclear safety and social acceptability of risk. Hydropower is widely used for the peak regulations, but does not have enough potential to stand for the major share in the electricity supply system. Moreover, large hydro is associated with the significant environmental pressure. Renewables at the moment is underdeveloped and require substantial financial investments.

2. High energy intensity. So far Ukraine has the highest indicator of energy intensity in Europe. Industry and households are two sectors that are responsible for the biggest shares of electricity consumption and high energy intensity. Both sectors have great potential to decrease electricity use by energy savings. In case of industrial electricity consumption, the major share in electricity use belongs to the export-oriented heavy industry. In fact, according to the preliminary estimates, without highly energy intense and export-oriented heavy industry, Ukraine has enough domestic resources to fuel the other sectors under certain conditions of technological improvements (Gochenour 2004).

3. Environmental impacts. Use of every energy resource for the electricity production is associated with the environmental pressure to higher or lower extent. Energy sector in general and fossil-based electricity generation in particular, made Ukraine one of the thirty biggest emitters of GHG (IEA 2006). Environmental management system is designed in the inefficient way (Solotka 2011). The costs of pollution are not completely compensated by the polluters. Environmental performance of the electricity sector is not accounted in the planning process. Environmental impacts are rather declaratively stated after the crucial decisions of system development are made.

4. Outdated electricity utilities, transition and distribution networks. The technical equipment in the majority cases is inefficient and lost its functionality as a consequence of its design and age. The total losses of the supply side from electricity generation utilities, transition and distribution networks could sum to 17% of the electricity produced (Ukrenergo 2011).

5. Low capacities for the peak regulations that results in electricity shut-offs (Gochenour 2004).

6. Failures in functioning of the WEM. The state intervention in the functioning of the market resulted in the poor pricing practices and cross-subsidizing, small investments in the renovation and system development (Diak 2001).

7. Electricity export and grid connections with the neighboring countries. Ukraine has excess capacities for the electricity production. Assuming the Ukrainian domestic electricity market is well-functioning and prices for Ukrainian customers are market-based, electricity export to the neighboring countries could be good long-term opportunity for the system development (IEA 2006). However, the technical synchronization of networks and adjustment of legislation should take place in order to export electricity to more attractive European market.

Currently Ukraine faces the need to review national Energy Strategy. So, which of the above listed challenges should be addressed at the first stage? What priorities should be put forward? What parameters should be accounted in the decision-making process for the future development of the electricity system? The future research is mainly focused on these questions.

2.4 Planning in the energy sector

The long and mid-term planning of the electricity system development is done within the overall planning for the energy sector. The results are reflected in the National Energy Strategy. Therefore, this section at first presents general approaches for planning in the energy sector and planning system. Further, it highlights legislative scope of the planning process. The section ends up with more detailed analysis of the plan for the electricity sector development within the Energy Strategy.

2.4.1 Traditions of planning and planning system

Planning was an important integral part of the Soviet-style economic system. After the changes in economic and political structure of the country in 1990s, planning remains part of the operational scope of the most governmental bodies. Strategic documents in the energy sector are usually facilitated by political process, but unfortunately, frequently remain declarative (IIIEE 2009). The logical framework of the planning process is presented in the Figure 2.7.

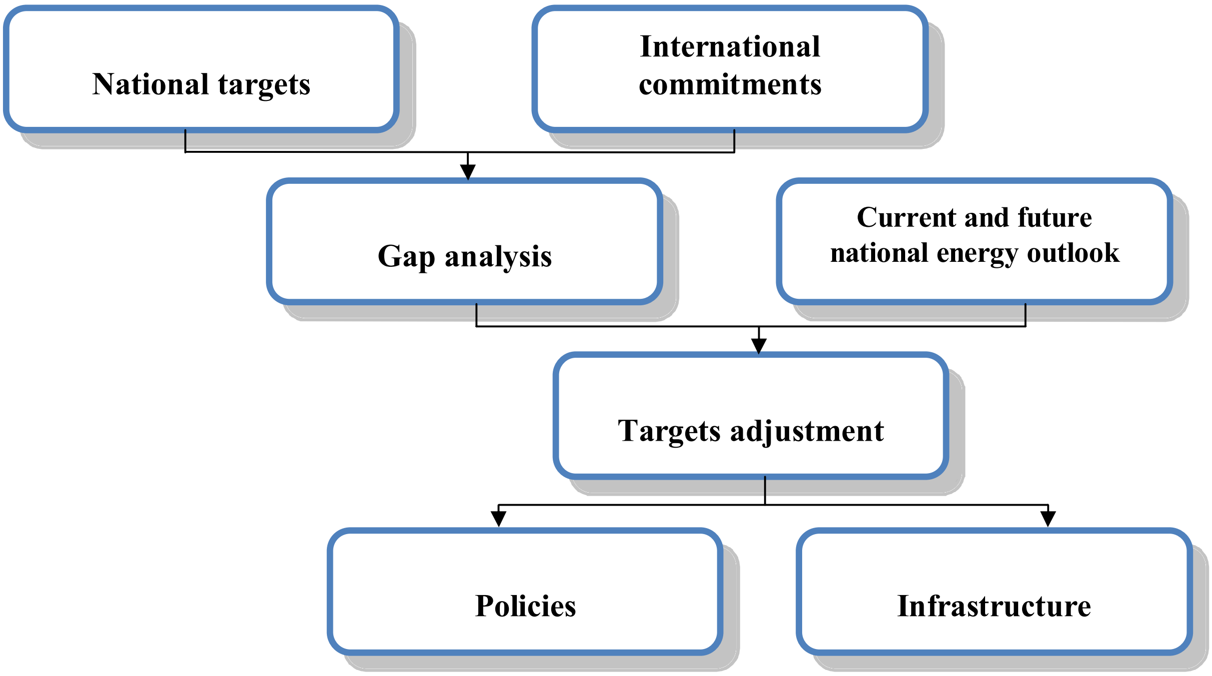

Fig. 2.7 Logical framework of the energy planning process (Adopted from Penglis 2010)

Strategic planning in the energy sector is traditionally handled by the Ministry of Fuel and Energy of Ukraine, with the assistance of the Ministry of Coal Industry (currently restructured) and Ministry of Economy, State Committee of Energy Supply, National Security and Defense Council, National Academy of Science and other energy market actors (IIIEE 2009). Theoretically, Ministry of Fuel and Energy, within the given background, develops strategic framework and prescribes concrete responsibilities to develop certain issues for its departments or research institutions. The results of the planning are presented in the Energy Strategy wich is guiding document for the development of the energy sector. After the round of consultations within the governmental bodies, the first draft should be released for the broader consultation with public. However, the common practice is exceptional participation of governmental and academia bodies, with no public discussion (Sheberstov 2004).

In April 2006 the government has adopted Energy Strategy of Ukraine for the period until 2030 (the Energy Strategy) and special action plan for it implementation (ESU 2006). The Energy Strategy does not prescribe concrete responsibilities or steps for the political or economic actors, but rather defines main goals and scope for the sectoral development. The implementation of the Strategy is regulated by the Plan of Action for the period 2006-2010 (Plan of Action). Not alike the Energy Strategy, Action Plan prescribes responsibilities and concrete actions for the number of actors like Ministry of Fuel and Energy, National Energy Companies Ukrenergo, Energoatom, Naftogaz, Ministry of Finance and Ministry of Coal, etc. The tasks range from strictly specifies assignments, such as amount of coal to be extracted, to wide conceptual responsibilities, e.g. development of market-based energy pricing scheme (IIIEE 2006).

Ukrainian electricity sector and its environmental profile apart from the Energy Strategy, is also guided by the State Programme of Energy Efficiency, programmes of energy conservation and efficiency that are developed by different Ministries (EBRD 2005). The regional and a number of sectoral complex programmes of energy conservation (also referred as Complex programmes of energy conservation and energy efficiency) include: Complex Programme of the Ministry of Industrial Policy that was adopted in 1997 and implemented up to 2010, Programme of Ministry of Fuel and Energy (1996-2010), Programme of the Ministry of the Coal Industry (currently is restructured), Programme of the Ministry of Housing, Programme of the Ministry of Agriculture. Unfortunately, these documents have declarative character (Ermilov 2011). Recently, the Ministry of Environmental Protection announced development of the first Ukrainian Plan for the adaptation to the climate change that could also be seen as a step to more deliberate commitments to improve environmental performance of the energy sector. However, the actual development of the plan is only on the initial phase (Ermilov 2011).

There are also a number of alternative energy strategies and suggestions, developed by the non-governmental and research organizations after they were excluded from the decision-making process on energy issues. Many of them contain analysis and critic of the Energy Strategy as well as suggestions of alternative development pathway. Within this literature overview the main attention is given to the Energy Strategy as the guiding governmental document, with the minor attention to the alternative strategy conjointly developed by such non-governmental organizations as MAMA-86, NECU, Ecoclub and otherls. Taking into account more specific thematic focus of additional programmes and their declarative character, they are not addressed here.

2.4.2 National goals and strategic features

The guiding notion for the development of the strategic document is ensuring national energy security as it was discussed earlier. However, the Energy Strategy declares five main strategic goals in addition to energy security: (ESU 2006):

- To create favorable conditions for the continuous and high-quality supply of the of the energy sources;

- To develop pathways and create conditions for the safe, reliable and sustainable performance of the energy sector and its development in the most effective way;
- To ensure energy security of the country;
- To decrease environmental pressure and provide public protection in the sphere of technogenic safety;
- To reduce energy losses in energy production and use through energy efficiency improvements, introduction of energy saving technologies and equipment, rationalization of public production structure and decrease of the share of energy intense technologies;
- To integrate United Power System of Ukraine with the European system and gradually increase energy export, strengthen position of Ukraine as transit country for gas and oil.

Theoretically, the Energy Strategy as the guiding document should address such issues as energy security, economic welfare, social development and environmental protection. However, not all of these issues are addressed in term of practical applications. The Energy Strategy pays much attention to the national energy security as the one of the top priorities of the strategy. The key threads for the energy security of the country are defined as high energy intensity, high dependence on the single importer's oil and gas, and significant environmental impacts. The economic welfare is also one of the strong attention.

The two other components – social development and environmental protection are neither formally pronounced nor adequately spelled (Ermilov 2011, IIIEE 2009, MAMA-89 2006). The analysis of the employers, labour forces and industry-specific analysis of the social transformation is not done, which could be valuable for example, for coal industry, where changes in the energy sector could lead to the social transformations. The Energy Staretegy also ignores social component in the discussion of the pricing and issues of energy affordability. The price setting is done without the references to the incomes of population. Environmental component is also addressed properly (IIIEE 2009, MAMA-86 2006). Nevertheless decrease of environmental impacts of the energy sector is considered as one of the priorities, the associated formal objectives are not stated, the quantitative indicators to monitor environmental performance are absent.

2.4.3 Legal scope, national and international commitments

The planning in the energy sector and is done with the references to national and international legal acts. The main Ukrainian laws that regulate energy issues are: Law on electricity, Law on the use of nuclear energy and radiation safety, Law on heat supply, Law on alternative sources of energy, Law on energy conservation, Law on environmental protection, Law on operation of fuel and energy complex, Law on oil and gas. Ukraine has also international commitments related to the energy sector. Ukraine collaborates with the European Union and its Eastern neighbors(IIIEE 2006). Ukraine is a party of the Energy Charter Protocol on energy efficiency and Related Environmental Aspects (PEEREAE), which is signed in addition to Energy Charter Treaty. It puts responsibilities on the signatories to develop energy efficiency strategies, establish appropriate regulatory frameworks, develop programmes to reduce environmental impacts by the energy sector and promote efficient use of energy (PEERA 2004). Since 2011 Ukraine has been a party of the European Energy Community which also puts requirements for the performance of energy sector. These requirements concern emissions from the energy sector, renewables and biofuels (for the complete list of EU Declarations to be adopted see Annex B) (Protocol Concerning Accession of Ukraine to the Treaty Establishing the Energy Community 2010). Ukraine is also a signatory of the Framework Convention on Climate Change and Kyoto Protocol. Within the Kyoto Protocol schemes Ukraine is cooperating with the quota buyers. In addition to that Ukraine is a part of the Convention on Long-range Transboundary Air Pollution and Montreal Protocol. Therefore, the international commitments could catalyze development and implementation of new approaches to the planning practices.

2.4.4 Development of the electricity sector within the Energy Strategy

The Energy Strategy (2006) is the main strategic document that determines development of the energy sector and its separate components, including electricity system. It contains projections on electricity supply and demand trends, changes in capacities and load factor of the electricity utilities, need for primary sources, etc. up till 2030. The energy Strategy covers the period 2006-2030 years.

According to the energy Strategy (2006) the total electricity required is expected to grow significantly. The strategy expects 123% rise in electricity consumption by year 2030 compared to 2005. In 2005 there was consumed 176 TWh of electricity, in 2030 the consumption is estimated to be on the level of 395 TWh level. Industrial and household sectors are expected to remain the leaders in electricity consumption. The growth of industrial consumption is estimated at the level of 2.4% annually so that in 2030 industrial enterprises will consume 169.8 TWh. The households' consumption is expected to rise to the level of 41.7 TWh per annum in 2030. The network losses are projected to be 32 TWh per annum in 2030. However, these losses account for 8.2% of total amount electricity produced, which is lower than current loss factor.

The Strategy is oriented on the nuclear and fossil fuels to fuel electricity production. The installed capacities are going to be increased to 88.5 GW by 2030 compared to current 53.1 GW. The increase should mainly touch NPPs. The total production is planned to be 420 TWh in 2030. Overall, the distribution of electricity production in 2030 is planned to be as follows: 47% of electricity will be produced by TPPs and CHPs, 33% by NPPs, 12% by hydro power plants, rest by renewables. The demand in fossil fuels is going to be 69.8 million toe among which 85.1% - in coal, 14.5% - in gas and 0.4% - in crude oil.

The Energy Strategy also emphasizes the use technological and structural potential to promote energy conservation. Technological potential includes the wide range of improvements: introduction of new energy efficiency technologies in industrial sector, decrease of energy losses, , improvement of the monitoring systems, use of secondary energy sources, renovation of utilities. The structural potential is focused on reorientation of economy from industrial to less energy-intense sectors like transportation and services. However, the declarative character of these statements was raised by the number of experts (IIIEE 2009, MAMA-86 2006, Naumenko 2009b)

The Energy Strategy was widely criticized by research and non-governmental institutions. The critic was based on overestimations of the economic growth, prognosis of significant consumption of primary and final energy, orientation towards nuclear energy, reliance on domestic coal, poor emphasis on energy efficiency improvements and alternative sources of energy. In 2006 several non-governmental organizations jointly presented alternative strategy of the sector "Concept of the non-nuclear path for the development of Ukrainian energy system" (MAMA-86 2006). The milestone of this alternative strategy is corrected estimations of the energy need. The energy need is estimated to be 285.5 million of toe for the whole sector compared to 341 million toe estimated in the Energy Strategy. Moreover, alternative strategy favors renewable sources. It proposes to decrease the share of nuclear, coal and hydro energy sources, so that in 2030 46.5% of energy will be produced by renewables, 34.4% based on coal combustion, 33.5% - on gas, 2.1 % - by hydro power plants and only 0.7%by NPPs (MAMA-86 2006).

Due to the number of inconsistencies and biases in estimations, Ukrainian Energy Strategy is currently under revision. The Ministry of Fuel and Energy is responsible for the correction of the Energy Strategy according to the real indicators of GDP growth, pricing tendencies on the world energy markets, energy consumption patterns, potential of renewable energy sources, latest technological improvements, European standards and experience on the restructuring of energy complexes, and also Ukrainian obligations connected to the accession to European Energy Community (Ukrainska Energetyka 2011). However, due to untransparent system of revision, it is unclear how the final version will look like.

CHPTER 3. RESEARCH DESIGN AND METHODOLODY

This chapter provides guidelines on the research deign and methodology. Firstly, scope of the research is presented. Secondly, the overview of the research design is given. Thirdly, justification and description of selected methods is presented. Finally, the chapter points out main limitation of the work.

3.1 Scope of the research

As it was presented in the literature review, the main considerations that traditionally are taken into account in Ukrainian electricity sector planning are economic efficiency and availability of supply. In fact, economic and political determinants guide the selection of the different primary energy sources. This is a result of past policy practices where decisions were made without embedding environmental considerations into the planning process. However, if the society is aiming towards sustainable performance, the planning basis should be reconsidered; environmental impacts related to the use of different primary resources should be accounted in planning and reflected in national energy supply strategies. Once embedded in the middle and long-term planning, environmental considerations could change the direction of energy sector development. So far, scenarios development and analysis is considered to be one of the most widespread planning tools. Therefore, this research aims to investigate possible scenario for the development of electricity supply system of Ukraine that account for economic affordability, availability and also the mitigation of environmental impacts.

3.2 Research design

Scenarios development for the electricity sector is conducted in accordance with the Guidelines for the Scenario Development and Analysis of the Global Environmental Outlook Assessment Manual (UNEP 2007), with the references to the methodologies applied in the World Energy Outlook developed by IEA (2010a), Global Energy Scenarios by World Energy Council (2007) and Emission Scenarios by IPCC (2004). Scenarios development is made with the combination of qualitative and quantitative approaches. The scenarios development is done through four stages within the framework presented on the Figure 3.1 (with references to the steps from WEC methodology). On the fifth stage of the research policy analysis is conducted.

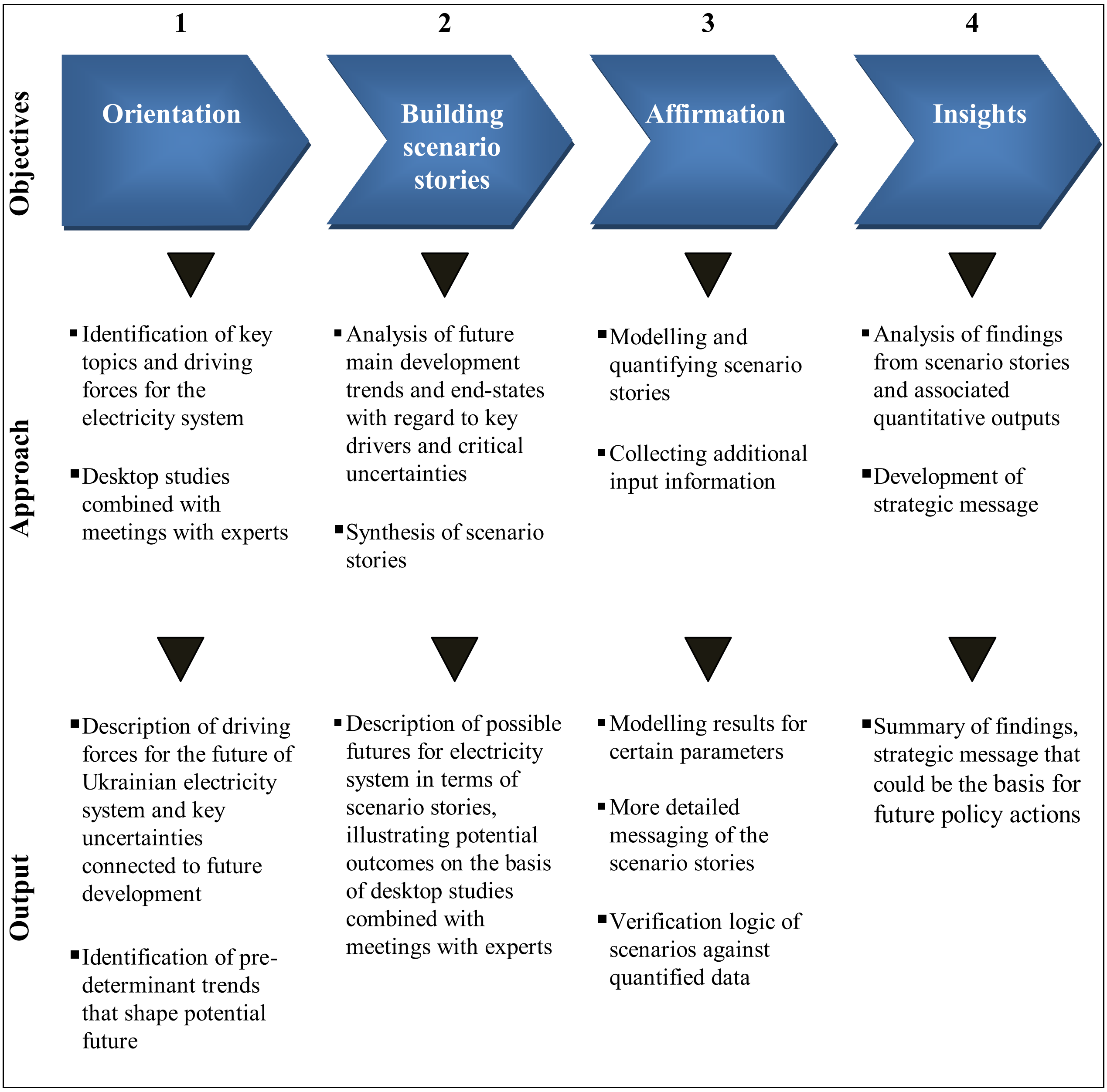

Fig. 3.1 Approach to scenario development applied within the research (on the basis of WEC methodology, WEC 2010)

In the first stage the key topics and main determinants for the sectoral development are defined: parameters that are crucial in the electricity sector planning process, stakeholders and their expectations, main uncertainties. The work is done on the basis of the literature overview and expertise of the expert opinions.

In the second stage of the research descriptive scenarios of the sector performance (scenario stories) are developed, which presented main trends of possible development. Scenario stories are developed on the basis of key drivers and crucial uncertainties surrounding the sector. There performance associated with business-as-usual (BAU) and alternative scenarios is also defined. The work is done on the basis of the literature review and interview expertise.

At the third stage of the work the quantitative model of Ukrainian electricity system is constructed. The model simulates performance of the sector associated with different scenario stories. The demand and supply patterns are calculated on the basis of such inputs as economic growth, technological developments, rate of implementation of developments, resource availability and policies direction.

In the fourth stage of the research scenario stories and associated quantitative outcomes are examined regarding their correspondence to national goals, economic affordability of proposed pathway. Indicators for the scenario comparison are described in the next subsections. On the basis of analysis of scenario stories and quantitative outputs strategic message for future action are developed.

The fifth stage of the research is focused on the policies and actions associated with the strategic message. Such groups of policies are examined: command and control, market, information and research and development. Policies are reviewed concerning their potential and limitations within the national context.

3.3 Methods and tools

3.3.1 Literature review

The research is made with the combination of qualitative and quantitative methods. The first stage of data collection involves broad literature review of planning practices in the energy sector, international experience, model development guidelines as well as overall performance of Ukrainian electricity sector. This is done through official Internet sources like web pages of International Energy Agency, United Nation Environmental Programme, U.S. energy Information Administration. Ukrainian national online sources, such as web page of the Ministry of Fuel and Energy, National Commission on Energy Efficiency and Energy Savings, National Energy Company of Ukraine, were consulted to obtain specific information on Ukrainian case. Many relevant official and unofficial documents have been collected in libraries, archive or through personnel communication. The data, which is obtained from the literature review, is partially validated and complemented through meetings with the experts.

Interviews with experts in combination with literature review together with the literature overview create the basis for the descriptive scenario development and quantitative model. On the basis of literature review the main trends in electricity sector development, parameters that were taken into account in the planning process, key challenges of the sector, main stakeholders are determined. The information from the literature is also widely used for the quantitative model development and scenario inputs, as well as for the policy analysis. The main types of document that are used for the data collection, scenario development and policy analysis are: official strategies and reports of the governmental bodies, position papers of national and international non-governmental organizations, reports of projects of technical assistance, research articles.

3.3.2 Interviews

Literature review is followed and complemented by face-to-face communication with the indentified stakeholders. One of the basic assumptions of the interviewing research is that it provides opportunities to look at the institution or process through the experience of the individuals, their perceptions, work and lives that make up organization or carry out the process (Strauss and Corbin 1998). Therefore, in addition to literature overview, interviewing is chosen to investigate insights of stakeholders' positions and on ground situation in the electricity market.

In-depth interviews are carried through open-ended questions and shaped as informal open discussions. They are aimed at collecting information on performance of the sector, its challenges, barriers, trends, perspectives and policies as well as indentifying more stakeholders. The discussion is generally tailored to the interviewee's background, specialization, involvement in the electricity sector planning and decision-making process and experience. Therefore, semi-structured format of interviews is chosen, however draft interview outline with preliminary questions was prepared (see Annex C). At some point during the discussion interviewees has been invited to illustrate general trends in primary energy resource use for the future, evaluate relevant importance of different energy sources in comparison to each other for the energy supply system for selected timeline, develop the most probable scenario, the most sustainable favorable scenario (if different) and the most unfavorable one. On the basis of the collected data from interviews and literature review qualitative scenarios are developed. On the later stages, the quantitative data collected from the experts provided the basis for the calculation of shares of primary resources within different scenarios.

The selection of the interviewees is made in accordance with the research needs, however equal representation of stakeholders in the field is kept. There are scoped four main stakeholders on the basis of their different roles, interests, capacities, contributions, potential to overcome and bare risks within the policy-making in the electricity sector (Post *et al* 2002). These stakeholders are: government, international experts, business, non-governmental and research institutions. However, the people selection is sometimes limited by their accessibility, availability and time constrains.

In total, the ideas and positions of thirteen experts are analyzed. Among them there are completed ten unofficial interviews with the experts from governmental bodies (ministries and subordinate institutions), private companies, and international organizations, non-governmental and academia institutions. These are complemented by the official statements and comments from closed discussions within energy forum. In many cases, the interviees have asked for unofficial interview and certain degree of anonymity. Therefore, a unified approach of referring to organizations rather than concrete specialists is applied. The list of organizations that are analyzed within each stakeholder group and sources of information is given in the Annex D.

Interviees have provided information on: historical trends of sectoral development and reasons that were spinning these trends; positions and expectations of different stakeholder groups toward the market development; perception of key challenges and ways to overcome them; predictions towards future trends of resource use expressed in quantitative data, insights in the actually work of certain policy instruments and barriers to their implementation.

On the basis of interviews and literature review the descriptive scenarios are developed. They determined the directions (trends) of possible sector development for the set of the most crucial and uncertain parameters. From the literature review and interviews these parameters are defined to be energy efficiency and orientation of long-term policy direction (low carbon electricity sector vs fossil-dependent electricity sector). Scenarios are formulated in four scenario stories. The timeline is chosen 2010-2030 in accordance with the current planning practices in Ukraine to ensure proper comparison with real performance. Within the descriptive scenarios the main trends that are associated with business as usual (BAU or reference) scenario and alternative scenarios are defined. BAU scenario is elaborated on the basis of historical trends and priorities of the main stakeholders concerning the future sector development. The outcome of each descriptive scenario for the market was examined with the help of quantitative model.

3.3.3 Model development

The quantitative model of Ukrainian electricity system is developed within the research in order explore the outcomes of scenarios in terms of demand patterns. The quantitative model is developed in addition to qualitative scenarios because the latest could not provide numerical information of sector development, which in many cases is crucial for decision-making process. The model is developed on the basis of Stella 6.0 software and consists of three layers: equations, visual representation of equations and user-friendly interface. Consumption patterns for each scenario were simulated on the basis of the model. Simplified version of main blocks is given in the Annex E.

The model consists of three main blocks: production, consumption and export/import. Production block simulates production patterns based on existing capacities for generating electricity from different primary sources: thermal power plants, combined heat and power, nuclear plants, hydro, renewable) and rate of increase or decrease of load factor for each utility type. These rates could be established manually. Consumption block simulates consumption patterns for two sectors that have the largest shares in energy consumption: households and industry. For the rest sectors it is assumed that the rate of change remains stable. Households and industry consumption are estimated as function of baseline electricity consumption, electricity efficiency (variables used: efficiency of electricity use for households, electricity intensity for industry), rate of growth for industrial and household sector. Export and import block estimates changes in the amount of electricity available for export as a function of domestic electricity demand and production. If domestic supply is not sufficient to cover domestic demand, the model evaluates amount of electricity to be imported.

The model simulates changes in the consumption of electricity depending on variation of the key parameters affecting the system as it was discussed above: energy efficiency improvements (high energy intense development vs low energy intense development) and choice of long-term policies for electricity sector (direction towards low carbon vs fossil-dependent development). The Energy Strategy (2006) and historical trends provide input data for the BAU scenario. For the alternative scenarios input data is obtained through interviews (like potential for energy efficiency improvements and load factor for electricity utilities as function of long-term policy directions).

The modal has number of assumptions and limitations. The baseline data is taken from International Energy Agency Electricity (2008) and Heat Data for Ukraine and presented. The baseline economic growth is set at 4.5% GDP per annum, according to the projections of Ukrainian Ministry of Economy. The approximate number of households is fifteen billion with the average consumption of electricity of 3900 kWh per annum (UNSC 2010). In the model industrial growth is expressed as a share of GDP growth which could result in some deviation from the real rate of industrial growth. The model neglects financial parameters, such as market price of different resources which is considered to be important determinant for the scenario analysis. However, this could be done the later stages.

3.3.4 Scenarios comparison

The outcomes of scenarios are compared within the theoretical framework proposed by World Energy Council (2007) in the analysis of the world energy policy scenarios. This theoretical framework is based on the analysis of energy accessibility, affordability, availability and acceptability, which are considered to cover main sustainability objectives. Accessibility is related to the issues of geographical access and presence of production, transmission and distribution networks. Affordability relates to economic affordability of the electricity use. Availability refers to the continuity of supply and reliability of services. Finally, acceptability addresses social and environmental acceptance and covers such issues as degradation, pollution, nuclear security and safety, waste management, prioritizing industrial, social or economic benefits in the decision-making process.

The WEC (2007) theoretical framework is closely related to the notion of energy security, the goal put forward by European as well as Ukrainian energy strategies. The energy security is defined as continuous access to economic affordable sources of energy that meet criteria of stability, environmental safety and social security (Diak 2001). Therefore, the chosen framework allowed evaluating each scenario concerning sustainability orientation and connection to European leading energy trends.

The concrete key indicators for the scenarios comparison are chosen following WEC methodology (2007), however with minor modification to the specific regional conditions. This research applied the following key indicators to the analysis of scenarios:

- Electricity required, total and for two sectors that are main consumers (industry and households),
- Energy mix and resource availability,
- Energy intensity,
- Carbon dioxide emissions,
- Electricity affordability.

Electricity required describes the total electricity needed to be supplied to satisfy domestic demand (total electricity required) or certain sector (sectoral electricity required). Indicator is measured in TWh. Primary electricity required is top indicator of economy's energy scene that is driven by socio-economic factors and technological changes. Electricity required was estimated through the Stella model for each scenario.

Energy mix describes the balance of primary electricity sources in country's portfolio and therefore measures diversity and security of the supply side. The indicator assumes that energy security is improving with the increase of range of energy sources, either in terms of number of energy carriers and value of their shares, or the sources of primary carriers (e.g. securing gas imports from the diverse countries rather than one). Energy mix was estimated on the basis of the graphic illustration of trends and numerical estimations by experts for each scenario in the Microsoft Office Excel.

Energy intensity is measured as energy required to produce a unit of economic outcome (e.g. dollar of GDP). The reductions in energy intensity are a sign that energy convention, distribution and end-use become more efficient.

Carbon dioxide emissions indicator refers to environmental component and indicates pressure on the regional and global level. Carbon dioxide emissions are measured in tonnes according to the methodology described in the IPCC Guidelines for National Greenhouse Gas Emissions (2006) for the energy sector and is linked to the total electricity required, energy mix and electricity intensity. Emissions were calculated on the basis of formula:

$$Emissions_{co2} = \sum_i FC_i \times NCV_i \times EF_{CO2\,i}; (1)$$

where $Emissions_{CO2}$ – carbon dioxide emissions,

FC_i – amount of fuel type *i* consumed during the period,

NCV_i – net calorific value (energy content) of fuel type *i*,

$EF_{CO2\,i}$ – CO2 emission factor of fuel type *i*.

Amount of fuel consumed by type during the period for each scenario is estimated on the basis of projections for the electricity production and available electricity utilities. Net calorific values and carbon emission factors for different fuel types are taken from estimations of the values for Ukraine from the National Inventory Report for the Greenhouse Gas Emissions (2008). For hydro, nuclear and renewable sources, emission factors are taken from the estimations of carbon footprint of electricity generation made by UK Parliamentary office of Science and Technology (2006).

Electricity affordability measures the affordability of electricity depending on supply-demand patterns, capacities, resource availability and export dependency.

The study fails to account for some social indicators, like fluctuations of the labour forces within electricity market is one of the social indicators or risks analysis giving the lack of studies in the area and time constrains of the research.

3.3.5 Policy analysis

In order to bring the changes into the real performance, scenarios should also account for possible policy mechanisms that enforce key message. Therefore, analysis of policy mechanisms associated with strategic message is done. Four main groups of policy mechanisms are investigated: command and control, market, information and research and development. For each group an overview within the national context on the basis of legislation, analysis of barriers that the policy could overcome and limitations of the policy in action is made. The choice of instruments is made on the basis of literature review and interviews. A short description of each group is given below.

Command and control instruments (CAC or regulatory instruments) are limitations, standards or requirements for performance that are legally set. Theoretically CAC instruments could be divided into two classes: technology standards and performance standards (Metz 2009). Technological standards set limitations or minimum required level of technologies that should be used within the sector. On contrary, performance standards regulate desirable or minimum requirements for performance without specification of the way this performance could be reached. Both classes were analyzed within the research.

Market or economic instruments regulate performance of economic entity by providing economic incentives for certain performance on the market. Within the work such market instruments as taxes and fees, subsidies, tradable permits and grants are analyzed.

Information instruments involve public disclosure of information related to performance of the electricity sector. Information instruments cover the issues of public discussion and involvement in transparent decision-making process, information release, labeling and certification which is discussed in more detail in results section.

Research and development mainly involves funding and focusing research on the specific issues. Research and development mechanism could be applied for different institutions: research, academia, non-governmental or private.

3.4 Limitations of the research

The research has a number of limitations in terms of research design, assumptions and data availability. Firstly, the scenario analysis is done without the comprehensive financial analysis that is in many ways determinant for the future development of the sector. Investment analysis of different options is not included in the research design. This is explained by the fact that financial analysis could be done at the later stages. It also requires specific insights into the micro and macro economy that exceed the framework of this research.

Moreover, the research is based on the assumptions of stable economic development of Ukraine, which is prognosed by Ukrainian state bodies for the next decade. However, despite the prognosis of stability, financial crises are happened to take place (like crises of 2008-2009 in Ukraine). Moreover, the research assumes that the GDP structure would remain relatively stable and no rapid change in sectoral shares of GDP would take place. The government of Ukraine widely proclaimed necessity of reorientation of economy from energy-consuming industrial sectors to less energy-intense service sectors. However, mining and processing industry accounted for more than 20% of GDP in 2001-2010 years and the major transformations in the economy is likely to take time. Therefore, assumption of economy structure could be accepted within the research.

The research applies carbon dioxide emissions as the indicator of environmental performance, leaving other numerical indicators, for example waste water produced per unit of electricity output or land degradation, outside the research framework. As the result, hydro and nuclear sources could have much better indicators of environmental performance than expected. Carbon dioxide emissions are taken as indicator, firstly, because methodologies for the calculation of carbon dioxide emissions from electricity sector are well developed and widely used on the national and international scale. Secondly, there are accumulated significant databases on carbon dioxide emissions associated with different primary sources which allows researcher to make the comparisons of the sectoral performance. Thirdly, almost no systematic information in time and measures is available from national official sources concerning pressure of electricity sector other than emissions. As far as this is an illustrative model, carbon dioxide emissions as the only indicator of environmental performance of the sector is applied.

The research is restricted to several social indicators for scenario analysis and leaves some of them, like poverty reduction, behind the scope of research. This is explained by time and resources constrains of the study. Finally, as it has been found during research and stressed by experts in the field, that electricity sector performance is in many ways is bound to the political climate in the country. In Ukraine this connection was defined as strong one. However, analysis of political situation was left outside the scope of the research, which in some ways limited scenario development and policy analysis presented in the results section.

As many researches in the electricity sector, this research is limited by the number of limitations and constrains. However, this work is not a comprehensive scoping platform for the desission-making on the national level, but rather an illustrative model of one of the possible ways in with economic, social and environmental considerations could be accounted on the way to the stable, secure and acceptable electricity system.

CHAPTER 4 SCENARIO DEVELOPMENT: PEAK INTO THE FUTURE

This chapter is focused on the main results of the study and their discussion. At first, the identification of key topics and driving forces surrounding the electricity sector is presented. Secondly, the formulation and description of the main development pathways, or scenario stories, for the Ukrainian electricity sector with regard to identified key drivers are given. Thirdly, the quantification of scenario stories and the examination of their potential to shape the development of the sector were made. Finally, the analysis of findings from scenario stories, formulation of key message and policy analysis are introduced.

4.1 Orientation: potential directions for the electricity system development

The aim of this section is to define the main directions for the development of scenario stories. This was done through the evaluation of the statements of different stakeholders concerning the current state of the electricity market, main challenges, expectations and barriers to the sector development. The section is focused on stakeholders such as international experts, national government, business, research and non-governmental organizations. List of the stakeholders that are analyzed and sources of their statements are given in Annex D. Main notions that are raised by stakeholders were examined towards and supported by specific facts from market performance. Such analysis enables to map the positions of stakeholders and the complexity of their interactions within the market, determine common or conflicting interests of crucial players that spin market performance and detect barriers for sustainable electricity market. The section results in the identification of the predominant trends.

The analysis of interviews and official statements indicates that there are several common concerns about overall electricity system development. Stakeholders tend to prioritize two key determinants for the development of the electricity system: the rate of energy efficiency improvements, which determines future domestic demand, and the structure of primary energy carriers of the future supply. There were also mentioned a number of organizational issues (pricing, ownership, organization structure of market, legal issues and outlook for the governmental support and leadership) that directly or indirectly affect these two determinants. The summary of the key issues to be addressed in the development of the electricity system, which were raised by different stakeholders, is given in the Table 4.1.

Table 4.1 Results of the analysis of the stakeholders' priorities for the mid-term development of Ukrainian electricity system

Stakeholders	Priorities to be addressed
Governmental institutions	- National energy security, use of domestic sources, diversification of primary energy carriers; - Energy efficiency and energy savings; - Reviewing the model of electricity market; - Reviewing tariff system, elimination of cross-subsidizing
International experts	- Strategic leadership of government; - Increase of energy efficiency and energy savings; - Adjustment of legislation to the European standards, implementation of taken liabilities according to international agreements; - Development of alternative sources; - Reviewing tariff system in order to embed all initial costs including investment costs
Business (national enterprises and international investors)	- Improve national investment climate to ensure continues of investment guarantees and cash flow for the energy efficiency and savings, alternative sources projects (implies revision of pricing system); - Liberalization and transparency of market operations; - Improvement of market administrations and bureaucratic procedures
Research and non-governmental institutions	- Energy efficiency and energy savings; - Development of alternative energy sources; - Incorporation of environmental and social components in the energy planning; - Openness of discussions and recognition of the civil society position in the decision-making process; - Strategic leadership of government.

Generally, representative of governmental institutions indicated national energy security as the mainstreaming priority for the present and future development of the electricity system, however leaving environmental considerations beyond security notion. Energy efficiency, energy savings and review of the market model (including ownership and pricing system) are also in the high priorities for governmental bodies. International experts tend to emphasize the respective importance of energy efficiency and savings. They are also interested in the development of alternative sources as the opportunity to minimize environmental impacts. Moreover, international specialists pay a lot of attention to the issues of legal liabilities, especially connected to the Ukrainian accession to the European Energy Community. National, as well as international businesses are more concerned about the internal political, legal and economic climate that determines investment guarantees. Their position implies that under the condition of secured investments the business will provide finances for the introduction of energy saving technologies, because these will decrease initial production costs and/or allow conquering new market niches. Finally, non-governmental and research institutions tend prioritize environmental and economic considerations and stress upon the necessity of rapid development of renewables.

Further, the detailed analysis is given of the main issues perceived by stakeholders as key topics that determine the future of Ukrainian electricity system which are: national energy security and choice of primary energy sources, energy efficiency and transformation of electricity market (that includes changes in pricing system, privatization, transparency issues and adjustment of legislation).

4.1.1 National energy security and choice of primary energy resources

The analysis of the interviews shows that the dominant priority of the government is energy security, which means orientation on domestic energy carriers and increase in diversification of primary sources (NCFF pers. comm., MFE 2011, NAEEEC 2011). According to the governmental position, energy security is seen as stable, continuous accessibility and use of the energy sources and transformation facilities that are affordable. The definition of energy security that is proposed by governmental representative I have compared with the definitions from the literature. Interestingly, that the first lacks references to environmental issues in contrast to European practices where environmental component is considered to be integrated and inseparable component of energy security. For example, according to the International Energy Agency, energy security is defined as “the uninterrupted physical availability of energy at a price which is affordable, while respecting environment concerns” (IEA 2010b). Therefore, energy security could be perceived as the much broader priority, where the use of primary energy sources should meet requirements of physical availability and accessibility, economic affordability and social and environmental acceptability. Therefore, currently the national goal of energy security is restricted to the search of affordable sources for stable, continuous supply.

The choice between different primary sources is defined as the key diver for the future development of electricity system that is associated with the critical uncertainties (Bureau Veritas pers. comm., IERPC 2011, MFE 2011, NCFF 2011, KT-Energy 2011, NECU 2011, NAS 2011). The Ukrainian electricity supply system is traditionally characterized by the high shares of fossil fuels, like gas and coal, and nuclear energy. Orientation towards nuclear energy is characterized by operational risks and dependence on other countries for the import of nuclear fuel (this issue is discussed in detail in the second chapter). The further orientation on coal and gas is also associated with some uncertainties. At the time of the adoption of the National Energy Strategy, the dependence of imported gas was recognized as one of the main threads for the Ukrainian electricity market (NCFF pers. comm.). Therefore, it was decided to reorient supply system from imported gas to domestically produced coal. It was planned to increase the share of coal in the structure of energy sources for TPPs and CHPs from 51,8% in 2005 to 85,1% in 2030. Nowadays, the Energy Strategy is under revision and security issues (without the environmental component) remain in the vanguard for the planning process. It is widely discussed the opportunity to use domestically produced shale gas as alternative to imported gas or domestic coal (NAS pers. comm., KT-Energy pers. comm.). The roots of the idea to substitute domestic coal to shale gas lie in low quality of Ukrainian coal and mainly unprofitable mining operations that require substantial budget financing. In fact, not environmental considerations about more severe damage from coal combustion than those of gas, but economic interests dictate retrieval of new solutions.

Renewables could be the substitute for nuclear energy and fossil fuels. Development of renewable sources is perceived as the necessary component for the stable evolution of the electricity supply system by all of the stakeholders taking into account the potential for their development in Ukraine. The increase in the shares of renewable is expected to take place, especially wind power plants (NECU pers. comm.), biogas and solar utilities (NECU pers. comm., NAS pers. comm.). However, generally, stakeholders state that the share of alternative sources in the overall supply system is much dependent on the governmental leadership (KT-Energy pers. comm., NECU pers. comm.).

Even though the renewable could account for significant share in primary energy mix, there are serious barriers for their development. Representatives of business, the stakeholder that could facilitate the development of alternative sources, state that the most serious barriers for the development of alternative sources are: lack of governmental support programmes and investment-unfriendly regulations. The lack of governmental support determines problems with energy investment market where the payback is long and quite unstable (CEET pers. comm., KT-Energy pers. comm., EBRD in Ukraine 2011). Brian Best, managing director for investment banking of Dragon Capital, statesd that their business could not support projects on alternative energy sources because they could hardly find projects with the suitable pay-back period and stable cash-flow guarantees within the Ukrainian market system (EUEA 2011).

The investment-unfriendly climate also includes the absence of clear legislative regulations on specific types of utilities, for example biogas plants, and the requirements for "green tariff" projects like project validation procedures and "local component" (Bureau Veritas pers. comm., CEET pers. comm., KT-Energy pers. comm.). The regulations securing green tariffs for the electricity produced from the alternative sources are presented in the Law on electricity. A serious concern for business is the administration of green tariff (or feed-in tariffs in English terminology), especially the validation of green tariff only after the project implementation, but not on the planning stage. Endi Kusich, director of business development of PriceWaterhouseCoopers in Ukraine, stated that the fact that green tariff is approved only after the utilities are being built is deterring many potential investors (EUEA 2011). Investors want to secure higher green tariffs for the projects and therefore receive guarantees for payback on the planning stage before putting finances into building.

The Law on electricity also regulates so-called "local component" of the projects for electricity production from alternative sources. According to the "local component" regulation, the green tariff could be applied only for projects that use 15% of local products for their performance for the period until 2012, not less than 30% of local products for the period until 2030 and not less than 50% for the period until 2014. According to business representatives this regulation limits business performance and fails to stimulate the increase in the shares of alternative sources (KT-Energy pers. comm., EUEA 2011).

The reasons why these barriers exist could be explained by the fact that governmental representatives see alternative sources as the expensive opportunity to diversify primary sources for electricity supply (EUEA 2011). On contrary, international experts and representatives of national research and non-governmental institutions underline importance of alternative sources as substitutes to traditional fossil fuels and nuclear energy (ECS 2011, NECU pers. comm., NAS pers. comm.). The latter position also brings environmental benefits on the scene and increases the value of alternative sources for stable development. So, the question of choice between different primary resources is put on the first place.

4.1.2 Energy efficiency

The other priority issues is energy efficiency. Energy efficiency and conservation are recognized as urgent topics by all stakeholders without exceptions. However, the reasons that lead to the recognition of these matters as the necessity for market development are different for the analyzed stakeholders. Business sees energy efficiency and conservation as opportunity to reduce production costs or potential for new business the development (CEET pers. comm., KT-Energy pers. comm.). For the government prioritizing energy efficiency and savings mean security and decrease of electricity consumption (MFE 2011), the minimization of expenditures for operation of state utilities (MFE 2011, NAEEEC 2011), the economic use of deposits and more stable positions in finding balance between imposts-exports on the international energy market (EUEA 2011). International experts also perceive energy efficiency and conservation as the potential to stabilize national electricity demand. However, international experts also emphasis environmental benefits from the improvement energy profiles of industrial enterprises and households, e.g. reduction of green house gas emissions (EBRD in Ukraine 2011, ECS 2011). Non-governmental and research institutions, on the contrary, put environmental benefits on the top place (NAS pers. comm., NECU pers. comm., EUEA 2011). They tend to point out that within middle and long term perspectives it is more beneficial for the country to improve energy efficiency and conservation than later to bare direct and indirect costs of environmental degradation, public health problems and spend money on the development of new facilities to fuel the growing demand in electricity.

The analysis of the conducted interviews also featured that the issues of energy efficiency and energy conservation are commonly perceived by Ukrainian stakeholders as synonyms or identical modes that influences the public perception as well as policies directions. Both modes are involved in the reduction of the final energy use. However, in practice, energy efficiency and energy conservation have different meanings. “Energy efficiency” is technically defined as activities aimed towards the decrease of energy input required to receive a unit of output and energy efficiency is not associated with the elimination of waste energy (Gochenour 2004, Driomin 2008). In contrast, “energy conservation” also involves cutting waste energy (Driomin 2008). For example, the industrial enterprise can use energy efficient technologies, however still waste energy by running them in the unreasonable way. Energy conservation has not been as popular as energy efficiency worldwide because it often requires sacrifice and change of behavior.

In contrast, implementation of energy efficient technologies could be implemented without behavioral change.

In fact, efficiency and conservation modes are different, but closely interrelated. For the environmental perspective, the best solution would be to strive for energy conservation as it implies both decrease of energy input per unit of outcome and the elimination of waste energy. Therefore energy conservation leads to the maximum decrease of the primary resource use and final electricity consumption. The Ukrainian normative documentation puts energy conservation to the top objectives, and technical and structural transformations to more efficient technologies are seen as one of the ways leading to this objective (ESU 2006). However, some governmental officials and business representatives tend to give priorities to the issues of energy efficiency, leave energy conservation beyond attention or substitute between these modes (NCFF pers. comm., MFE 2011, EUEA 2011, ICPS 2011). This bias was present in five out of twelve discussions within the interviews or official statements of the analyzed stakeholders.

The fact that energy efficiency concedes energy conservation mode in people's perception could result in the decrease of electricity consumption on the lower levels than expected. Due to limited information from interviews and literature on the energy conservation potential in Ukrainian electricity sector (it includes behavioral change on the individual level) and time constrains of present research, further insights in sectoral performance were restricted only to the issues of energy efficiency. However, the suggestion for future works is to broaden the scope of analysis in order to cover all aspects surrounding energy conservation issues.

Energy efficiency is recognized as the key driving forces that would shape the development of the Ukrainian electricity system (NAEEEC 2011, NAS pers. comm., NECU pers. comm., CEET pers. comm., ECS 2011, MFE 2011, KT-Energy pers. comm., Bureau Veritas pers. comm.). However, the actual future levels of improvements are characterized by many uncertainties. One of the main threads for the energy efficiency improvements, which is raised by stakeholders, was the declarative character of strategic commitments (Bureau Veritas pers. comm., KT-Energy pers. comm., NAS pers. comm., ICPS pers. comm.). The Ukrainian Energy Strategy states that energy conservation is one of the defining factors for the effective functioning of the national economy. The Strategy oversees the potential in technological and structural energy conservation that could insure up to 318 million tonnes of standard fuel savings by 2030. The responsibilities for the elaboration and monitoring energy conservation issues, as well as closely connected issues of energy efficiency and alternative sources development, are laid to the National Agency of Energy Efficiency and Energy Conservation. The Agency expects that by the year 2030 Ukraine would reach the European level of 0,26 tonnes of oil equivalent per one dollar of GDP and 0,2 level in 2050 (compared to 0,46 toe/$ GDP in 2008), which is almost impossible in practice within the current market according to international and national experts' opinion.

Some experts, especially representatives of NGO, research and civil society institutions, point political barriers for the implementation of these ambitious goals (NECU pers. comm., NAS pers. comm., NCFF pers. comm.). In particular, the strong political barrier is created by lobbing of the coal, oil and gas companies that are interested in the increase of the consumption to secure cash flow (NCFF pers. comm.). Mykhajlo Gonchar, national energy expert, states that Ukraine has increasable potential for energy conservation that is failed to be realized and is not likely to be implemented within the Energy Strategy (EUEA 2011). According to Gonchar, resource extraction companies that have strong lobbing and support try their best to keep high shares of energy intense industries and poor performance of energy sector in order to secure incomes from resource use. The failures to implement the planned energy efficiency initiative is also explained by weak cross-sectoral interaction and cooperation, the poor elaboration of concrete actions needed to make a change, poor implementation of policies, severe dependence on the other factors of country's development like transparency and stability of economic activities.

4.1.3 Transformations of the electricity market

Much attention is paid to the general transformation of the electricity market organizational model that in many ways would affect development pathways of the previously discussed key issues. These transformations fall within: pricing system and cross-subsidizing, privatization, transperancyand changes in legal acts.

Pricing system

The current system of pricing electricity production, distribution and services is of high concern for all groups of stakeholders because it fails to cover costs of electricity services and therefore endanger the economic functionality of the market (KT-Energy pers. comm., Bureau Veritas pers. comm., EBRD in Ukraine 2011, ICPS 2011, MFE 2011, NECU pers. comm., IERPC pers.

comm.). Currently, the barriers to be addressed within the pricing system are cross-subsidizing and incomplete costs compensation through and tariff system.

The incomplete costs compensation through the tariff system is a result of state intervention in the market that misbalances the initial design of the market regulation (IERPC pers. comm.). As it was discussed previously, the government distinguished electricity market structure into production, transmission and distribution components with the single state buyer of electricity produced (so-called wholesale market or WEM). This was done to facilitate competition between producers to sell electricity on the lowest price to the WEM and competition between distributors to provide final consumers with electricity at the lowest price. However, state regulation of price on the market of electricity generators and electricity suppliers undermines market mechanisms of price setting.

Generally, the price for the electricity that is supplied to the wholesale market is determined by the Rules of Wholesale Market and implies market price regulations (Tsarenko 2008). However, 68% of electricity generators and the much higher share of electricity suppliers are state regulated. Only 32% of the price setting at the market of electricity generators consists of competitive subcomponent. Tariffs on the regulated subcomponent (68% of the electricity generators market) are set administratively by the National Electricity Regulation Commission for the nuclear, hydro, wind and majority and combined heat and power plants. The electricity output from these utilities has ensured sales market. Tariffs on the competitive subcomponent are set daily through bidding. The bidding procedure is taking place for the electricity produced on TPPs and number of CHPs (Kyiv CHP-5, Kyiv CHP-6 and Kharkiv CHP). The bidding is won by the utilities that propose the lowest bids; however, the electricity is purchased from these utilities on the highest price that is proposed on bids for that day. Market competition between generators becomes almost impossible because of this state intervention.

Price setting at the market of electricity suppliers is also regulated by the state (Tsarenko 2008). The price for electricity suppliers is the price on which electricity is supplied to the industrial consumers and distribution companies that further sell electricity to retail consumers. The price to suppliers is set by National Electricity Regulation Commission on the basis of average wholesale price from producers and additional charges. Average wholesale price from producers is calculated as an average price of electricity purchased from state-controlled tariff producers and competitive producers. Additional charges include fees for the administrative services of Energorynok, charges for electricity transmission through high-voltage networks and fees to the investment fund of wind energy. There is also a small share of non-regulated tariff suppliers that are usually industrial enterprises purchasing electricity for their own needs.

The majority of stakeholders (including representatives of government) agree that current prices fail to cover all costs connected to the generation and operation of electricity utilities and could not create the credible basis for the renovation of all outdated equipment and networks. Andre Kuusvek (2011, see Annex D), director and country manager at the European Bank of Reconstruction and development, stated that the tariff methodology of full costs compensation, including compensation of investments costs, fails to work in Ukraine. This is one of the reasons of low investments inflow into renovation and development of electricity sector in the country.

Another issue that threatens market regulations in the sector is cross-subsidizing. In Ukraine prices of electricity for the industry are set higher in order to compensate lower prices for retail consumers. For the comparison of prices for the industry in 2011 were at the level 0,51-0,6 UAH/kWh (depending on the voltage), while for retail consumers 0,18-0,28 UAH/kWh (depending on the consumers' class) (Ukrenergo 2011). Traditional relatively low prices for households provide poor incentives for energy savings on the individual level (NECU pers. comm., CEET pers. comm.).

The challenge of inefficient pricing system could be solved trough market transformation that is discussed by the number of experts (ICPS pers. comm., NCFF pers. comm., Bureau Veriras pers. comm., EUEA 2011). The solution could be to restructure the wholesale market system into system with two-side contracts and therefore decrees state intervention into pricing. The two-side contracts system will allow players to choose between different providers of electricity services that will bring back competiveness. This option is under discussion at the moment, whereas eliminating cross-subsidizing is gradually taking place by increasing tariffs for the retail customers (EUEA 2011).

Privatization

Several attempts to privatize state-owned generation, transportation and distribution utilities have been made since 1991 to attract investments and renovate the outdated system (MFE 2011).

However, the process was not completed. Currently, only the minor share of utilities belongs to the private sector. The government, international and businesses indicate their willigness to finalize the privatization. Ivan Plachkov, ex-minister of fuel and energy, states that the government will probably decide to privatize utilities to attract investors. However, hardly any serious steps are made in reality. It is likely that within the next short-term period the electricity system would not experience serious ownership changes (EUEA 2011).

Transparency

Businesses and civil society representatives raised the question of transparency of operations and open participation of all stakeholders in the decision-making process several times (NECU pers. comm., IERPC pers. comm., KT-Energy pers. comm., CEET pers. comm.). It seems that after economic transformations and political situation in 90s, the country is still on the way to the development of democratic traditions.

Adjustment of legislation

Energy efficiency improvements and choice of energy carriers were described by stakeholders as key driving forces that will shape the future of the electricity system in Ukraine. These driving forces were chosen by the majority of stakeholders mainly because of economic and political considerations. However, experts from non-governmental and research organizations and international experts also emphasized the environmental side of these notions. In fact, environmental consideration could be perceived as determinant at the orientation stage of scenario building in the future (NAS pers. comm.). Legislation boundaries could be one of the facilitating factors towards this direction.

With the accession of Ukraine to the European Energy Union the issues of national legislation adjustment to European occupied one of the dominant positions for the international community. The European Union, unlike Ukraine, has evolved traditions of embedding environmental parameters in the energy planning and striving for better environmental performance of energy sector. Currently the EU community is aiming towards 20-20-20 targets for the Green Energy Strategy (EC 2010). The 20-20-20 targets foresee for the European Union a twenty percent increase in energy efficiency, twenty percent of renewable in the energy supply system and twenty percent decrease in greenhouse gas emissions by the year 2020. Ukraine joined the Energy Community in 2010 and therefore became a party of common regulatory framework for energy markets in Europe. Not surprisingly, notable actions, especially those related to environmental issues, are expected from the country by international partners (ECS 2011).

With the accession of Ukraine to the Energy Community, Ukraine took commitments to adjust legislation to European standards in several issues (Protocol concerning accession of Ukraine to the Treaty establisging energy community 2010). Among the others, the accession agreement implies implementation of such acquis communautaire as Directive 2001/80/EC concerning implementation of maximum permitted emissions of certain pollutants into the atmosphere by huge combustion facilities. The full list of acquis communautaire to be adopted by Ukraine is presented in the Annex B. The Directive 2001/80/EC examines the influence of three groups of pollutants that are associated with performance of electricity generating facilities. These are: sulfur dioxide (SO_2), nitrogen oxide (NO_x) and dust. The pollution by carbon dioxide is not examined as it is regulated by other framework conventions, e.g. by Framework Convention on Climate Change and Kyoto Protocol.

Table 3.2 Comparison of actual level of emissions in Ukraine, national standards and standards from the Directive 2001/80/EC for the modernized combustion utilities

Pollutant	Capacity of utility	Actual level of emissions, mg/m^3	Standards of emissions, mg/m^3		Exceeding of European standard, times
			National standard, decree of Ministry of environment 309	European standard, Directive 2001/80/EC	
Dust	P>160 MW	1000-1700	50	50	20-34
	P<160MW			100	
Sulfur dioxide	P<160MW	3000-7000	500	2000-400	7,5-17,5
	P>160 MW			400	
Nitrogen oxide	P<160MW	700-1800	500	600	3,5-9
	P>160 MW			200	

Source: Petrov 2010

The problem is that emissions by Ukrainian electricity generating facilities are much higher than standards established by the Directive 2001/80/EC (IERPS pers. comm., Naumenko 2009a). Power plants are the major polluters of atmosphere in Ukraine. The sector is responsible for 80% of of SO_2 and 25% of NO_x emissions in the country (IEA 2006). Significant share of enterprises fail to meet even national standards that established on the lower level than European ones. For the comparisons of actual level of emissions, national standards and standards from the Directive 2001/80/EC see Table 3.2.

The environmental performance of electricity sector could become a thread to future extension of Ukrainian electricity market in the European direction (IERPC pers. comm., NECU pers. comm.). The European Union could introduce some sanctions (like carbon tax) for the import of electricity that is generated in such environmental unfriendly way. However, once being introduced, the tax could make it unprofitable to Ukrainian enterprises to export electricity to the EU (Numenko 2009a).

On the other hand, significant investments are needed to adjust environmental performance of power plants to the EU requirements (IERPS pers. comm.). According to different estimates, Ukraine needs to invest from 5 to 17 million of US dollars depending on the numbers of electricity utilities selected to be repaired and types of improvements to be applied. In fact, financial inflows that are aimed to secure accordance of emissions of the power plants to the European standards should be several times higher than annual investments in the electricity sector nowadays.

To summaries, this subchapter has been aiming to detect key driving forces with high uncertainties in order to build scenarios on the later stage. As it is perceived by stakeholders, the key parameters that will determine the future development of the Ukrainian electricity system are defined as: national energy security and choice of energy sources, and rate of energy efficiency improvements. It was also find out that the future of the electricity system would be in many ways dependent on organizational issues such as ownership structure, electricity pricing, fulfillment of legal commitments and governmental leadership. Despite their importance, these issues would be mainly excluded from further analysis because of the time restrictions of the study.

4.2 Scenario building and analysis

On the basis of literature review and interviews a number of parameters for the development of the electricity system were found. Two among these parameters - energy efficiency and long-term direction of the policy toward fossil fuels vs. towards alternative sources were defined as determinant for the future of the Ukrainian electricity system. This section is aimed to identify ways in which these parameters can shape development trends. Firstly, this section presents the examination of possible scenario stories. Secondly, the outcomes of these scenarios estimated on the basis of the model are given. Finally, comparison between scenarios is made.

4.2.1 Descriptive scenarios development

The descriptive scenarios are focused on the two parameters which were defined at the previous phases of the research as crucial determinants that have the highest level of uncertainty: energy efficiency and long term directions concerning types of primary resource use. Energy efficiency determines domestic demand and the amount of primary resources needed to satisfy this demand. The choice of primary resources determines the structure of the supply system and therefore economic, social and environmental performance of the sector. Sectoral development could be streamed either in the way of high or low electricity efficiency, and the supply of primary electricity sources could be oriented towards alternative sources or towards fossil fuels. These considerations created the basis for the formulation of four scenario stories. The mind map of scenario stories is presented in the Figure 4.1.

Four major simplified scenarios of the sector performance were defined: a Traditional Development scenario, an Uphill Development scenario, a Fossil Dependent Development scenario and a Green Development scenario. Each scenario was given an alternative name with the reference to Greek mythology in order to make stories and assumptions associated with each scenario illustrative. The detailed description of these scenario stories is given below.

The Traditional Development scenario, or Cornucopia, describes the development of electricity system under the conditions of low energy efficiency combined with electricity supply oriented toward fossil fuels. These characteristics were traditional for the last decades for Ukraine and describe the current situation in the sector. This approach for electricity production and consumption assumes that no effort is needed to change the current performance of the sector. The Traditional Development scenario has some analogy with the cornucopia idea of abundance and nourishment. Cornucopia in Greek mythology is a horn of plenty (Ruck *et al* 1994). In fact, just as cornucopia could provide unlimited supply of goods, electricity supply and consumption could be based on the notion of unlimited resources availability to fuel any level of consumption. However, in the life conditions, supply could be limited to resources availability, affordability or acceptability dictating necessity to limit demand.

In this research the cornucopia scenario was considered as being the closest to the business as usual scenario (BAU, or reference scenario). Slow increase in energy efficiency improvements and orientation on fossil fuels described in the cornucopia scenario are traditional characteristics of the Ukrainian electricity system (see Chapter 2).

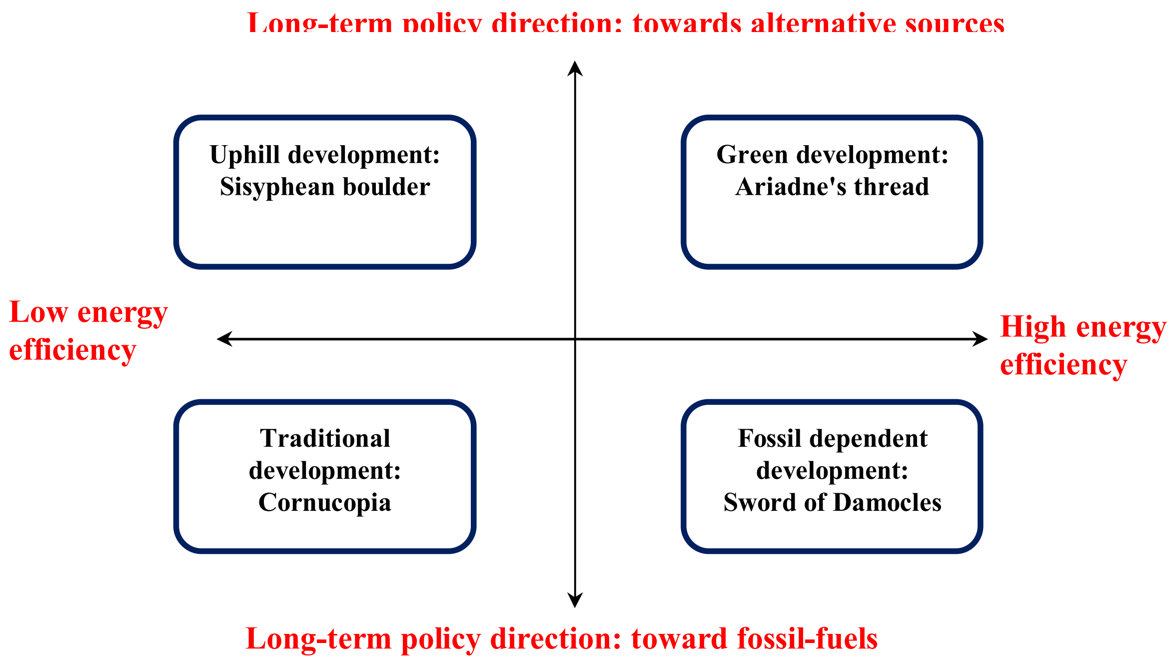

Fig.4.1 Mind map of the scenario stories

Fossil Depended Development, or sword of Damocles, scenario assumes high end-state energy efficiency of production and consumption and orientation on the fossil-fuels as the primary energy sources. The end-state of the scenario is characterized by decreased electricity demand compared to the previous scenario and therefore lower volumes of production. However, the major share in the primary resources belongs to fossil fuels like coal, gas and crude oil. The potential thread of this scenario lies in limited deposits of the fossil fuels. According to UN (2011) estimates the oil reserves could become exhausted in 50 years, gas – in 70 years and coal – in 200 years worldwide. These timeframes seem to exceed much the timeline of scenario, but to neglect potential limits of deposits is risky. The threat of running out of resources, even if it is in the remote future, accompanies this development pathway and endangers the stability of future supply. This notion determined the alternative name of the scenario – "The sword of Domoclus". According to the Greek legend, the courtier Domoclus was fascinated by the power and authority of tyrant Dionicuis and the latter gave Domoclus his place to taste the life of the ruler (Ruck *et al* 1994). However, the tyrant hang a sword on the single horse's hair under the head of Domosclus as a symbol of constant fear and threat accompanied with wealthy and magnificent life of the ruler. Just as the sword was threatening the life of Domoclus, the possible limits of deposits in the remote future could threaten the Fossil Dependent Development pathway for the electricity supply system.

The Green Development, or Ariadne's thread, scenario is associated with high energy efficiency of consumption and production and high share of alternative primary energy sources as the end-state of the electricity system. The scenario received the alternative name of "Adriane's thread" in connection to Greek myth about Theseus and Minotaur's labirynth, where Ariadne's thread helped Theseus to find his way out of Minotaur's tangled maze (Ruck *et al* 1994). The Green Development scenario could be perceived as "thread" refereed to its potential to track the potential solution for complicated situation in electricity sector: stabilize electricity demand through energy efficiency improvements and ensure secure energy supply from diverse sources. However, striving for both energy efficiency and alternative sources is quite an ambitions task because both directions require high investments at the first stages. At the same time interviews discussed previously indicated that nowadays Ukraine lacks guarantees to secure stable financial inflows in these directions.

Finally, the Uphill Development scenario, or Sisyphean boulder, is associated with the increase of alternative sources as primary energy suppliers, but at the same time the scenario is characterised by low energy efficiency of electricity production and consumption. This scenario combines controversial development pathways because it favours inefficient electricity use and high demand on the one hand, and increase of alternative sources that are of high investment costs and limited potential (as for current estimates) on the other. The Uphill Development scenario could lead to impetuous pursuit for additional production units to fuel growing demand in electricity by excluding efficiency improvements. This could be compared to the exhausting, ever-lasting task of Sisyphus, the Greek king punished by gods (Ruck *et al* 1994). As punishment Sisyphus should roll a huge boulder up to the hill and, once the boulder reached the top, Sisyphus watched it roll down, so the king repeated the task through eternity. Just as Sisyphus was bound with eternal hard work of rolling the boulder on the hill, the uphill development scenario is bound with the ever-lasting aspiration to satisfy growing demand, which is non-restricted by efficiency standards, by electricity production from new and relatively expensive sources.

The Uphill Development scenario was excluded for the further analysis on the basis of expert opinion from interviews and additional consultations (NECU pers. comm.). The roadmap towards increase of share of alternative sources and neglecting energy efficiency issues was rejected by the specialists as the least likely to happen. At the current level of development of the Ukrainian sectors, it is cheaper to introduce energy efficiency technologies widely than satisfy growing demand in electricity by expensive alternative sources like wind, solar or biogas. Further there would be analyzed three scenarios: the Draditional Development, the Fossil-Depended development and the Green Development.

4.2.2 Scenarios quantification

Each scenario story has pros and cons as described in the previous subsection. The more detailed review of the scenario stories requires quantitative estimations. The outcome of each scenario is examined through the numerical model. The further development of scenarios is made according to the methodology under the assumption of stable economic and demographic growth, predicted by national analytics. At first “low energy efficiency vs. high energy efficiency” trends are examined. Then, the possible shares of primary resources for each scenario are estimated.

The potential domestic electricity demand for each story is calculated on the basis of baseline demand, economic and demographic growth and, what is important, levels of energy efficiency and rate of it improvements. The increase of energy efficiency was estimated separately for industrial and household sectors, developments in the other sectors were estimated conjointly. The estimations are made at first for the BAU scenario and then for the alternative Green Development and Fossil Dependent Development scenarios (the domestic demand is expected to be similar for these two scenarios, see Fig. 4.1). The BAU scenario is estimated on the basis of the historical trends for electricity consumption in sectors and rates of energy efficiency improvements validated by national experts (estimated as national average, level of energy intensity is decreasing at the rate 0.5-0.7% per annum for industrial enterprises, energy efficiency improvements for households are increasing at the rate 0.1-0.3% per annum). For the alternative scenarios, the feasible level of energy intensity decrease is estimated by experts as 2% per annum for industrial enterprises and for the household energy efficiency increase - 1.5% per annum. Results are presented in the Figures 4.2 and 4.3.

In 2010 the total domestic demand was at the level 137 TWh, with industry responsible for 77 TWh and households – 38TWh of electricity consumed. For the BAU scenario the consumption is projected to be at the level 210 TWh (excluding losses, consumption by energy utilities and export) by the year 2030. For this scenario the industrial sector is expected to consume 108 TWh, households – 53 TWh. In the alternative scenarios (Fossil dependent scenario and Green development scenario), which are focused on energy efficiency improvements, the total domestic demand was estimated to be 147 TWh per annum with industry responsible for 74 TWh and households 41 TWh per annum (this estimations exclude consumption of electricity by energy utilities, losses and export). Compared to the BAU scenario, energy-efficiency oriented scenarios require 63 TWh for netto demand less by 2030.

If to compare potential production that also should include losses, electricity consumption by electricity sector utilities and export, than the BAU scenario is associated with the production on the level 282 TWh per annum in 20 years while alternative Fossil Dependent and Green Development scenarios – 191 TWh per annum. So is to account the full production needed to take place, the difference between BAU and alternative scenarios could be more than 90 TWh per annum in 2030.

Further the potential shares of primary electricity sources for each scenario are estimated on the basis of illustrative trends proposed by experts. As it is described in the methodology each expert illustrated potential shares of primary resources for each scenario. The results of the scenario quantification according to the parameter “choice of primary energy sources” are presented in the Annex F and Figures 4.4 – 4.6.

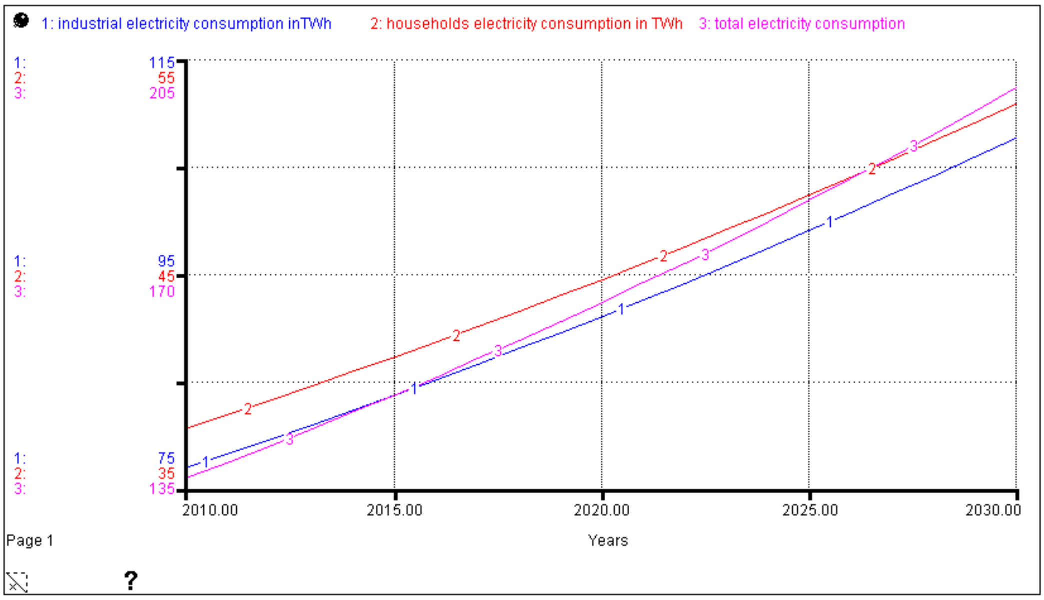

Fig. 4.2 Projected electricity demand (total and sectoral) within BAU scenario for the period 2010-2030, TWh[1]

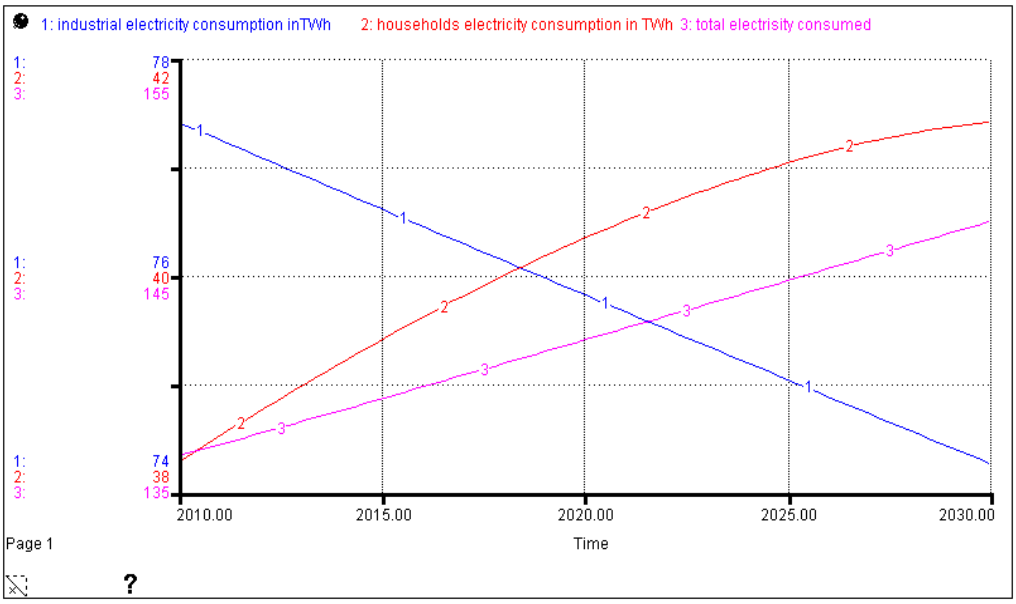

Fig. 4.3 Projected electricity demand (total and sectoral) within energy-efficiency oriented scenarios for the period 2010-2030, TWh[*]

[1] NOTE: each component has separate y-scaling due to Stella software design
[*] NOTE: each component has separate y-scaling due to Stella software design

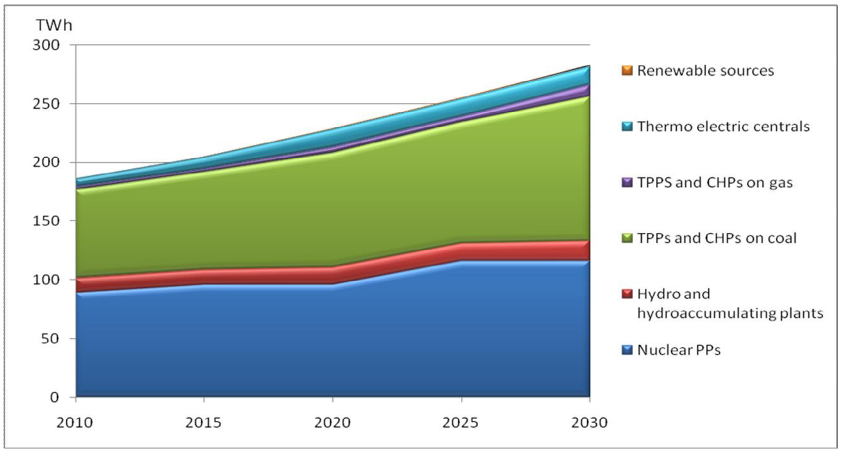

Fig. 4.4 Electricity produced by sources within Traditional development scenario, TWh

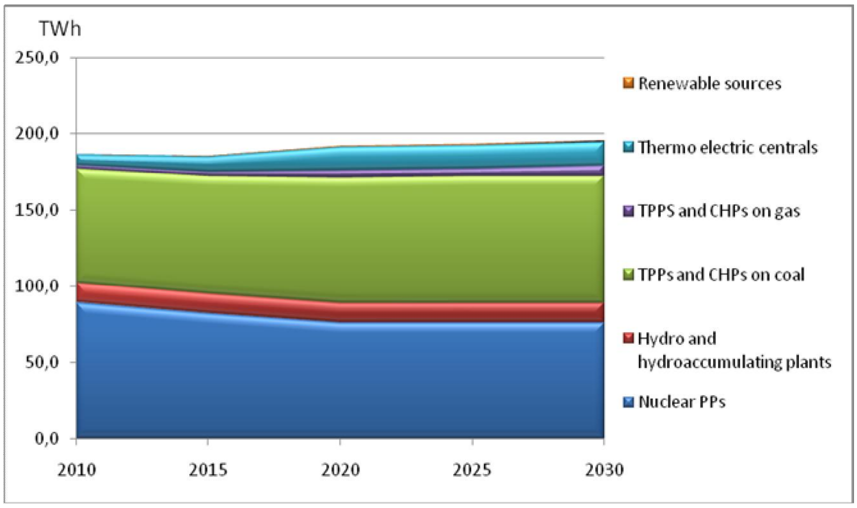

Fig. 4.5 Electricity produced by sources within Fossil dependent scenario, TWh

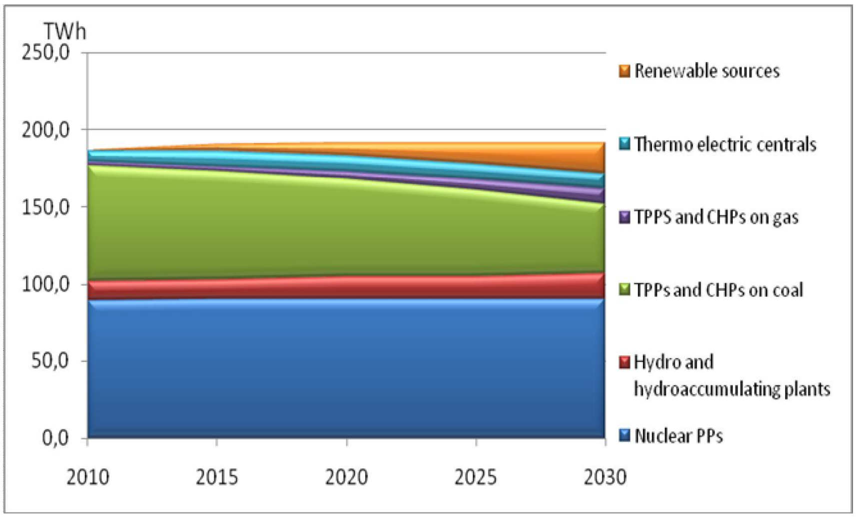

Fig. 4.6 Electricity produced by sources within Green development scenario, TWh

The Traditional Development Scenario favours the use of fossil fuels and nuclear energy to fuel demand in 210 TWh per annum. According to this scenario 52% (or 148 TWh) of electricity will be produced by fossil fuelled power plants. The majority of electricity will be produced on the coal– more than 120 TWh, with the minor share of gas as primary sources (mainly domestic shell gas). The extension of lifetimes of some reactors and also renovation and construction works are likely to be done to ensure share of nuclear energy at the level of 116 TWh per annum in 2030. The share of renewable sources will remain very small – 0.4%.

The Fossil Dependent Development scenario is characterized be decreased electricity demand, compared to Traditional development scenario, and the same trends towards fossil fuels. The shares of electricity produced on the basis of such primary sources as coal, gas and crude oil will be 54% by 2030. In the absolute values the total electricity production is expected to be on the level of 191 TWh per annum, including 105 TWh produced by combustion of fossil fuels. The shares of hydro and renewable sources would remain relatively unchangeable. The share of nuclear energy will also remain high - 39% by 2030. However, in comparison with Traditional dDvelopment scenario, the volume of electricity produced by nuclear power plants will decrease. The Fossil Dependent Development scenario even assumes that some of the outdated reactors, for example reactors Rovno 1 and 2 and South Ukraine-1, could be closed before 2020. To compare, within Ukrainian Energy Strategy is it planned to extend lifetime of these reactors for additional 15 years to fuel ever-growing demand in electricity. Fossil Dependent Development scenario due to improvements in energy efficiency allows to stabilise demand and therefore to shut down some of the outdated nuclear utilities.

The Green Development Scenario seems to be the most diversified supply system in terms of electricity sources and their shares. In 2030 the total electricity production is expected to be 191 TWh including 90 TWh (47%) produced by nuclear power plants, 64 TWh (34%) produced by heat and combined heat and power plants, 19 TWh (10%) by renewable sources and 17 TWh (9%) by hyrdopower pants. Though, the scenario is oriented towards alternative energy sources, the use of fossil fuels would not be completely abandoned. Utilisation of coal as primary energy source will steadily decrease, but remain on relatively high level in 2030 – 45 TWh of electricity will be produced by power plans on coal. The scenario also has high share of nuclear energy, as alternative energy source, and increase in the hydro energy.

Emissions for each scenario are calculated according to the methodology presented in the third chapter. The results are given in the Table 4.2.

Table 4.2 Results of estimations of emissions from electricity production for different scenarios

	2010			2030		
Energy sources	Electricity produced by the carrier, TWh	Volume /amount of primary source, th t for coal/mln m3 for gas	Emissions, t CO2	Electricity produced by the carrier, TWh	Volume /amount of primary source, th t for coal/mln m3 for gas	Emissions, t CO2
Traditional development scenario						
Coal	74.6	42376.1	87992776	123.0	69886.4	145116938
Gas	2.6	1129.5	2144862	10.0	4347.8	8256457
Coal for thermo electro centrals	7.0	3571.4	7415964	15.0	8522.7	17697188
Nuclear energy	89.1	na	445500	116.0	na	580000
Hydro energy	12.9	na	129000	17.0	na	1290
Renewable sources	0.2	na	10000	1.0	na	50000
Total		na	98138102		na	171701900
Fossil-dependent development scenario						
Coal	74.6	42376.1	87992776	83.0	47159.1	97924438
Gas	2.6	1129.5	2144862	7	3043.5	5779520
Coal for thermo electro centrals	7.0	3571.4	7415964	15.0	8522.7	17697188
Nuclear energy	89.1	na	445500	76.0	na	380000
Hydro energy	12.9	na	129000	13.0	na	1290
Renewable sources	0.2	na	10000	0.9	na	45000
Total		na	97553600		na	121827400
Green development scenario						
Coal	74.6	42376.1	87992776	45.0	25568.2	53091563
Gas	2.6	1129.5	2144862	10	4347.8	8256457
Coal for thermo electro centrals	7.0	3571.4	7415964	10.0	5681.8	11798125
Nuclear energy	89.1	na	445500	90.0	na	450000
Hydro energy	12.9	na	129000	17.0	na	1290
Renewable sources	0.2	na	10000	19.0	na	950000
Total		na	97553600		na	74547430

Note: na – not available

4.2.3 Scenario insights

According to the research design each scenario should be evaluated with regard to the chosen indicators. These insights into the scenario stories and associated quantitative estimations provide the basis for the formulation of the strategic message.

Traditional development scenario, or cornucopia

Indicator 1 - Electricity required in 2030: Domestic demand is expected to be 210 TWh (excluding losses, consumption by energy utilities and export), demand by industry – 108 TWh, demand by households – 53 TWh. Potential production to cover domestic demand, electricity consumption by energy utilities, losses and export should be at the 282 TWh per annum.

Indicator 2 - Energy mix and resource availability: In 2030 52.4% of electricity will be produced by fossil-fueled power plants and 41.2% by nuclear power plants (see Table 4.3). The electricity produced by hydro and renewable sources would account for 6.4%. The coal required, 78 thousand tonnes of coal (see Table 4.2), could be available from the domestic coal resources. Gas could be supplied from domestic shell gas deposits that are expected to be developed by that time. If by 2030 Ukraine fails to introduce full nuclear cycle, fuel for the nuclear reactors should be imported. Currently, around 30% of national nuclear energy production is based on domestic uranium; the rest is imported from Russia (NEC 2010).

Table 4.3 Energy mix within the Traditional development scenario

	2010		2030	
Utilities	Electricity production, TWh	Percent of total, %	Electricity production, TWh	Percent of total, %
Nuclear PPs	89.1	47.8	116	41.2
Hydro and hydroaccumulating plants	12.9	6.9	17	6.0
TPPs and CHPs on coal	74.6	40.0	123	43.6
TPPS and CHPs on gas	2.6	1.4	10	3.5
Thermo electric centrals	7	3.8	15	5.3
Renewable sources	0.2	0.1	1	0.4

Indicator 3 - Energy intensity: 0.45 tonnes of standard fuel per dollar of GDP by 2030.

Indicator 4 - Carbon dioxide emissions: Carbon dioxide emissions are expected to be 171.7 million tonnes CO_2 in 2030 compared to 97.6 million tonnes of CO_2 in 2010.

Indicator 5: Resource affordability: Electricity prices are mainly determined by coasts of primary resources and operational costs of electricity system. The prices for coal could be expected to be on the stable level as far as extraction of this resource is mainly state-controlled. The prices for domestic shell gas, which resources and utilization is expected to be developed by 2030, is likely to be state controlled and also stable. However, nuclear fuel is mainly imported and therefore, the prices will in higher extent depend on regional economic and geopolitical situation. The situation with the nuclear fuel is valid for all scenarios as far as share of nuclear energy is relatively high in each scenario.

Fossil dependent society scenario, or Sword of Domoclus

Indicator 1: Electricity required in 2030: Domestic demand is expected to be 147 TWh (excluding losses, consumption by energy utilities and export), demand by industry – 74 TWh, demand by households – 41 TWh. Potential production to cover domestic demand, electricity consumption by energy utilities, losses and export should be at the level 191 TWh per annum.

Indicator 2: Energy mix and resource availability: The overall pattern of primary energy carriers and insights into resource availability is comparable with one in Traditional development scenario. In 2030 the major shares of electricity will be produced on fossil fuels (53,9%) and nuclear energy (39%) (see Table 4.4). However, the scenario assumes much lower level of electricity required, therefore require less primary resources for the production.

Table 4.4 Energy mix within the Fossil dependent development scenario

	2010		2030	
Utilities	Electricity production, TWh	Percent from total, %	Electricity production, TWh	Percent from total, %
Nuclear PPs	89.1	47.8	76.0	39.0
Hydro and hydroaccumulating plants	12.9	6.9	13.0	6.7
TPPs and CHPs on coal	74.6	40.0	83.0	42.6
TPPS and CHPs on gas	2.56	1.4	7	3.6
Thermo electric centrals	7.0	3.8	15.0	7.7
Renewable sources	0.2	0.1	0.9	0.5

Indicator 3 - Energy intensity: 0.34 tonnes of standard fuel per dollar of GDP.

Indicator 4 – Carbon dioxide emissions: Carbon dioxide emissions from the electricity production are expected to be 121.8 million tonnes CO_2 in 2030 compared to 171.1 million tonnes of CO_2 in for the same year within Traditional development scenario.

Indicator 5 - Electricity affordability: The predictions and assumption that were made for Traditional development scenario is valid for the Fossil Dependent scenario as far as the main pattern of primary energy mix is comparable. However, due to lower demand compared to Fossil dependent scenario, less primary resources is needed.

Green development scenario, or Ariadne's thread

Indicator 1 - Electricity required: In the analogy with Fossil dependent development scenario, in 2030 domestic netto consumption will be 147 TWh, including industrial consumption 74 TWh and households – 41 TWh. Potential production should be at the level 191 TWh per annum.

Indicator 2 - Energy mix and resource availability: By 2030 the majority of electricity (90 TWh or 47,1%, see Table 4.5) is expected to be produced by nuclear power plants. The share of fossil fuels will remain also significant – 34%, however this could be satisfied by domestic resources. The scenario is characterized by relatively high share of renewable sources – up to 10% of electricity would be produced with the use of renewables.

Table 4.5 Energy mix within the Green development scenario

	2010		2030	
Utilities	Electricity production, TWh	Percent of total, %	Electricity production, TWh	Percent of total, %
Nuclear PPs	89.1	47.8	90.0	47.1
Hydro and hydroaccumulating plants	12.9	6.9	17.0	8.9
TPPs and CHPs on coal	74.6	40.0	45.0	23.6
TPPS and CHPs on gas	2.6	1.4	10	5.2
Thermo electric centrals	7.0	3.8	10.0	5.2
Renewable sources	0.2	0.1	19.0	9.9

Indicator 3 - Energy intensity: 0.34 tonnes of standard fuel by 2030.

Indicator 4 – carbon dioxide emissions: The lowest carbon dioxide emissions among three scenarios –74.5 million tonnes of carbon dioxide emissions per annum in 2030.

Indicator 5 – resource affordability: The scenario is characterized by lower demand of electricity due to the energy efficiency improvements, and therefore less need for of primary energy sources compared to Traditional Development scenario. The amount of 31 million tonnes of coal and around 4 million cubic meters of gas could be extracted from the domestic deposits with the minor import. The fact that domestic coal and gas extraction is mainly state controlled could provide some guarantees for the economic affordability. Issues related to the nuclear energy, absence of full nuclear cycle in Ukraine and dependence on imported uranium are discussed within the Traditional Development scenario insights. Ukraine has also enough potential to develop renewable sources (IEA 2006). However, at the first stages development of renewables requires significant investments.

Some indicators, like fluctuations of the labour forces within the electricity market or potential risks, have not been included in the scenario analysis because of the lack of data and time limitations of the study. However, they could be also of significant importance for the decision-making because, for example such indicator as fluctuations of the labour forces within electricity market can capture threats of restructuring coal sector in Ukraine or benefits from renewable energy development from the perspective of social transformations. Risks analysis could give insights into the social acceptance of the scenarios. So, analysis of the indicators that are connected to social issues could be suggestion for the future researches in the field.

4.2.4 Scenario comparison and formulation of the strategic message

As it is presented above, the scenarios differ in electricity need, energy intensity, resource mix and therefore CO_2 emissions. The prioritization within these indicators and the choice of final development pathway determines the future performance of the electricity system. This subsection is focused on the comparison of indicators within different scenarios, the discussion of the main highlights and the formulation of the strategic message for decision-makers.

All scenarios assume the stable economic growth, however they differ in their projection for the electricity need and production. The Traditional development scenario, which is also referred to as BAU scenario, is associated with the highest electricity consumption and production – within this scenario the electricity production could reach 282 TWh per annum in 2030. The trend results from the gradual increase of consumption by all sectors, which is accompanied with slow rate of energy efficiency improvements. In 20 years the energy intensity will reach the level of 0.45

tonnes per dollar of GDP. This is almost twice better than the current indicator, but far away from the current EU practices (Ukrainska Energetyka 2011). In contrast, in the Fossil Dependent and Green Development scenarios the electricity production should reach the level of 191 TWh per annum in 2030. The savings in up to 91 TWh per annum, which are financially beneficial, could be done through the improvements in energy efficiency in the industry and households sector alone.

The comparison of the energy mix and resources availability also indicates that the Traditional Development scenario is the most unattractive from the three alternatives. The Traditional Development scenario is characterized by high share of fossil fuels – 52%, among which 43% of electricity will be produced by coal-fueled thermal power plants. In term of volumes of primary fuels, it means that the country should provide TPPs with more than 70 million tonnes of coal annually, which is twice the current fuel demand. However, as it was discussed in the literature review, Ukraine has 34,150 million tonnes of proven coal deposits (WEC 2001), which is enough to satisfy the significant demand in 70 million tonnes of coal per annum by domestic coal for 488 years. The other question is the price in terms of environmental degradation and health impacts that should be paid by society for the extraction. The Fossil Dependent development scenario is characterized by the comparable trends in shares of electricity produced on coal, however much less demand in the volumes of this primary source. Only the Green Development scenario is associated with 23% of coal in the primary resource mix, which is relatively high share for the scenario that is oriented towards renewable sources.

Although scenarios have different development directions: towards alternative sources or fossil fuels, within each scenario the shares of coal and nuclear energy appear to be significant. The maximum share of renewables is 10% within the Green Development scenario. This is explained by the fact that currently nuclear and coal energy carriers occupy predominant positions in energy supply and are seen as reliable domestic sources. Considerable decline or complete exclusion of these resources as primary energy carriers requires substantial time and significant financial inflows for the reorientation of the energy sector. Even specialists from non-governmental and research institutions, which expressed the strong interest in abandoning nuclear energy and development of renewable sources, in their questionnaire pointed out that development directions towards alternative sources could take the shape of slow transformations rather than rapid re-orientation of the electricity market under the current economic and political situation in the country.

From the point of resource affordability each scenario has positive and negative sides. All three scenarios rely on nuclear energy. Prices for nuclear energy will be determined by the prices of imported nuclear fuel and waste storage, or by investments in the introduction of full nuclear cycle in Ukraine. The Traditional development scenario seems to be the most unattractive because it needs significant inputs of primary resources, whose prices are likely to increase in the future, however it is oriented towards domestic coal and gas, meaning more independence from exported fuels. The Fossil Dependent scenario is characterised by the decreased demand in primary energy sources and the comparable orientation towards fossil fuels, which is more favourable than perspectives under the Traditional Development scenario. The Green Development scenario requires substantial investments and governmental assistance to increase the share of renewables almost to 10% by 2030. In fact, if social and environmental considerations are not accounted for, it is not likely that the Green Development scenario could be more beneficial in the short-term perspective than Fossil Development scenario. However, a comprehensive economic analysis is needed for correct estimations.

As it could be expected, CO_2 emissions are the lowest in the Green development scenario as a result of demand patterns and primary energy resource mix. If the country would take the pathway for the environmental impacts mitigation for the benefit of natural and social environment, the rate of decrease in 97.2 million tonnes of CO_2 emissions per annum by 2030 will ensure the accomplishment of the commitments that Ukraine has taken on the national and international levels.

Consequently, the strategic message for policy makers, which is obtained from the scenario analysis and comparison of indicators, is to focus on energy efficiency improvements in the industry and households at the first place with the slow transformation of the electricity supply system from fossil fuels to alternative sources. The decrease in energy intensity alone from 0.7 till 0.34 (not planed 0.45) tonnes of standard fuel per dollar of GDP over the next 20 years could bring savings of 91 TWh annually and decrease CO_2 emissions from 171.1 million tonnes annually to 121.8 million tonnes of CO_2. In addition o the energy efficiency improvements, the orientation towards the 40% decrease in electricity produced by coal-fueled TPPs, the increase of the production on gas-fueled TPPs to 10 TWh and by alternative sources to 19 TWh per annum in 2030 would allow Ukraine to move closer to the European standards and increase the reliability of electricity supply system. However, even the direction towards alternative sources implies relatively high shares of coal and nuclear energy in the energy mix.

4.3 Policy analysis

Research findings show that energy efficiency should have the leading priority for the sector development, so the policy analysis is focused on this issue. Based on the methodology presented in the second chapter, policy mechanisms are analyzed according to four cluster divisions: regulatory (command and control), economic, information, and research instruments. The policy instruments are used as tools to implement the policies or strategies, overcame barriers and therefore stimulate electricity market transformation and development. Therefore, this section is focused on the ability of each group of instruments to reduce certain barriers and their potential for electricity market transformation in the field of energy efficiency improvements.

4.3.1 Regulatory instruments

Regulatory instruments, also referred to as command and control, consist of a "command" component that sets standards or norms through regulatory acts and a "control" that monitors and enforces the standards (Metz 2009). Command and control instruments were the major tools of policy making during the Soviet times, when the government controlled almost every aspect of economic activity. After 1991 the general dominance of command and control methods started to be replaced by market instruments. However, the traditional regulatory tools are still widely used in energy and environmental management.

Standardization in the sphere of energy efficiency is done to establish the complex of obligatory norms, regulations and rules concerning the rational use and conservation of energy sources. The established standards create the basis for regulation and penalties for the inefficient use of resources, the production and use of energy inefficient equipment and materials. In Ukraine, the norms and standards in energy efficiency are regulated by the Law on energy conservation, more than 150 legislative acts, more than 100 methodologies, 50 national (so-called DSTUs) and 60 international (so-called GOSTs) standards (NAEE 2009). They normalize and standardize energy input and performance associated with the production and use of materials, technologies, equipment, buildings. However, the majority of standards was established at the beginning of 1990s and has not been updated since then (Tsapko-Piddubna 2009). Therefore they are outdated and fail to follow the technological improvements in the area. Moreover, the concrete criteria and methodologies to monitor energy efficiency improvements are usually not defined, which prevents this policy mechanism from successful operation. For example, from more than 50 national standards, only 10-15 contain the concrete indicators to capture the change in the energy use by equipment or technology (NAEE 2009). As a result of outdated and in some cases poorly elaborated norms and standards, it is difficult to ensure the proper monitoring and enforcement of the issues related to energy efficiency. The revision of current norms and standards and the establishment of clear indicators could facilitate the realization of the energy saving potential for the building and household sectors.

Command and control mechanisms could be useful for installing and enforcing the level for the energy intensity of 0.34 tonnes of standard fuel per dollar of GDP by 2030 by strict regulations for industrial, households and building sectors. In industry this could be done by making energy efficiency indicators for heavy industries more strict, in households – by introducing energy efficiency norms for appliances and in buildings – by reviewing existing building standards (Tsapko-Piddubna 2009). Another advantage of command and control instruments is the profound experience in the area that makes the elaboration and implementation of concrete actions easier for developing countries (Metz 2009). For example, in the building sector in Ukraine the widely used Building Codes that standardize designing and construction processes, materials and characteristics of the final building could be improved by making the energy efficiency indicators of input materials, works and final performance stricter, so that the level of 70% energy efficiency in new civil buildings could be reached (Petrov 2010). The example for Ukraine could be Denmark, where in 2006 the building norms were reviewed to decrease the demand in energy carriers by 25-30% compared to previous standards (Tsapko-Piddubna 2009). China also introduced a new building construction statute that contains strict regulations for mandatory energy efficient materials and technologies for heating, air conditioning, ventilation and lighting system (Metz 2009). In contrast, Ukraine does not have standards for energy efficiency even for household electricity appliances, which is another area to pay attention on.

Command and control instruments also associate with several minuses that could be crucial for the Ukrainian case. Firstly, the enforcement of stricter standards and norms should be combined with increase of charges and penalties for non-compliance. Currently, in many cases charges for non-compliance, especially for energy and environment-related performance, fail to be high enough to change the behavior. It is economically more beneficial for companies to pay penalties than to change performance (Panchenko 2008). However, the significant change in charges and penalties for the industrial energy and environment related performance during the current economic decline could be perceived as the political unpopular step. Another minus of command and control instruments is little incentives for the private and public sector to increase energy efficiency at the higher rate than the agreed targets. The command and control instruments are good in regulating energy efficiency associated with certain activities or materials by the established targets, but these instruments do not provide incentives to reduce primary resources or electricity use further than this target (Metz 2009). The last issue could be addressed by the economic instruments.

4.3.2 Economic instruments

Economic instruments include taxes, priorities in giving contracts, financial guarantees, tradable certificates and other mechanisms that provide market or economic benefits to energy efficient products and services. Taxes as economic instruments could take the shape of decrease of value added tax for energy efficient goods, giving extension for tax payments for energy efficient projects and introduction of taxes for the resource consumption and GHG emissions. The state could use the tax system to stimulate projects in energy efficiency through discount taxes for such projects. The share of discount taxes is regulated with regard to the energy efficiency of the project, the volume of primary energy resources that were saved and the influence of the project on the energy intensity of GDP (Petrov 2010). Economic mechanisms could also take the shape of discounts for the purchases of energy efficient equipment, grants.

Tax for energy resource consumption is another economic mechanism. Such taxes are usually direct so that the tax is bound strictly to the amount of resource consumed. The tax for the resource consumption could be effective stimulus for the decrease in the use of resources because every consumer is aiming to decrease primary expenditures. In many ways this scheme resembles GHG emission taxation, which is another way to strive for the increase of efficiency on fossil-fueled electricity production utilities. However, in Ukraine, the scheme could hardly be introduced because of the lobbying of companies that supply fossil fuels resource and therefore are interested in the increase in the increase in the consumption of these resources (Tsapko-Piddubna 2009).

Another effective economic mechanism is tradable certificates, which is one of the main systems to promote energy efficient improvements in some EU states. A certificate in energy efficiency, or the white certificate, is the certificate that testifies certain increase in energy efficiency, which is established by regulations. According to the system of white certificates electricity producers and consumers should reach the stated level of energy efficiency. The white certificate is issued for the amount of electricity that is saved. Individual enterprises could improve energy efficiency and obtain the certificate or buy it from other enterprises. The system of tradable certificates ensures the achievement of the stated goals in the most cost-efficient way for customers. Similar systems of tradable certificates work in France, Italy, and Great Britain (up to year 2008). In Great Britain the system saved 40% of electricity during the period 2002-2005 (Tsapko-Piddubna 2009). However, specialists indicate that the introduction of this system in Ukraine is not an urgent policy (NECU poers. comm., NAS pers. comm.). The system is extremely good for unlocking the hidden potential for energy efficiency improvement within the country, while Ukraine does not take advantage of its explicit potential.

Financial guarantees is an economic mechanism that could help in providing secure investment climate (Metz 2009). Financial guarantees can be, for example, municipal obligations for local projects that include the guarantees of the pay-back for credit that are issued by the municipalities to minimize the risks of non-payments. However, the credibility of municipalities should be high to enforce mechanism.

Several of the instruments that were presented are currently used in Ukraine, although not very successfully (NECU pers. comm., NAS pers. comm., CEET pers. comm., NCFF pers. comm.). The system of reduced income taxes has been working in Ukraine since 2008. The system ensures reduction in the income taxes for the enterprises 2005 (Tsapko-Piddubna 2009). For the introduction of energy efficient technologies the enterprises could be exempt for up to 50% of income tax for the period of up to 5 years. Ukraine also introduces exempt from the excise payments for the import of energy efficient equipment. However, the effect from the policies has been less than expected because of the unstable political and economic situation in the country, high investment costs and long pay-back period of the projects in energy efficiency. The introduction of the government guarantees as economic instrument can reduce this barrier. On the other hand, it requires governmental interest and wide assistance, but representatives of business and non-governmental institutions point out that the lack of governmental support and interest at first place cause poor functioning of economic policy mechanisms in the energy sector (NECU pers. comm., KT-Energy pers. comm., CEET pers. comm.). Moreover, such policy mechanism as cross-subsidizing that is currently used in the electricity sector negatively affects performance of both – industry and household. Currently the higher prices for industrial consumers cover lower prices for households, which raises production costs and therefore costs of final goods from industry on the one hand and provide poor economic incentives for household to reduce the use of relatively cheap electricity.

4.3.3 Information instruments

Information instruments are aimed towards the popularization of economic, environmental and social benefits of energy efficiency, awareness rising. Information instruments have been paid increasing attention over the last decades as results of their ability to create motivation for the behavioral change among people that stand behind governmental and civil institutions, industries, and individual households. Experts emphasize that willingness of actors to accept and contribute to the changes serves as background for success of the other instruments.

The information instruments consist of such components as general information campaigns aimed towards awareness raising and providing information for the wide public, specialized trainings aimed towards narrower groups of stakeholders in the energy sector, creation and support of the information centers, energy labeling that is usually aimed to provide consumers with the information of energy performance of the goods or services, energy audits that is aimed towards creating energy profile of the companies and their analysis and energy management of the customers.

In Ukraine all types of the information instruments are used, however in the initial phase (NAS pers. comm.). Energy auditing and energy management of the customer are made by private companies, but in some cases with the state supervision. For example, the enterprise should pass mandatory state audit, including energy audit to change ownership status, but could also complete optional energy audit according to international standards 2005 (Tsapko-Piddubna 2009). Following the Ministerial decree a special training centre in energy efficiency and energy management was created in Kyiv (NAEEEC 2011). The specialized training campaigns for stakeholders are made regularly. However, the information campaigns for the wide public are held rarely and in the irregular way due to usual high costs and uncertain feedback (NAS pers. comm., NECU pers. comm.).

4.3.4 Research and development

The improvements in the energy efficiency are determined by the number of drivers. The availability of new, improved and cheap technologies is one of the most essential determinants. Moreover, research and development could sometimes be used as a substitute to direct policy actions in cases where political will is weak or strong opposition against energy efficient improvements exists (Metz 2009). In Ukraine, where there is a substantial human and institutional potential for the research (IEA 2006) on the one hand and lack of governmental interest on the other (NECU pers. comm., NAS pers. comm), research and development could provide push for the market transformation.

The weak side of research and development mechanism is that it has a limited effect on the change in energy efficiency on the national level in the short-term perspective. The reason is that the cost reduction from new technologies implementation is driven more by the learning effect of their implementation (Metz 2009). Subsequently, there is a time gap between development or improvement of technologies, their implementation and results.

Summarizing, the review of the policy mechanisms has been done as an illustrative approach of the ways in which strategic message could be brought into the practice in Ukraine. As it is shown, command and control instrument could ensure the fulfillment of the energy intensity indicator at the level of 0.34 tonnes of standard fuel per dollar of GDP, economic mechanisms could provide opportunities to reach the goal in the most cost-efficient way, the information instrument could unlock the behavioral change in public, while the research and development mechanism could support transformation by providing affordable and efficient technologies.

CHAPTER 5 CONCLUSIONS

The guiding strategic drivers for the development of the Ukrainian electricity system are security and uninterrupted access to energy sources, economic affordability and mitigation of environmental impacts. However, not all of these components are sufficiently accounted for in energy planning. Economic and political considerations usually play a leading role in the process, with environmental issues being left out of the planning framework. However, the impacts of the electricity system on the environment and public health, national and international commitments related to the performance of the electricity sector suggest that environmental considerations should be adequately addressed in the decision-making process. This research provided an illustrative example of the possible ways in which environmental criteria could be incorporated in the electricity sector planning through indicators and scenario analysis, which is an unexplored approach for Ukraine.

The main research question has been focused on the potential direction of the development of the electricity sector if environmental considerations are accounted for in the planning phase. The question was addressed through the following complementary steps: identification of key driving forces and parameters, elaboration of the scenario narratives with regard to the change in these crucial parameters, scenarios quantification, comparison of the potential outcomes and formulation of the strategic message for policy makers. The review of the stakeholder perceptions of the key driving forces for the electricity system development has indentified that the rate of energy efficiency improvements and the direction of policy towards fossil fuel use vs. alternative sources are the two issues with the highest degree of uncertainty that affect the development of the electricity system in Ukraine in the future. Therefore these parameters have been chosen as the main axes to build scenarios around. Four scenario stories were developed; however, one scenario (Uphill Development scenario) was excluded from the further research based on the consultations with experts. Consequently, on the later stages three scenarios have been elaborated and compared based on economic and environmental indicators: the Traditional Development scenario, the Fossil Dependent Development scenario and the Green Development scenario. As it has been expected, the Green Development scenario could be considered as priority scenario if environmental and economic indicators are given the same weight. However, a comparison of the scenarios has also highlighted several crucial issues concerning both key drivers "policy direction towards fossil fuel use or alternative sources" and "rate of energy efficiency improvements". Insights from these could also be useful for planning in the electricity sector.

In each scenario the share of coal and nuclear energy as primary energy sources is projected to be significant. The highest share of renewables - 10% in 20 years (19.9 TWh per annum) has been associated with the Green Development scenario. This is 75% less than the estimated total potential of renewables for Ukraine. The reason for the high share of nuclear and coal sources even within the Green Development scenario is explained by the fact that currently these energy carriers are considered by stakeholders as domestic, reliable sources. Moreover, a considerable decline or complete exclusion of these resources requires time and substantial investments. Even specialists from non-governmental and research institutions that expressed a strong interest in abandoning nuclear energy and development of renewables, indicate that rapid development of renewable sources is very desirable, however not likely to happen because of the economic and political situation in the country. Consequently, the research showed that the development of the Ukrainian electricity system towards the increase of renewables could happen through slow transformations rather than rapid re-orientation of the electricity supply system even if environmental criteria are prioritized in the decision making process.

The rate of improvement in energy efficiency will shape future trends in consumption and production patterns, affect energy affordability and environmental performance. The analysis showed that a decrease in energy intensity alone from 0.7 to 0.34 (not planned within the Energy Strategy 0.45) tonnes of oil equivalent per dollar of GDP over the next 20 years could bring savings of 91 TWh annually and decrease of CO_2 emissions in 50 million tonnes. This will allow Ukraine to improve the environmental performance of the sector, move closer to European standards, fulfill obligations under national and international legislation and increase the reliability of the electricity supply system. Therefore, a key strategic message for decision-makers for the medium term planning could be to focus first on energy efficiency improvements in industry and households accompanied by the gradual transformation of electricity supply system from fossil fuels to alternative sources.

The analysis of policies within the work was focused on the possibility of policy mechanisms to facilitate electricity market transformation towards the improvement of energy efficiency as the main strategic objective. It has been shown that the while command and control instrument could ensure the fulfillment of established targets in the energy intensity, economic mechanisms could provide opportunities to reach the goal through the most cost-efficient way. The information instrument could unlock behavioral change in public, while research and development mechanism could support transformation by providing affordable and efficient technologies.

Currently, the Energy Strategy of Ukraine is under revision that highlights the importance of the planning process, its accuracy and ability to address present and future electricity demand. The suggestion for future research based on this work could be to conduct a comprehensive economic analysis as part of a scenario development, account for a more diverse set of environmental indicators (not only CO_2 emissions), elaborate multifunctional scenarios and explore the longer time horizons. The recommendations for policy making derived from this work could be to revise current planning practices in the energy sector, develop concrete environmental indicators and incorporate them into the analysis of the alternative pathways for the development of the electricity system. This does not necessarily mean that environmental considerations should lead the development of electricity system. However, taking into account the influence of the energy sector on the environment and people's life, environmental indicators should at least be accounted for in the planning stage rather than declaratively assessed after the main decision-making process had already been done.

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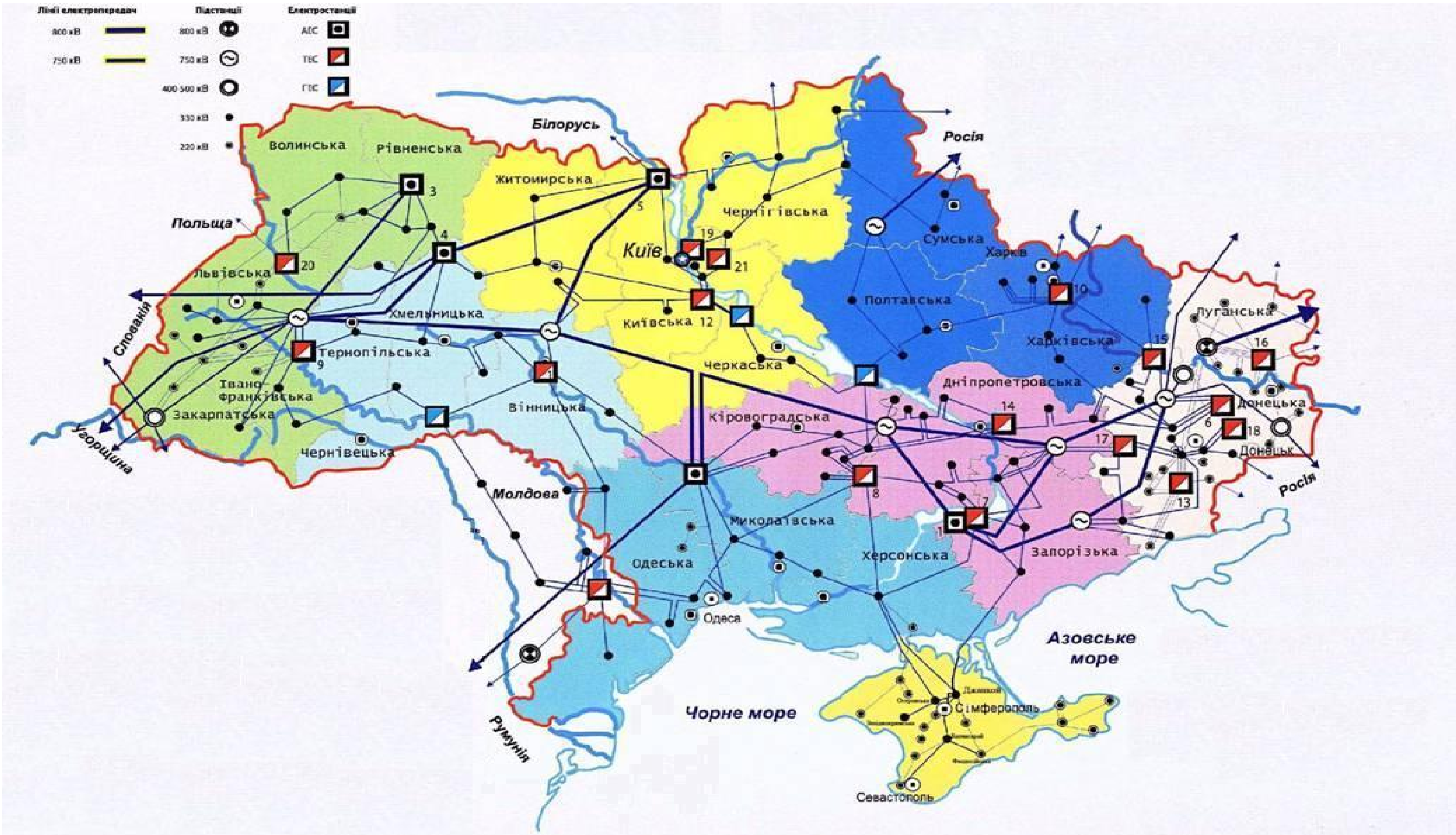
ANNEX A



Legend

transition lines

Power plants

nuclear PPs

TPPs and CHPs

hydro PPs

Substations

Fig. A.1 Scheme of the Ukrainian power network, 2011 (Source: Ukrenergo, 2011)

ANNEX B

Acquis communautaire that should be adopted by Ukraine according to the agreement of accession of Ukraine to the European Energy Community and deadlines for their adoption

- Directive 2003/55/EC concerning common rules for the internal market in natural gas (by 1 January 2012);
- Regulation No. 1775/2005 on conditions for access to natural gas transmission networks (by 1 January 2012);
- Directive 2004/67/EC concerning measures to safeguard security of natural gas supply (by 1 January 2012);
- Directive 2003/54/EC concerning common rules for the internal market in electricity (by 1 January 2012);
- Regulation No. 1228/2003 on conditions for access to the network for cross-border exchange in electricity (by 1 January 2012);
- Commission Decision 2006/770/EC amending the Annex to Regulation No.1228/2003 (by 1 January 2012);
- Directive 2005/89/EC concerning measures to safeguard security of electricity supply and infrastructure investment (by 1 January 2012);
- Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment as amended by Directive 97/11/EC and Directive 2003/35/EC (by 1 January 2013);
- Directive 1999/32/EC concerning reduction in the sulphur content of certain liquid fuels (by 1 January 2012);
- Directive 2001/80/EC concerning restriction of emissions of certain pollutants into the air from large combustion plants (by 1 January 2018);
- Directive 79/409/EC, Article 4(2) on the conservation of wild birds (by 1 January 2015);
- Plan for implementation of Directive 2001/77/EEC on the promotion of electricity produced from renewable energy sources on the domestic electricity market (by 1 July 2011);
- Plan for the implementation of Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport (by 1 July 2011).

Source: Protocol Concerning Accession of Ukraine to the Treaty Establishing the Energy Community 2010

ANNEX C

Form with preliminary questions used for the semi-structured interviews
(Originally in Ukrainian)

EXPERT QUESTIONNAIRE

Development of Ukrainian electricity system

Date	
Time	
Place	
Organization: address,webside, general information	
Interviewee's name and surname	
Position	
Contact details	
NOTES	

1

PRELIMIARY QUESTIONS

1. What do you consider the most critical issues in the electricity system and why?
2. What considerations are accounted in the planning of the electricity system?
3. What parameters and variables determine choice of energy suppliers for the electricity system at the national level?
4. What is the relative importance of different energy sources in Ukrainian energy supply system?

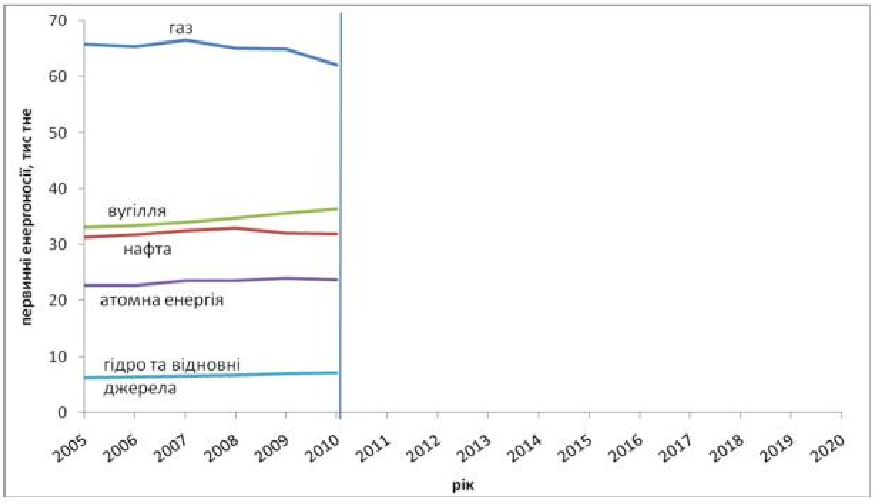
Sources	Not important	Important	Very important	Difficult to answer
Natural gas				
Oil				
Unconventional oil				
Methane gas hydrates				
Coal				
Nuclear fission				
Solar (photovoltaics, solar power towers)				
Wind				
Hydro				
Geothermal				
Tides				
Traditional biomass, waste				
Other				

5. To your opinion, what will be the pattern of primary energy supply in 2030?

Primary sources	2005		2030	
	Absolute, toe	Shares	Absolute, toe	Shares
Gas	65854	41%		
Oil	31297	19%		
Coal	33150	19%		
Nuclear	22678	17%		
Hydro and renewable sources	6275	4%		
Total	159084			

2

6. Given your experience, knowledge and feelings, how could the graphic representation of primary energy supply change over time?

7. 

8. In your opinion, what will be the future trends for such parameters as:
   - Economic growth
   - Energy efficiency/ energy intensity
   - Energy policy directions (fossil-oriented economy vs low carbon economy)
9. What is (a) the most probable scenario of energy electricity system development, (b) the most sustainable and feasible, (c) the most unfavorable one?
10. What crucial factors are associated with implementation of each scenario?
11. What policies would make a significant difference for improvement of the electricity system?

Thank you very much for your participation.

3

ANNEX D

List of stakeholders that were analyzed and sources of information

1. Governmental institutions:

Ministry of Fuel and Energy (MFE). Makuha, V., Deputy minister. Discussion on the roundtable during the Ukrainian Energy Day. Kyiv, 31 May 2011.

National Agency on Energy Efficiency and Energy Conservation (NAEEEC). Senior spacialst. Discussion on the roundtable during the Ukrainian Energy Day. Kyiv, 31 May 2011.

National Company of Fossil Fuels(NCFF). Chief specialist. Informal interview. Kyiv, 13 May 2011.

2. International organisations:

European Bank of Reconstruction and Development in Ukraine (EBRD in Ukraine). Kuusvek, A., Country manager for Ukraine. Official statement on the Ukrainian Energy Day. Kyiv, 31 May 2011.

Energy Community Secretariat (ECS). Kogalniceanu, V., Head of infrastructure unit. Official statement and discussion during the Ukrainian Energy Day. Kyiv, 31 May 2011.

International Centre of Policy Studies (ICPS). Leading expert. Informal interview. Kyiv, 23 May 2011.

3. Business:

Bureau Veritas. Skoblyk, O., Eromin,V. Project managers. Informal interview. Kyiv, 24 May 2011.

Centre of Energy Efficiency Technologies (CEET). Poplavskyj V., director. Informal interview. Kyiv, 25 May 2011.

KT-Energy. Chief specialists in energy sector. Informal interview. Kyiv, 16 May 2011.

4. Non-governmental and research institutions:

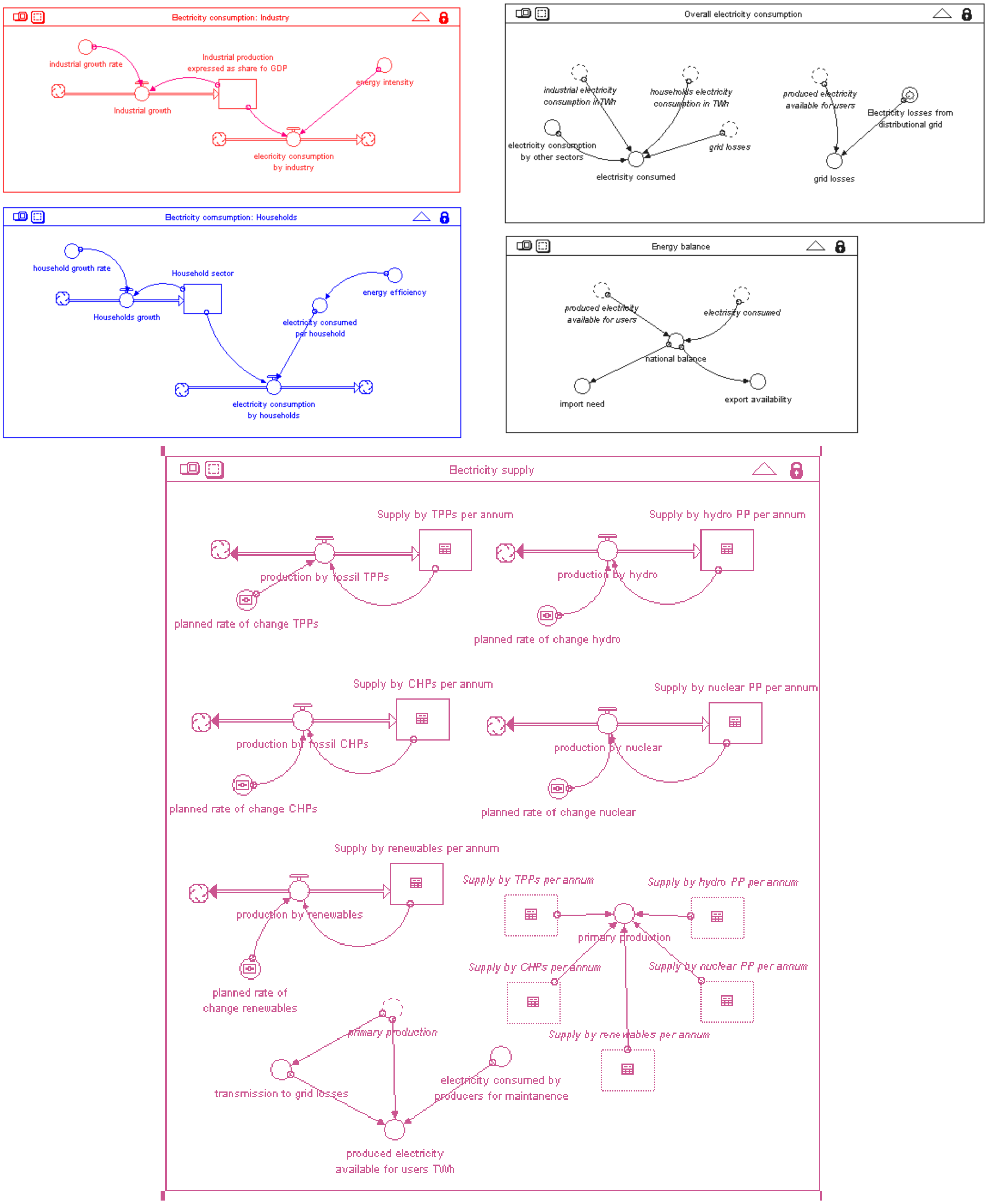
Institute for Economic Research and Policy Consultancy (IERPC). Senior research fellow on energy and economic issues. Informal interview. Kyiv, 19 May 2011.

National Academy of Science (NAS). Dr. Movchan, leading expert. Informal interview. Kyiv, 27 May 2011.

National Ecological Centre of Ukraine (NECU). Pasyuk O., Khmara D., Project coordinators. Informal interview. Kyiv, 27 May 2011.

ANNEX E

Simplified schematic representation of Ukrainian electricity system model developed within the research



ANNEX F

Output from the quantitative scenario assessment of electricity production 2010-2030

Table F.1 Electricity produced by sources within different scenarios, TWh

Electricity source	Electricity produced, TWh				
	2010	2015	2020	2025	2030
Traditional development scenario					
TPPs and CHPs on coal	74,6	83,0	97,0	100,0	123,0
TPPS and CHPs on gas	2,6	2,6	5,0	7,0	10,0
Thermo electro centrals	7,0	10,0	15,0	15,0	15,0
Nuclear PPs	89,1	96,0	96,0	116,0	116,0
Hydro and hydroaccumulating plants	12,9	13,0	15,0	15,0	17,0
Renewable sources	0,2	0,4	0,6	0,8	1,0
Total for the sceanrio	186,4	205,0	228,6	253,8	282,0
Fossil-dependent development scenario					
TPPs and CHPs on coal	74,6	77,0	82,0	83,0	83,0
TPPS and CHPs on gas	2,6	3,0	5,0	5,0	7,0
Thermo electro centrals	7,0	10,0	15,0	15,0	15,0
Nuclear PPs	89,1	82,0	76,0	76,0	76,0
Hydro and hydroaccumulating plants	12,9	13,0	13,0	13,0	13,0
Renewable sources	0,2	0,4	0,6	0,8	0,9
Total for the scenario	186,4	185,4	191,6	192,8	194,9
Green development scenario					
TPPs and CHPs on coal	74,6	70,0	63,0	56,0	45,0
TPPS and CHPs on gas	2,6	3,0	5,0	7,0	10,0
Thermo electro centrals	7,0	10,0	10,0	10,0	10,0
Nuclear PPs	89,1	90,0	90,0	90,0	90,0
Hydro and hydroaccumulating plants	12,9	13,0	15,0	15,0	17,0
Renewable sources	0,2	4,0	8,0	13,0	19,0
Total for the scenario	186,4	190,0	191,0	191,0	191,0