CLIMATE CHANGE COUNTRY STUDY

REPORT

KAZAKSTAN GREENHOUSE GAS MITIGATION ASSESSMENT

Prepared by

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NOTATION

ACRONYMS AND ABBREVIATIONS

CCG	coal cogeneration power plant
CCN	coal condensed power plant
CGP	cogeneration power plant
CNP	condensed power plant
ENPEP	ENergy and Power Evaluation Program
GCG	oil gas cogeneration power plant
GCN	oil gas condensed power plant
GHG	greenhouse gas
GWP	global warming potential
HPP	heat power plant
HR	heat rate
HYP	hydro power plant
ICE	internal combustion engine
IPCC	Intergovernmental Panel on Climate Change
NMVOC	nonmethane volatile organic compounds
NPP	nuclear power plants
NRES	nontraditional renewable energy sources
O&M	operating and maintenance
OECD	Organization for Economy Cooperation and Development
PPP	photovoltaic power plants
SHY	small hydro power plants
UED	useful energy demand
WPT	wind power turbines

CHEMICAL SYMBOLS

CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
N_2O	nitrous oxide
NO_x	nitrogen oxides

UNITS OF MEASUREMENT

cal	calorie
Gcal	gigacalorie
GCE	gram of coal equivalent
Gg	gigagram
kcal	kilocalorie
kW	kilowatt
kWh	kilowatt hour
MMTCE	million metric ton of carbon equivalent
tce	tonne of coal equivalent
TWh	terawatt hour
W	watt

EXECUTIVE SUMMARY

SUMMARY

The mitigation assessment for Kazakstan is addressed mainly to energy sector. In non-energy sector some possible GHG mitigation options and their GHG reduction potential were estimated based on expert judgments.

The mitigation assessment for energy sector is based on ENPEP model. A baseline and six mitigation scenarios were developed to evaluate the most attractive mitigation options, focusing on specific technologies in energy production, which have been already included in sustainable energy programs. According to the projections, Kazakstan's CO_2 emissions will not exceed their 1990 level until 2005. The maximum potential for CO_2 emission reduction is supposed to be about 21 % of the base year 1990 emission level. The main mitigation options in the energy production sector, according to the criteria of mitigation potential and feasibility include rehabilitation of thermal power plants aimed increasing efficiency, use of nuclear energy and further expansion in the use of hydroenergy based on small hydroelectric power plants introduction.

BACKGROUND

The Republic of Kazakstan possesses a reasonable potential comprising accumulated national budget, and natural resources. There are substantial reserves of polymetallic and ferrous ores, oil, gas, coal and other valuable mineral resources on the territory of Kazakstan. It is one of the major regions to produce non-ferrous metals, it has developed branches of ferrous metallurgy, chemical industry, agricultural complex, and machine-building complex. However, the formation of its economic potential has been greatly influenced by certain peculiarities of the previous national economy development. For a long time the Kazakstan economy was developing as a part of the former USSR complex. The formation of the primary industrial structure was determined by both setting up extracting branches and removing of the USSR industrial enterprises to the East during the war, thus, it was completely aimed to satisfy the needs of the "center". The economy of Kazakstan was characterized by essential structural distortions, irregularity and spottiness (a combination of big industrial giants with vast undeveloped regions), the lag in industrial and social infrastructure development, production of finished products, especially complex ones. This led to emergence of heated acute social problems in transition to the market economy and state independence.

The Government of Kazakstan has expressed its concern about climate change and its current policies will continue to focus primarily on solving the severe economic problems. The Kazakstan energy sector is the largest source of greenhouse gas emissions (GHG) according to the National Greenhouse Gas Inventory (*Inventory of Kazakstan Greenhouse Gas Emissions and Sinks: 1990*, 1996), and in Kazakstan, as in country of transition economy, reducing GHG is mostly a side-product of measures and technologies addressed to increasing energy efficiency, energy and fossil fuel saving, etc.

In non-energy sector there are also some possibility of GHG reduction in agriculture, land-use change and forestry, as well as in coal mining.

ENERGY SECTOR

Method and Data

The key goal is to estimate GHG emissions for baseline and mitigation scenarios, as well as costs and impacts of different mitigation scenarios. 1990 was chosen as a base year, since the statistical data available for this year is the most accurate, and because the GHG Inventory was carried out for this year, which is necessary for model calibration. The time horizon for the analysis was chosen from 1990 to 2020.

Model description

For Kazakstan's GHG mitigation analysis the ENPEP model was chosen, since all the mitigation options refer to the electricity and heat generation sector, and because ENPEP can be adapted to the conditions in developing countries and countries with economies in transition.

The ENPEP model, developed at Argonne National Laboratory, incorporates the dynamics of market processes related to energy via an explicit representation of market equilibrium, i.e. the balancing of supply and demand. ENPEP consists of ten technical modules. In this study only two modules of ENPEP were used—BALANCE and IMPACTS ones.

The first step is to draw a picture of the energy supply and demand sectors for the base year. The input data consisted of:

- Base-year energy balance and prices;
- Energy technology performance and costs;
- Energy price projections
- Predictions of energy sector development.

The development of GHG mitigation scenarios required making appropriate changes in the base energy network according to each chosen mitigation option. Then, for each option, the appropriate GHG emissions scenario was developed using the IMPACTS module. In conclusion, all chosen measures were estimated for various criteria: cost of implementation, impacts on environment, etc.

Developed Kazakstan energy system scheme were based upon energy balance data for the base year 1990 and also includes nodes on projected activities through the year 2020 according to baseline scenario. In the current analysis all fuel and energy resources were divided into the following categories: 1) domestic crude oil, 2) imported crude oil, 3) imported gasoline and diesel oil, 4) imported fuel oil, 5) domestic natural gas, 6) imported natural gas, 7) domestic lignite, 8) domestic subbituminous coal, 9) imported lignite, 10) imported subbituminous coal, 11) imported electricity, 12) hydropower resources. The model characterizes 88 electric generation options, including 33 existing and 11 new cogeneration plants. They are 2 existing and 11 new coal-fired plants, 1 existing oil-gas-fired, 27 existing and 3 new hydroelectric plants. There are 27 processes characterized in the model: 14 distribution processes, 3 transportation processes, and existing and 7 new oil refineries. It is simulated that electricity is distributed between metallurgy, industry, residential transport, agriculture and export. The heat is distributed between the largest consumers - industry and residential sector. In this analysis end-use technologies were not considered. The same energy demand for all scenarios were introduced into the energy network according to energy demand projections (see below). All the others nodes of the demand sector were introduced to close the fuel and energy balance. Primary sources of data are the state statistical information (*State Statistical Committee,* 1991) and the monograph by Chokin (*Chokin Sh.*, 1990).

The comparison of model outputs with real statistical data and with the GHG Emissions Inventory shows that the model adequately simulates heat and electricity production. Therefore, the obtained results during the forecast period through 2020 can be considered as good approximation for electricity and heat generation. However, the model overestimates actual prices, that can be explained by a high aggregation level of the energy network and lack of cost data.

Scenario Assumptions and Definitions

The dramatic current and future changes in the economy and system of Kazakstan over the next twenty years make any standard techniques of extrapolation of previous trends of little or no value. Policies and behavior are in the process of substantial change. Thus, scenario assumption used in our analysis provide the initial framework by which to begin to estimate energy demand assuming different key premises.

Current rapid occurring in Kazakstan and the lack of reliable detailed data make it difficult to perform the kind of analysis normally undertaken in OECD countries to project long-term economic growth and energy demand. Trends based on historical data provide limited information about Kazakstan's future as Kazakstan makes the transition to a market-based economy. There is a great uncertainty surrounding macroeconomic and sectoral developments in the short and longer term. As a result, any projection of GDP, population and energy demand at this time would be one of many possible outcomes.

The development of macroeconomic and sociodemographic scenarios is based on methodology designed at the Institute of Market Relations of Republic of Kazakstan. Using this methodology macroeconomic trends are obtained up to the year of 2020.

The population of Kazakstan was 16.7 millions in 1990 and the population density was 6.2 inhabitants per square kilometer. The serious socioeconomic problems that arose a few years ago and the recent emigration wave have resulted in a substantial decrease in population. Using the demographic tendency analysis and the basic demographic indicators for 1990, a forecast was prepared for the period to 2020. It predicts a decrease of the Kazakstan population by about -3.0 % from 1992 to 1997 with an average annual rate of - 0.6 %. As a whole for the period 1990-2020, the population growth can increase by 22.8 %.

One of the key features of the economy of Kazakstan is large shares of industry and agriculture in the overall economy. Recent World Bank economic reports indicate that agriculture and industry shares of employment in 1992 were about 24 % and 30 % respectively. These are about the same shares as reported for 1980. The percentage of net material product originating in the agricultural and industrial sectors in 1993 were about 31 and 51 percent, respectively. It is foreseen that after 1996-1998 the economic decline will come to an end. An average annual GDP growth is expected within the range of -12.7 % in 1990-1996 to 46.2 % in 1996-2000. The six main economic sectors have been analyzed are as follows: metallurgy, agriculture, transports, residential, industry and others. The forecast assumes stable growth rates for all sectors after overcoming the drastic downfall of the 1990-1996 period. It is expected that the total GDP level of 1990 can be reached by 2003.

Using this GDP forecast, relevant scenarios for exports and inflation indicators rate have been designed. Total exports scenario in US dollars was develop as well. It is expected that exports growth rate will increase most considerable after 2000, but the base level of 1990 can be reached only by 2015. According to this forecast of local currency (tenge) inflation, the inflation will reduce by one half from 60 % in 1995 to 33 % in 1997. After 1997 it will gradually reduce and its stabilization is expected to be 3-5 % by 2005, that is close to average world value.

Using the GDP forecast and taking into account experts' estimates, relevant scenarios for energy resource prices have been developed. These projections are based on November 1994 real prices at a fixed exchange rate of 51.4 tenge per US dollar. It is also assumed that there is no real increase in the world prices. In our study, when energy resource prices forecast was developed it has been assumed that prices of domestic and imported energy will go up at the same pace. The prices of imported oil, subbituminous coal, fuel oil and electricity will reach the world prices in the year 2000, for imported gas this will happen in 1995.

Based on GDP, import-export and population growths final energy demand projections were developed. According to the projections, growth of coal, gas, oil products and heat demand are about of 1.06, 1.2, 1.5, 1.6 and 1.3 times respectively in 2020 compared to 1995 can be expected. This growth compared to 1990 is insignificant, because of decline in period of 1990-1998. Experts judgments bottom up approach was used for developing electricity demand and electricity export projections. Four major economic sectors are addressed at this stage with emphasis on energy intensive subsectors. It was assumed that electricity export will not change after the year 2000. The result shows a growth in power energy demand of about 1.3 times by 2020 year compared to 1990 and a growth of about 1.6 times compared with 1996. Electricity demand downfall of the 1990 - 1997 period reflects the general decline of national production.

Since general scenario assumptions have been defined, scenarios for long-term development of energy sector have to be elaborated. To conduct the analysis of the most promising mitigation options the baseline and six alternative mitigation scenarios based on ENPEP model have been developed. Let us define considering scenarios.

At first, all possible GHG mitigation options in the energy production sector in 1996-2020 were considered. We examined six main directions for GHG mitigation in the energy production sector of Kazakstan. Based on screening of the mitigation options by the number of major criteria, only five of them have been chosen for further analysis. They are: the rehabilitation of cogeneration and thermal power plants (TPP) aimed to increasing efficiency; further expansion in the use of hydro power energy and the use of wind, solar and nuclear energy. Table ES1 presents the estimated additional electricity generation by new, more efficient TPPs and possible produced electricity at the expense of installation of renewable and nuclear power plants according to the data of the Ministry of Energy and Coal Industry of Kazakstan (*Program for Urgent Measures on Energy Development*, 1996) .

Table ES1.Electricity Generation for Different Mitigation Options (TWh)

Mitigation option	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020

Modernization of TPPs:					
Cogeneration cycle	3.10	7.70	10.20	14.70	18.20
Combined-cycle	8.56	14.03	15.47	16.01	16.01
Hydro Power Plants	0.680	1.7	2.9	4.1	6.5
Solar Power Plants	0.125	0.250	0.250	0.500	0.500
Wind Power Plants	0.914	0.675	0.750	0.900	1.050
Nuclear Power Plant	-	-	-	2.00	5.00

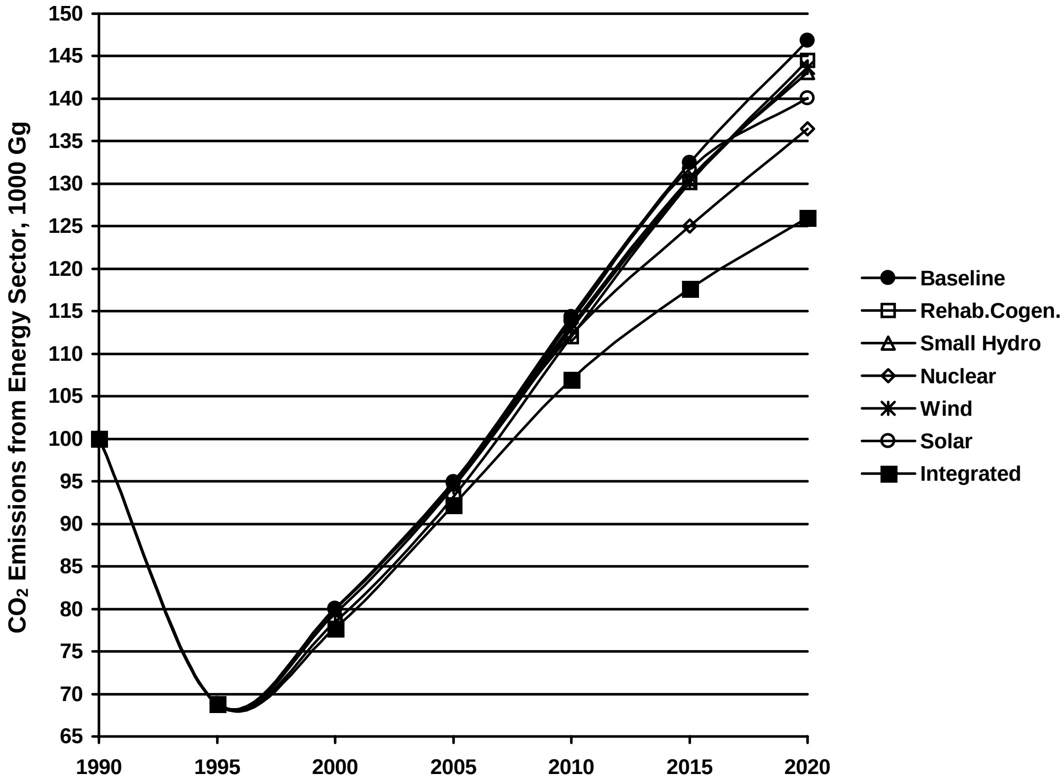
In addition to baseline scenario we developed the following six alternative scenarios: (1) **Rehabilitation of Cogeneration** scenario, which includes the options on modernization of cogeneration and thermal power plants; (2) **Small Hydro** scenario, which includes hydroelectric power plants installation; (3) **Wind** scenario, which includes wind power plants installation; (4) **Nuclear** scenario, installation of nuclear power plant; (5) **Solar** scenario, which includes the use of solar energy and (6) **Integrated** scenario which includes all mentioned mitigation options. When all those mitigation scenarios had been developed it was assumed, that additional energy capacity would be introduced through the year 2020 according to data, presented in Table ES1. In addition, the number of additional assumptions have been accepted for different mitigation scenarios. For example, for Rehabilitation Cogeneration scenario capital expenditures have been increased by 20-50 % , as more perfect facilities are more expensive. When the scenario with installation of hydropower capacity was elaborating we took into account, that an installation the large plants has been taken into account in the baseline scenario, therefore only small ones were involved in the mitigation scenario developing. Price of nuclear fuel was assumed to be twice more than the most expensive type of fuel (fuel oil) to take into account expenditures for utilization of nuclear waste. To run the mitigation cases related changes have been introduced in the energy network, BALANCE module.

Results

GHG emissions

The GHG emissions were projected according to the baseline and mitigation scenarios of the energy sector development using the IMPACTS module of ENPEP package. The projection was accomplished for CO_2, CH_4, NO_x, CO, and NMVOC, as well as for SO_2 and particulates. All scenarios have the same emissions in the base 1990 year. The results for CO_2 which is the most important GHG, are presented in Figure ES1.

Figure ES1. CO2 Emissions for the Baseline and Mitigation Scenarios (1000 Gg)



The difference between the base year CO_2 emissions estimates using the IMPACTS module and the National GHG Inventory (*Monokrovich et al*., 1996) is not significant and amounted to about 5 percent. The results obtained for the baseline scenario indicate the following level of CO_2 emissions compared to the 1990 base year: 1995, 69 percent; 2000, 80 percent; 2005, 95 percent; 2010, 114 percent; 2015, 132 percent and 2020, 147 percent. Such a time run of CO_2 emissions reflects the general decline of economy at the first stage of a transition period. This projection differs from those developed by expert judgments approach (*Monokrovich et al.*, 1996) and most likely reflects a very optimistic GDP projection.

As we can see from the Figure ES1, Cogeneration Rehabilitation, Wind and Solar scenarios considered can lead to emission reduction since 2000. Installation of small hydro power plants (Small Hydro scenario) can reduce emissions since 2005, and introduction of the nuclear power plant (Nuclear scenario) can reduce them since 2010. The maximum CO_2 emissions reduction under Integrated scenario totals about 21 thousand Gg or million metric tons, or about 20 % of the base year 1990 emissions level. The comparison of the baseline emissions level with each mitigation scenario shows that the potential of CO_2 reduction considerably differs under different mitigation scenarios. Development of nuclear energy can lead to the most considerable CO_2 emissions reduction. According to the Nuclear scenario, there are 1.9; 3.8 and 7.1 percents of annual emission reduction in 2005, 2010 and 2020 respectively in comparison with the baseline scenario. The rehabilitation of power plants (Rehab.Cogen. scenario) can reduce annual CO_2 emissions to 1.6 thousand tons by 2000 and about 2.3 thousand tons by the year 2020, that totals about 2 percent of the baseline level. The mitigation potential of the Small Hydro and Wind scenarios totals from 0.2 to 2.6 percents in 2000 and 2020 respectively. Level of CH_4 , NOx , CO and NMVOC emissions is incomparably less than level of CO_2 emissions. At the same time the relative changes of the other GHG emissions reductions, as well as of SO_2 and particulate emissions under the different Mitigation scenarios compared to the baseline scenario are similar to those for CO_2.

Energy Use

Implementation of all considered mitigation measures would result in reduction of coal and oil utilization as well as reduction of import of electricity. Under the baseline scenario coal consumption is to be reached its level of the year 1990 after the year 2010 and will increase by 35 % in the year 2020. More considerable changes under the baseline scenario are expected to occur in the consumption of gas and fuel oil. The use of these fuel will increase twice, and twice and a half by the end of the year 2000 and by the end of the considering period, respectively, compared to the year 1990. Introduction of small hydro power plants (Small Hydro scenario) offers predominantly reduction of coal consumption and slight reduction of oil-gas consumption. Putting into operation the nuclear power plant ousts coal only from fuel balance and the reduction is significant because of large capacity of station. The reduction of traditional fossil fuel consumption at thermal power plants totals from 3,1 % to 13,3 % in 2000 and 2020 respectively. As expected, all mitigation measures lead to decreasing share of electricity generation at traditional fuel-fired plants, i.e. oil-gas and coal condensed plants compared to baseline conditions. Share of nuclear, wind, hydro and solar energy is to be increasing by 6 %, 2 %, 1 % and 0.8 % respectively by the end of considered period. Under Integrated scenario decrease of electricity import can reach more than 27 % of the baseline level by the year 2020. The most significant import reduction (from 0.4-2 % in 2000 to 12 -13 % in 2020) can be achieved under Wind and Small Hydro scenarios.

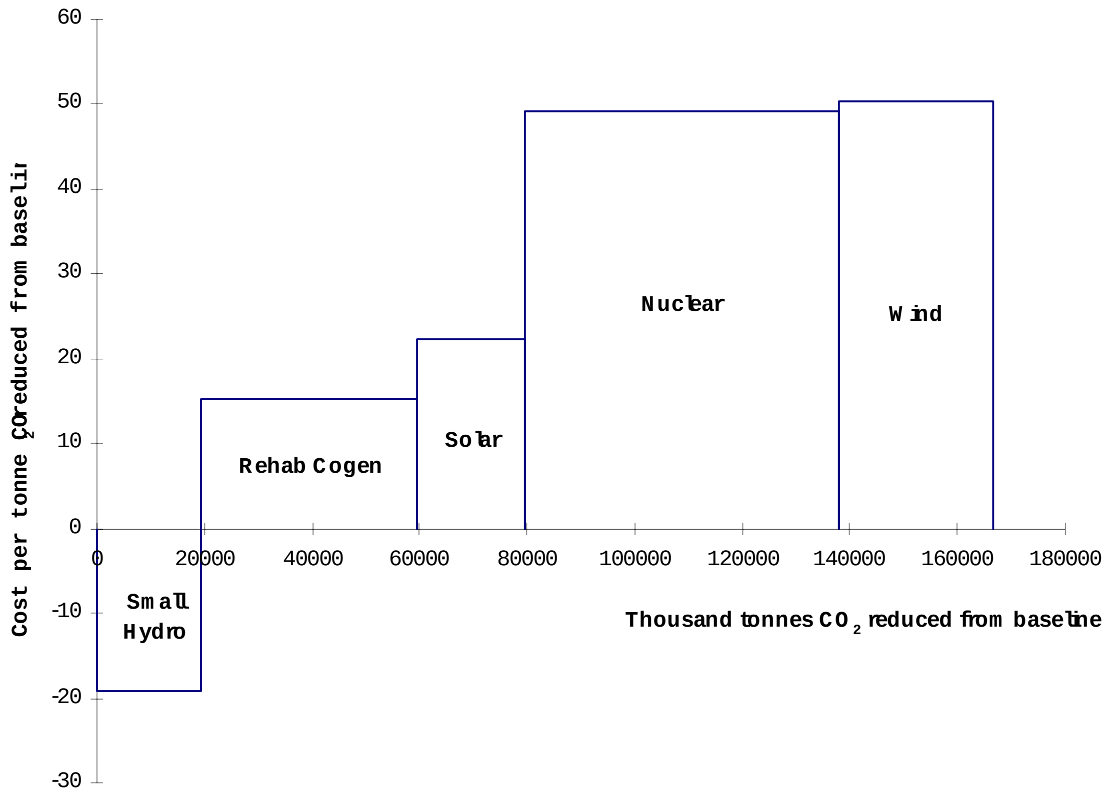
Cost Analysis

The presentation of the costs of emission abatement depends on the model used in the analysis, on level of aggregation and degree of assurance and completeness of the input data. In this study cost analysis supposes to be mainly of qualitative nature because of rather high level of aggregation of the energy network and high level of uncertainties of cost data. Nevertheless, we supposed that even such analysis is useful for initial assessment of costs of emission abatement for every considered mitigation scenario and allows to compare different mitigation measures on their additional energy system costs.

To compare the total costs of the energy system under different mitigation and baseline scenarios we used cost output of the BALANCE module. This cost figure investment costs to replace and expand stock in energy supply (through introducing or increasing capital expenditures and O&M costs for new capacities); fuel supply costs, and other costs like capital expenditures and operating and maintenance costs.

Cost curves for emission abatement express the cost per unit of emission reduction as a function of the quantity of GHG reduced *(J. Sathaye and S. Meyers*, 1995). The curves can be established in different ways, depending on which model is used and the level of detail in study. The Figure ES2 presents discrete step CO_2 - reduction cost curve, which we chose for our study to compare different mitigation options.

Figure ES2. CO_2 - Reduction Cost Curve



In the Figure ES2 the blocks of such curves correspond to individual mitigation scenarios with the widths representing the potential GHG reduction and the heights representing the cost per unit of GHG reduction. In our analysis we considered average costs which reflect the difference in total energy system costs, expressed in sum of difference of producer energy prices under mitigation and baseline scenario when a specific mitigation scenario is compared to baseline, divided by the difference in emissions between the two scenarios. The cost curve in Figure 4 was developed for all considered time period and presents cumulative reduction over the time horizon studied. As we can see from the figure, the Wind scenario has the highest cost of emissions abatement, totaled about 50$ per tonne of reduced CO_2. It followed by Nuclear scenario, which has a bit lower cost of emissions abatement. Rehab. Cogen scenario has the lowest cost of emissions abatement amounted less than a half of that for Wind scenario. Small Hydro is the only scenario which lead to saving funds, because the installation of small hydro plants lead to decreasing of total energy system cost.

Summary of Mitigation Options

In the table below the description of all considered mitigation options with respect to main criteria is presented.

Table ES2.Summary of Mitigation Options

Criteria	Nuclear	Rehab. Cogen.	Wind	Small Hydro	Solar	Integrated

GHG reduction CO_2 (1000 tonnes):						
Cumulative over the period	58,288	40,083	28,622	19,421	18, 022	157,851
Annual average	10.40	2.33	3.14	3.74	6.74	20.82
Methane (net annual average change, tonnes)	104	20	31	37	52	206
Cost of emission abatement, $/tonne	49.05	15.26	50.33	-19.96	22.35	31.21
Reduced import (average annual value, US $)	Uncertain	Uncertain	64,606	68,793	24,088	145,522
National environmental impacts (net annual reduction, tonnes):						
Sulfur oxides	745	148	224	265	375	1466
Particulates	863	112	256	297	106	1619
Potential impacts implementation policies	Low	High	Medium	High	Low	-
Sustainability of option	Medium	High	Medium	High	Low	-
Consistency with national development goals	High	High	Medium	High	Medium	-
Uncertainty of data :						
Technology performance and costs	Low	Low	High	Low	High	-
Costs of implementation programs	Low	Low	High	Low	High	-

As one can see, Nuclear scenario has the highest GHG and the other pollutants reduction potential. It suppose to be from about 1.5 to 3 times more than those for the other scenarios and cumulative for the whole period reduction totaled more than 58 thousand metric tons. At the same time the cost of emission abatement of the scenario is supposed to be the highest and exceeded those for the rest scenarios in 2-3 times.

Developing a nuclear power has a good potential in Kazakstan because it has 25 percent of the world resources of uranium. Installation of the two units of nuclear turbine instead of putting into operation six coal units at the South Coal Power Plant, which is the main Nuclear Scenario assumption, and it is also included in the plans of the Ministry of Energy (*Program for Urgent Measures on Energy Development*, 1996) . But the main legislation act about developing nuclear energy in Kazakstan—the "Law about Use of Nuclear Energy"—is still under consideration by the Kazak Government. Therefore, an assessment of this option from the point of view of sustainability and potential impacts implementation policies is rather uncertain in the nearest future, in spite of the fact that developing nuclear energy meet national goals in general.

Rehabilitation of Cogeneration mitigation scenario looks as one of the most attractive one. Firstly, modernization of Thermal Power Plants has a big potential for saving GHG emissions, taking second place after Nuclear scenario. For the whole period it supposes to total more than 40 million metric tons. At the same time this scenario has rather low cost of emissions abatement. As one can say that reducing 1 % of GHG emission "costs" about half of percent of increasing price of electricity. For comparison, this value for Nuclear and Wind scenarios amounted to about 2 %; for Small Hydro and Solar scenarios — 0.7 % and 1.5 % respectively. Secondly, this option has been included in all mentioned above national energy development programs as the main priority of the medium- and short-term measures in electricity generation sector. Therefore, this option has good possibility of implementation, and it is quite sustainable and consists with national development goals. At least, data about technology and implementation costs of this measures are the most accurate and complete.

Developing wind energy in Kazakstan (Wind scenario) is one of the most supported and sustainable option for long - term program of energy development in Kazakstan (*Program on Energy Saving in the Republic of Kazakstan*, 1996). According to this study Wind scenario allows to reduce about 1.2 % of annual baseline GHG emissions. From the other hand, it suppose to be the most “expensive” scenario. Expenditures for this scenario totals about 0.4 billion dollars. From the other hand the scenario has the most reducing import possibility. As mentioned, it appears that favorable wind resources exist in Kazakstan. But at the same time for Kazakstan conditions special systems need to be designed that will not only withstand the strong winds but also cope with the frequent reversal of wind direction. Therefore data about costs and technology implementation is of high level of uncertain.

The installation of the small hydro power plants (SHP) are planning since 2005, so the suitable scenario lasts 16 years, therefore this option has a big potential of cumulative GHG reduction. It was obtained, that under this scenario the reduction of CO_2 emissions supposed to be 1 % of annual baseline level in average during this period. The introduction of small hydro power plants is the most profitable option. It is the only option that leads to reducing the price of electricity and therefore saves funding -- $0.4 billion in 2005 - 2020 or $24 million annually compared to baseline scenario. Moreover, under Small Hydro scenario expenses for import decrease on $ 0.4 billion. The introduction of SHP have a good chance from the point of view of technology availability, as far as a production of SHP is well organized in Kazakstan. At least, developing hydro power in Kazakstan has a very positive social effect because it will permit to improve electricity supply in the South and South-East of Kazakstan, where the largest deficit of electricity is experienced. The measure has been included in all the energy development programs as well.

Reducing GHG emissions under Solar scenario can be amounted for about 0.9 % annually of the baseline level. Introduction of solar power plants leads to GHG reduction twice less than modernization of TPPs (Rehab. Cogen. Scenario), but the expenditures are twice more. However, at the same time installation of solar plants, according to the scenario, can cause reducing import by approximately $10 million annually.

Integration of all options is supposed to lead to total cumulative CO_2 emissions reduction of 158 million tonnes or, in average, 5.7 million tonnes annually. Expenditure for the reduction is about $ 4.9 billion, and for considering scenario every percent of CO_2 emissions reduction lead to 1 % of increase of electricity cost.

NON-ENERGY SECTOR

Agriculture

One of the important mitigation option in agriculture can be implementation of the technologies of biogas utilization. The implementation of this option is potentially very effective. Biogas contains 55-80 percent methane and 20-45 percent CO_2. Assuming that by 2010 only 10 percent of the available resources of biogas are utilized, and by 2020 this share amounts to 20 percent, the total methane emissions reduction can be about 800 Gg in 2010 and 1,600 Gg in 2020. According to expert assessments (Monokrovich, et al. 1996), the implementation of this measure could decrease methane emissions by 5-6 percent of the base year emissions from agriculture annually.

Land-use change and forestry

Among the options in the non-energy sector related to forestry, the most promising mitigation measure is increase of carbon absorption by expanding the planted area and preserving of existing absorbers. According to expert estimates the optimal share of forested territory for Kazakstan is 5.1 percent. According to the Program "Forests of Kazakstan" the forest area of the country should be increased up to 4.6% of the whole Kazakstan territory by 2010 and up to 5.1% - by 2020. The areas (about 3.8 million hectare) are to be planted mostly with mixed softwoods forest. According to the IPCC recommendations annual increment in biomass should be taken as 14.5 tonnes/ha. Taking into account that carbon fraction of dry matter is equal 0.45 (*IPCC/OECD...*, 1994), annual carbon uptake increase is equal to 2,140 Gg/year. If the forested area increases to 5.1 percent of the territory of Kazakstan, the CO_2 uptake by forests will increase from 1.7 to about 2.7 percent of the total CO_2 emissions. The cost of implementation of this option is assessed as $3.5 billion. To implement such measures foreign investments are necessary.

Planting of perennial herbs and bushes on available land after the decrease in the area of cultivated fields is another emission mitigation measure. In 1991, crops were cultivated on 24 million ha. In 1997, it is planned to use only 18-19 million ha: in the future this use of land may decrease to 16-18 million ha. Perennial herbs would be planted in the territory thus freed, which would increase the absorption of CO_2. In the near term, the implementation of this measure would cost 1.2 million US $.

Coal Mining

Every year about 200 million m^3 of methane are extracted by degasation in the mines of Karagandy coal basin, 12-15 million m^3 of which are utilized in boilers to generate heat. The rest of methane goes irretrievably into the atmosphere thus polluting it. At present methane practically is not used as a feedstock for oil industry but is burnt out in various energetic installations. Being a secondary power resource in the processing of coal layers, methane can be used both as an power supply source and as a feedstock for chemical industry. The mitigation option from coalbed methane utilization may be very attractive from the viewpoint of criteria of consistency with national environment goals and indirect economic impacts.

INTRODUCTION

Kazakstan is one of the countries that signed and recently ratified the UN Framework Convention on Climate Change (FCCC). An important commitment in the UN FCCC is conducting greenhouse gas (GHG) mitigation analysis.

The results of evaluation of mitigation options in Kazakstan are presented in the report. The GHG Mitigation Analysis is a part of the US Country Studies Program which also includes GHG inventory, and vulnerability and adaptation assessment.

This work has been done by Working Group of Kazak Country Study Team at the Climate Laboratory of the Kazak Scientific and Research Institute for Environment and Climate Monitoring in cooperation with the specialists from Ministry of Energy and Coal Industry, Ministry of Agriculture as well as the Institute of Market Economy of the Republic of Kazakstan. For fulfillment of the work official statistical data and primary data of organizations taking part in the Project were used.

The Report consists of the chapters covering mitigation analysis in the energy sector and non-energy sector.

The main objective of carrying out Mitigation analysis in energy sector is to evaluate the most attractive mitigation options, focusing on specific technologies in energy production, which has been already included in sustainable energy programs. The GHG mitigation analysis in energy sector is carried out on the basis of the ENergy and Power Evaluation Program (ENPEP) model of energy planning, developed by the Argonne National Laboratory (USA). 1990 was chosen as a base year, since of this year statistical data are the most complete, and also, because the GHG Inventory was carried out for this year, which is necessary for model calibration. Time horizon for the analysis was chosen from 1990 until 2020.

In this report authors tried to follow structure of reporting a mitigation assessment, suggested by GHG Mitigation Assessment: Guidebook (*J. Sathaye and S. Meyers*, 1995) The structure of the report of the study is as follows.

The overview of energy sector and GHG emission inventory in 1990 is presented in Section 1.1.

Model energy sector network for the base year and data description, as well as the results of calibration of the model (using the BALANCE module) is given in Section 1.2.

Main scenario assumption and energy demand projections is considered in Section 1.3.

Identification and screening mitigation options in energy production sector is considered in Section 1.4.

In Section 1.5 description of the baseline and mitigation scenarios of the energy sector is presented.

The obtained results is presented in Section 1.6. The baseline and mitigation scenarios of appropriate GHG emissions (using IMPACTS module) are analyzed in section 1.6.1. Energy use under different scenarios and cost of emission abatement, based on analysis of cost curve are presented in 1.6.2 and 1.6.3 respectively. In section 1.6.4 all chosen measures and scenarios were estimated on various criteria: cost of implementation, impacts on environment, etc.

In Part 2 some possibilities of GHG mitigation non-energy sector based on expert judgments is considered.

Main conclusions, limitations and next steps in further mitigation analysis are presented in conclusion sections.

1. ENERGY SECTOR

1.1 Overview of Energy Sector and GHG Emissions Inventory in Kazakstan

The energy sector occupies a key position in Kazakstan's national economy. Kazakstan is richly endowed in raw materials, including large deposits of oil, natural gas, coal, copper and other nonferrous metals. Energy and raw materials were traditionally exported to the other republics of the former Soviet Union. Energy and metallurgy are two of the most important sectors in the Republic's economy. These two sectors are the primary sources of foreign exchange and in attracting foreign investment, restoring traditional trade patterns, integrating Kazakstan into the global economy via the development of new trading and transport routes, and providing a competitive advantage to existing energy-intensive and mineral-intensive industries.

The substantial increase in fuels prices has resulted in corresponding increases in labor, material, spare parts and facility costs. The production transmission and distribution costs of electricity and space heating have also increased. The power industry is a "natural" monopoly which, by its nature, is still developing into a true market economy. The development of this industry requires long-term planning, regulatory adjustment and considerable investment.

1.1.1 Electric power system

At the moment there are 11 power electricity systems in Kazakstan, of which Altai, Karagandy, Pavlodar, Ekibastuz, Akmola and Kostanai are integrated into the North Kazakstan energy system; Almaty and South Kazakstan - into the Middle Asia energy system; Atyrau and Uralsk power networks - into the middle Volga energy system; the Aktobe power network of the West Kazakstan complex - into the Ural energy system. The North Kazakstan energy system provides communication of the Siberia energy system and Ural in Russia along electricity transmission lines under 500 and 1,115 kilowatt (*Dukenbaev*, 1992). The vast size of the republic, second only to Russia in the former Soviet Union, as necessitated a vast transmission system of varying voltages. The length of the system is almost half million kilometers. In Kazakstan there are vast energy resource reserves. These reserves have the potential to cover the country's own and still leave a surplus which could become available for export to other countries. Kazakstan expects to become a net exporter of both raw energy resources and electric power.

The present electric power sector of Kazakstan can be characterized by the following basic indicators: the capacity of heat power plants (HPP) is approximately 18 million kilowatt (kW) (the annual output is about 86 billion kWh) including 15.6 million kW from HPP, 2.2 million kW from hydro power plants (HYP) and 0.17 million kW - from nuclear power plant (NPP). The structure of electric power output by the fuel types is as follows: coal HPP (79 %), oil-gas HPP (12-13 %), HYP (6-7 %), NPP (0.7 %).

In 1990 the electricity consumption was 102.2 billion kWh. About 29.3 billion kWh was imported to meet the total demand for energy in the republic: 19 billion kWh from

Russia and 10.3 billion kWh from the Middle Asia. However, Kazakstan not only buys, but also sells electric power. The exports amount to 11.9 billion kWh. It should be noted that out of 163 operating turbines: 8 turbines are completely depreciated, but are still operating because of the power deficiency; 22 turbines will depreciate in 2-3 years, and 54 more turbines will depreciate by the year 2000. These 84 turbines represent 50 % of the stock and 20 % of the stipulated capacity of HPP.

Heat consumption is one of the most important components of the fuel and energy balance in the Republic of Kazakstan. During past 15 years (1975-1990) national economy demand for heat of middle and low potential went up 2-3 times. The annual heat consumption in the republic is approximately 442 million gigacalories (Gcal). Heat load is covered by HPP (about 200 million Gcal), large commercial and municipal boilers (143 million Gcal), and small boilers, private and commercial facilities (79 million Gcal). More than 80 % of heat produced by the republic's energy resources is consumed by urban populations (about 40 % of population), and rural residents (approximately 60 % of population). The biggest heat consumers are residential sector and industry, the latter uses 68.5 % of heat.

1.1.2 Primary energy carriers

The total energy resource balance is dominated by black and brown coal. The Ekibastuz and Karaganda coal basins are of world importance. Maykube coal basin and Torgay brown coal basin contain significant reserves.

The coal industry is represented by two large corporations such as “Karagandacoal” and “Ekibastuzcoal” and a number of small enterprises which have significant technical and economical characteristics among coal-extracting enterprises. The total amount of coal extraction is 130 million tonnes, while domestic demand is 82.9 million tonnes. Coal is the republic's main source of fuel. For example, the share of coal in the fuel balance of the republic is 90 % for power generation and 40-50 % for residential sector. 84-85 million tonnes of coal is consumed in energy and residential sectors, 15 million tonnes are used by industry. An additional 50 million tonnes of coal is exported, including 8 million tonnes of coal for coke. 10 million tonnes of coal is imported from Russia and 1 million tonnes is improved from the Middle Asia (*Baimuhametov*, 1992).

In 1990 26.6 million tonnes of oil were extracted in Kazakstan, and 12.6 million tonnes of oil were imported to meet refinery capacities. 2.5 thousand tonnes of light oil products, 4.34 thousand tonnes of diesel oil and 530 thousand tonnes of fuel oil are also imported in Kazakstan. The capacity of refineries is 18.5 million tonnes a year. Out of 11,940 thousand tonnes demand for light oil products, 9,226 thousand tonnes (77.3 %) is produced locally, the demand for lubricating materials (530 thousand tonnes) is completely satisfied by importing from other regions. The Republic of Kazakstan is a big oil exporter: 20,8 million tonnes of crude oil are exported annually. This oil is not processed at Kazakstan's refineries due to economic and technological constraints. The oil extracted in Kazakstan contains large amounts of heavy hydrocarbons and the refineries are not to process this oil. At present out of 7.9 billion m^3 of natural gas extracted in Kazakstan, only 2.9 billion m^3 is processed on the spot. The demand for gas is covered by exports, primarily from Russia and Middle Asia. These two regions account for 12.8 billion m^3 while domestic demand is 16.5 billion m^3. The share of gas in the fuel balance is less than 15 % (*Sartaev*, 1991).

1.1.3 Renewable resources

Kazakh electric power system is in deficit to fulfill consumption requirements and is obliged to import electric energy from neighboring countries of Asia and Russia. As mentioned in view of significant resources of cheap coal in Ekibastuz and Karaganda, the energy production is based mostly on coal burning power plants that negatively affect the environment. The largest deficit is experienced in the south which is supplied by local facilities and power imports from Asia and the North-South power transmission line.

At the same time, it appears that considerable renewable energy resources exist, particularly in the southern part of the country. Excellent, but not fully utilized hydro resources and considerable potential wind resources. There are a number of sites that are considered as prime locations for the development of renewable energy projects, especially for wind and small hydro (for example, the Dzhungar Pass, near the border with China, where an excellent wind corridor exists).

Hydro power resources are of great importance. Hydro potential of rivers is roughly estimated to be 30 billion kilowatt hours (kWh) of electricity per year, of which at present a little more than 20 % is used. During past years several ecological disasters have created an interest in renewable energy sources (RES), such as wind power turbines (WPT), photovoltaic power plants (PPP) and geothermal sources, including them into the energy balance is the pressing problem. Nowadays, the fraction of RES in the overall electric power output is 0.3 %, 80 % of which is provided by small hydro power plants (SHY), and the fraction of solar, wind and thermal water power amounts to less than 0.06 %.

Geothermal and biomass resources are known to exist, but to a much lesser extent.

There are several scientific and technical institutes, universities, and centers where an impressive amount of work has taken place in the past on renewable energy aspects. Although some, if not most, of this work is presently stopped owing to lack of finding by the original sponsors. The technical capabilities of the institutions, the human potential, and the strong interest still exist and could form an excellent basis for the development of renewable energy. Indeed, such a potential is a necessary condition for the successful development of renewable energy in any country. In addition, the existence of the manufacturing capabilities in various sectors, albeit not directly related to renewable energy technologies, can form the basis for the establishment of local renewable energy industries, once the market for such renewable energy products is established and commercialized.

1.1.4 Energy prices

Energy prices play an important role in the economy of the country. Under centrally planned economic conditions, the energy prices were set by the government and most of these prices were substantially subsidized, in particular prices paid by households for heat and electricity. At present, although the process of price deregulation is evolving, the energy prices are still controlled by the government. The new pricing system aims to gradually diminish the subsidies with the ultimate goal of completely eliminating them.

For energy development to succeed, particularly if international lending institutions and investors are to be attracted, a proper energy legal and regulatory framework has to be put in place, along with adequate levels and structure of energy prices and tariffs. The

Decree of the President of the Government of Kazakstan has recently (December 1995) been issued, outlining a scheme of sector reform and envisaging the creation of an independent regulatory agency to establish national tariff levels for energy services that have a monopolistic character. Foreign consultants, sponsored by USAID, are assisting the Government to take the necessary steps to implement the decree. The preliminary information indicates that price levels are still inadequate even to cover running costs. The Government has decided to proceed in the direction of commercialization and privatization of energy entities.

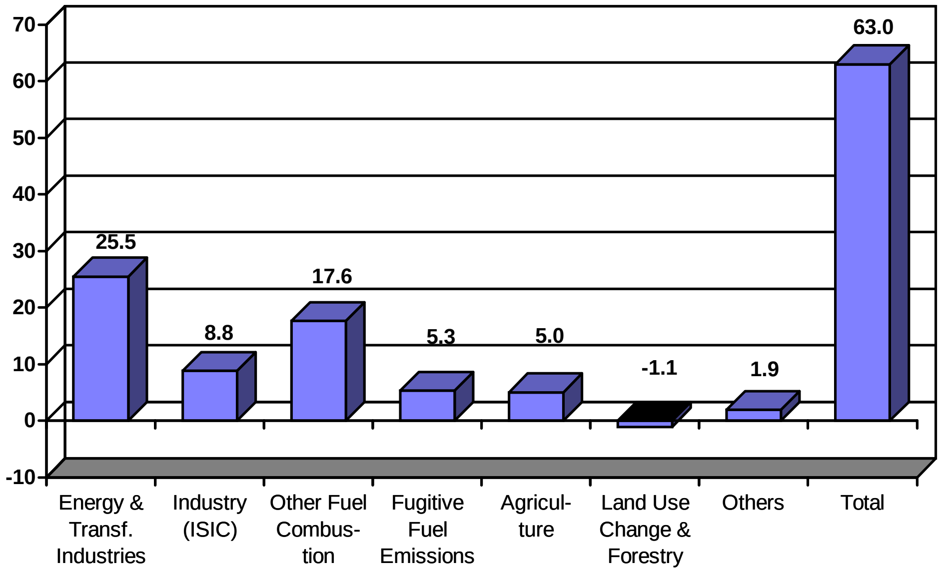
In conclusion we can note that a) the country is dependent on imported electricity to a large amount which the authorities would like to decrease; b) good renewable energy resources seem to exist; c) considerable local capabilities exist and the Government has placed high priority to their development; and d) policy reforms in the energy sector seem to be moving forward, which would create an enabling environment for energy development.

1.1.5 Structure of GHG Emissions

The emissions of six GHG - carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), nitrous oxide (N_2O), methane (CH_4) and non-methane volatile organic compounds (NMVOC) - from the territory of Kazakstan in 1990 has been determined as the result of the GHG inventory (*Monakrovich, et al*., 1995). For calculations, the methodology of IPCC/OECD (1994) is basically used.

Figure 1 presents the breakdown of the total emissions by economic sector in million metric tons of carbon equivalent (MMTCE). These numbers depend on the value of the global warming potential (GWP) for each gas; the GWP is used for the comparison of inputs of various GHG into the total emission (GWP for CO_2 is assumed to be 1). According to IPCC (*IPCC/OECD*, 1994), the GWP for methane is 11 or 22 with the consideration of indirect impacts; GWP for nitrous oxide is 270. CO_2 accounts for more than 96 % of all GHGs.

Figure 1. Total Kazakstan Greenhouse Gas Emissions By Source: 1990 (MMTCE)



The most important emission source is the energy production sector: the emissions of more than 50 Heat Power Plants and large boiler-houses considered in the inventory amount to 25.5 MMTCE or more than 40% of all GHG emissions. The second most important emission source is the industrial enterprises; their emissions are about 9 MMTCE or 14% of total emissions. The list of major emitters in this sector contains 105 facilities. Somewhat less are emissions from the facilities of fuel extraction and processing, from internal combustion engines (ICE) and from the residential sector. Their total (the “Other Fuel Combustion” column in Figure 1) is 28% of the total emissions. The emissions from mines and refineries (Fugitive Fuel Emissions) and agriculture amounted to 8 % each.

Calculation of the forest absorption of CO_2 has shown that the share of this process is about 2% of the total emissions. It is clear from the emissions inventory overuses that measures in the energy production sector should play the major role in the development of the GHG mitigation options in Kazakstan.

1.2 Model Description

There are a number of energy-economy models which can be applied to a GHG mitigation study. These models vary greatly in terms of their sophistication, data intensiveness, and complexity. Usually, energy-economy models are divided into two types, “bottom-up” and “top-down”, depending on their representation of technology, markets, and decision-making.

For instance, energy accounting models, such as LEAP and STAIR, represent an engineering or “input-output” conception of the relations among energy, technology, and the services they combine to produce. The STAIR and LEAP models can simulate the effect of selected mitigation options on overall costs and emissions. In engineering optimization models such as ETO and MARKAL, the model itself provides a numerical assessment and comparison of different policies. The main criterion is total cost of providing economy-wide energy services under different scenarios. In hybrid models, such as MARKAL-MACRO and ETA-MACRO, the basic policy measure is the maximization of the present value of the utility of a representative consumer through the model planning horizon. Top-down models, such as MIMEC and LBL-CGE, focus on economic equilibria, with less emphasis upon details of energy technology and end-use analysis. They are built upon the assumptions of competitive equilibrium and optimizing behavior on the part of consumers and firms.

For Kazakstan GHG mitigation analysis the ENPEP model has been chosen, since all mitigation options in Kazakstan concern to electric generation sector and because ENPEP is adapted to conditions of developing countries and countries with economies in transition.

The ENPEP model, developed at Argonne National Laboratory, incorporates the dynamics of market processes related to energy via an explicit representation of market equilibrium, that is, the balancing of supply and demand. ENPEP is used to model a country’s total energy system and does not explicitly include an economy model integrated with the energy system model. ENPEP occupies an intermediate position between engineering, energy-focused models, and pure equilibrium models. ENPEP is used to do total energy system analysis and electric sector studies. It is organized in modular form for flexibility and easy-of-use. ENPEP’s representation (particularly as regards the electric generation sector) can be quite detailed.

1.2.1 ENPEP description

As mentioned, ENergy and Power Evaluation Program (ENPEP), a microcomputer-based energy planning program, was specifically created to provide a state-of-the-art energy analysis capability to developing countries. The models on which the ENPEP modules are based were dimensioned to accommodate small- and moderate-sized economies, as well as the more complex economies of larger industrialized countries.

ENPEP consists of an EXECUTIVE module and ten technical modules. The components of ENPEP are fully integrated, but it is also possible to use many of the technical modules independently.

EXECUTIVE Module

The EXECUTIVE Module integrates the technical modules. It guides a user through each of the major components and modules and coordinates the storage and retrieval of information used by the technical modules. EXECUTIVE uses a forms package that has been standardized for use by the other modules. An invisible part of EXECUTIVE is the Data Dictionary that is used as a common repository of information that is shared between two or more ENPEP modules. The EXECUTIVE Module automatically coordinates this data sharing.

MACRO Module

The objective of the MACRO Module is to format macroeconomic growth projections for use in developing energy demand projections. MACRO is not an economic planning model or a forecasting model, but is an analytical methodology based on the assumption that energy growth (or decline) is driven by macroeconomic variables. Macroeconomic variable forecasts are developed outside of ENPEP and are input to the MACRO Module.

DEMAND Module

The purpose of the DEMAND Module is to compute projections of useful energy or fuel demand based on the macroeconomic growth rates generated by the MACRO Module and to generate a set of energy demand growth rates for use by the BALANCE Module. One must define the energy demand sectors and the base-year energy consumption by fuel type for those sectors. These base-year fuel consumption data must be calculated outside of ENPEP and entered into DEMAND.

The energy growth rate in any year is computed by using a linear combination of growth rates from one or two macroeconomic variable growth rates in the same year. Once these equations are specified, DEMAND will calculate energy demand for each consuming activity for every year in the study period.

PLANTDATA Module

The PLANTDATA Module serves as a library of basic information about thermal and hydroelectric generating facilities for both the BALANCE and ELECTRIC Modules. Since these two modules share common information, PLANTDATA was created to reduce redundancy and provide a convenient way to enter the large quantity of data required.

MAED Module

The MAED Model (Model for Analysis of the Energy Demand) is a simulation model designed for evaluating the energy demand of a country or region in the medium and long term. MAED is intended to be used in with the ELECTRIC module to carry out energy and electricity planning studies. The primary objective of MAED is to determine the structural changes in the energy demand of a country in the medium and long term and the evolution of the potential markets of each form of final energy: electricity, coal, gas, oil, solar, etc.

LDC Module

The LDC Module allows to transform data and perform calculations necessary to prepare input data on electricity generation requirements for the ELECTRIC Module. LDC does not "forecast" future electrical demands. Instead, it uses data from BALANCE, data entered, or a combination to calculate and specify the character of the electric demand, that is, annual electricity generation requirements, annual peak loads, period generation requirements (up to 12 periods per year), period peak loads, period load duration curves, and annual load duration curves.

ELECTRIC Module

The ELECTRIC Module calculates an electrical generating system expansion plan that meets demand at the minimum cost, subject to system requirements (e.g., reliability). It is a microcomputer version of the WIEN Automated System Planning Package (WASP-III), the well-known mainframe system planning model distributed by the International Atomic Energy Agency (IAEA).

WASP-III handles most of the critical issues of generation planning well. These issues include:

- Generating Unit size,
- System reliability representation,
- Existing system representation,
- Varying types of hydroelectric plants,
- Seasonal variations of loads and hydroelectric energy,
- Annual variations in hydroelectric energy,
- Domestic vs. foreign expenditures, and
- Method for production-cost calculations.

ICARUS Module

ICARUS (Investigating Costs and Reliability in Utility Systems) is a production cost model which calculates: (1) a system maintenance schedule, (2) the loss-of-load probability, (3) unserved demand for electricity, (4) required capacity reserve to meet a specified reliability criterion, (5) the effects of emergency interties, (6) expected energy generation and cost from each unit and block, (7) total generating system cost, and (8) fuel use. ICARUS uses a modified probabilistic simulation technique that produces an acceptable level of accuracy while significantly reducing computation requirements. Input requirements for ICARUS include capacity, forced outage rate, number of weeks of scheduled maintenance, and economic data for individual units, along with expected utility load characteristics.

BALANCE Module

The purpose of the BALANCE Module is to project energy supply and demand balance for any study period up to 30 years. BALANCE is based on the approach of generalized equilibrium modeling, which is applicable to modeling the energy systems of countries having different energy-sector characteristics. The basic assumptions in the equilibrium approach are that the energy sector consists of autonomous energy producers and consumers that carry out production and consumption activities while pursuing individual objectives.

An equilibrium model consists of a system of simultaneous nonlinear relationships that specify the transformation of energy quantities and energy prices through the various stages of energy production, processing, and use. Solving an equilibrium model consists of finding a set of prices and quantities that satisfy all equations and inequalities.

The BALANCE Module is based on an energy network, consisting of nodes and links, that model the energy supply and demand sectors. The nodes of the network represent processes, such as petroleum refining, and the links represent energy flows between pairs of nodes. The first step in the use of BALANCE is to draw a picture of the energy supply and demand sectors using node symbols. Then the user uses the menus and forms in BALANCE to encode the picture of the energy sector.

To describe the energy sector to BALANCE, the following information must be provided:

- Base-year supply and demand balance,
- Reserves, capacities, and costs of production,
- Energy processing efficiencies, capacities, and capital and operating costs,
- Electric sector data, such as load duration curves,
- Demand projections for the study period (which can be developed by the DEMAND module), and
- Import fuel price projections.

BALANCE uses this description of the energy sector and the demand projections to balance energy supply and demand using the equilibrium approach. BALANCE computes annual energy flows and energy prices for all energy activities (each link of the energy network). BALANCE is not an optimization model, but instead simulates and describes energy market choices that are made by producers and consumers.

IMPACTS Module

The purpose of the IMPACTS Module is to calculate the environmental burdens and resource requirements for the energy supply systems (electric and nonelectric) that are computed by the BALANCE and ELECTRIC Modules. Data from these modules are automatically transferred to IMPACTS for analysis.

Environmental burdens and resource impacts are computed by multiplying the appropriate impact factor by the activity for any given year (impact = impact coefficient x energy source activity). Default values are available for all impact coefficients, but the user can change any of these coefficients (e.g., kilograms of pollutant emitted per metric ton of fuel burned) by using a scalar function.

Impacts are broken down into mining, transportation, and power plants for the electric system. This breakdown was made because the boundary for impacts is the study region. In cases where fuel for power plants is imported (from outside the region), the impacts associated with mining and transportation would not be included. If the fuels were obtained from within the boundary, then the impacts associated with resource extraction and transportation would be included.

1.2.2 Network structure

Figure 2 shows the energy network based upon energy balance data for the base year 1990 and including nodes and data on planned activities through the year 2020, data on energy resource production and reserves, their conversion to electricity and heat and its consumption at the end-use sectors. There are nodes in the network referring to primary domestic and imported energy resources, nodes describing energy conversion and energy consumption. The energy network represents the energy flow going from nodes, representing primary energy resources in the form of nodes for different types of fuel at the bottom of the network, through the allocation and conversion nodes to the top of the scheme, representing the energy demand sector. The first level in the bottom of the network represents primary energy resources that include nodes for domestic and imported coal and gas, crude oil and oil products both imported and domestic. Relatively small fraction of energy resources is represented by imported electricity from the Middle Asia and Russia, and electricity generated by HYP. All energy resources were divided into the following types: 1) domestic crude oil, 2) imported crude oil, 3) imported gasoline and diesel oil, 4) imported fuel oil, 5) domestic natural gas, 6) imported natural gas, 7) domestic lignite, 8) domestic subbituminous coal, 9) imported lignite, 10) imported subbituminous coal, 11) imported electricity, 12) hydro power resources.

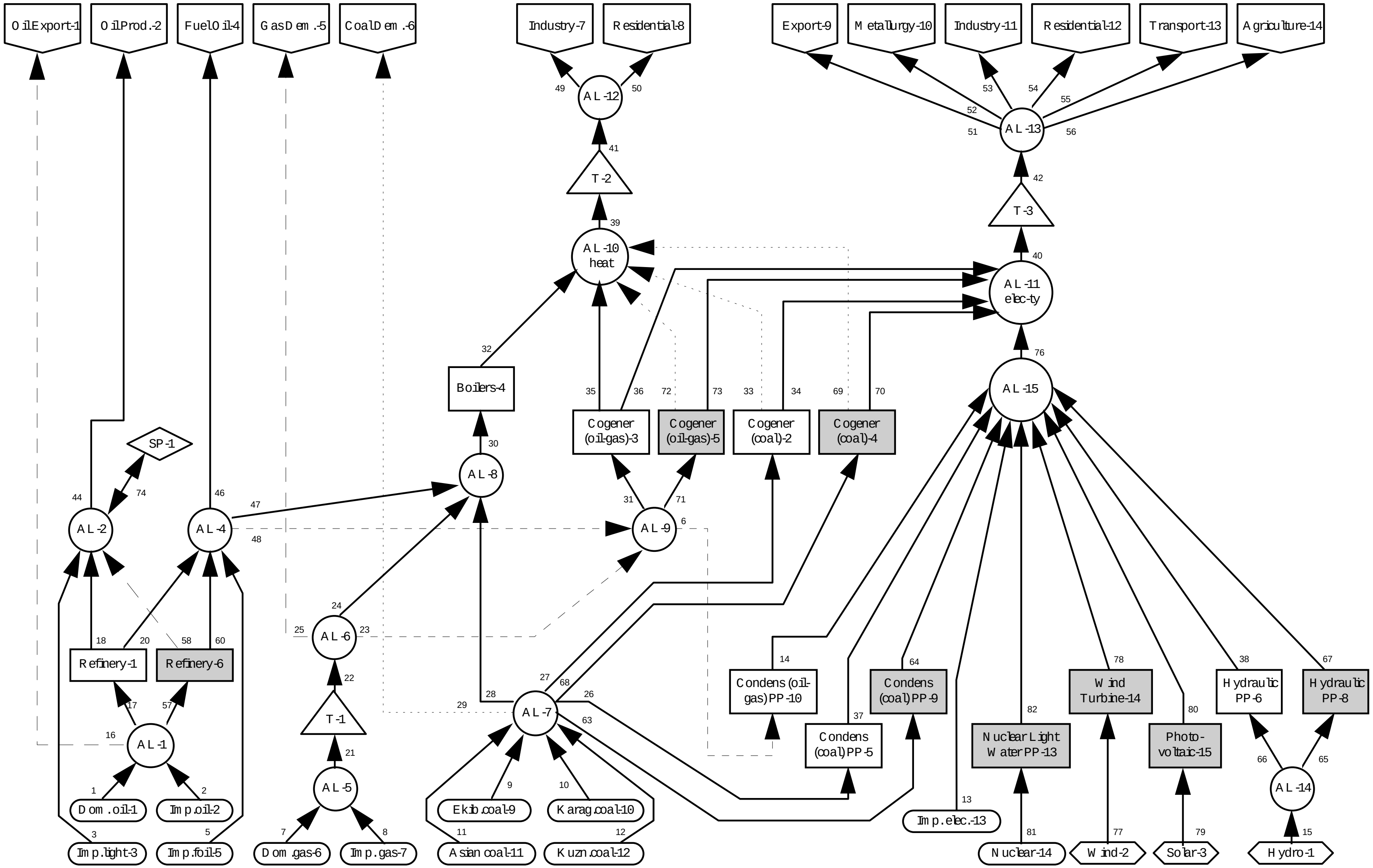
To compare different types of fuel they were expressed in tonnes of coal equivalent fuel (tce). This unit is a universal index of the energy content in a given amount of fuel:

$$1 \text{ tce} = 29.3 \times 10^9 \text{ J.}$$

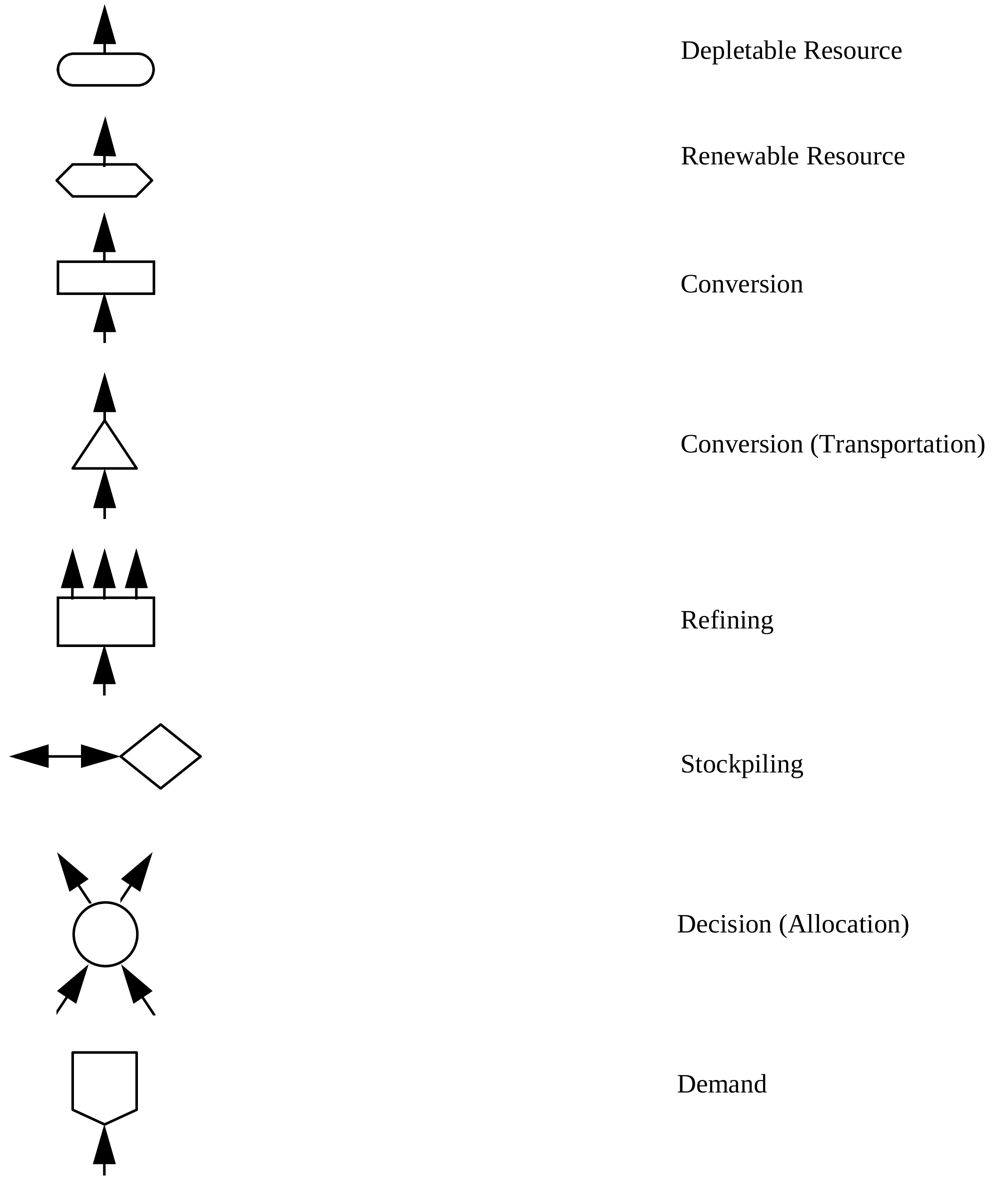
The allocation sector is described by the nodes where decision and energy allocation are simulated. Allocation nodes can have up to 10 inputs and 10 outputs.

The heat and electricity generation sector is described by the nodes of conversion processes simulating operating and planned heat power plants, boilers and refineries. Two types of conversion processes are considered: one-output process, when either conversion of energy resources into heat or power or energy losses during transportation occur, and a multiple output process (such as refineries and cogeneration power plants) when energy is transformed into several other types.

Figure 2. Kazakstan Energy Network



LEGEND



Note: Shaded nodes represent new capacities

In separate one-output nodes more than 18 thousand boilers operating in 1990 (node Boilers-4); 27 operating HYP (Hydraulic PP-6), and 3 projected HYP (Hydraulic PP-2), 2 operating coal condensed power plants (CCN, Condens PP-5), one oil-gas condensed power plant (GCN, Condens PP-10) and 11 nodes of projected CCN (Condensing PP-9) are aggregated.

It should be noted that some of existing CCN, such as Almaty, Karaganda-1, and Karaganda-2 (node Cogener(coal-2)) are described as multiple output process, because these plants produce not only electricity but also a substantial portion (33%, 72% and 17%, respectively) of heat.

Multiple output nodes simulate 3 operating refineries (Refinery-1) and projected refineries (Refinery-6); 26 operating coal cogeneration power plants (CCG)

(Cogener(coal)-2); 6 projected nodes of CCG (Cogener(coal)-4); 7 operating oil-gas cogeneration power plants (GCG) (Cogener(oil-gas)-3); and 5 projected GCG and nodes (Cogener(oil-gas)-5).

The energy demand sector is on the top of the network. The electricity is distributed between metallurgy, industry, residential transport, agriculture and export. The heat is distributed between the largest consumers - industry and residential sector. All the others nodes of demand sector were introduced to close fuel and energy balance.

1.2.3 Input data

For the energy resource nodes the following data is needed: resource amount; resource price; annual capacity. Quantitative fuel characteristics for each type are given in Appendix A. Model input data are summarized in Appendix B. Primary sources of initial data are state energy sector statistics data (*Ministry of Energy and Electrification of Kazakstan*, 1991; and *State Statistical Committee*, 1991) and the monograph by Chokin (*Chokin Sh.*, 1990).

Taking into account that 1 cal = 4.19 J and 1 kWh = $3.6 \cdot 10^6$ J, the following relationships have been used to convert power units into tce:

$$1 \text{ tce} = 7 \times 10^9 \text{ cal}$$

$$1 \text{ tce} = 8.14 \times 10^3 \text{ kWh}$$

$$1 \text{ tce/year} = 9.29 \times 10^{-4} \text{ MW}$$

$$1 \text{ tce/year} = 7.99 \times 10^{-4} \text{ Gcal/hour}$$

In Table A1 of Appendix A initial values are given for all types of resources: the amount in natural units and the cost in rubles for a natural unit of the energy resource.

To convert the gas mass into the standardized unit the following formula has been used:

$$A = V \times D \times \frac{8{,}000}{7{,}000},$$

where A is the gas mass, tce;

V is the gas volume, m^3;

D is the gas density (0.8 tonnes/thousand m^3);

8,000 is the gas calorific value, kcal/kg;

7,000 is the calorific value of standardized fuel, kcal/kg.

The following formula has been used for coal, crude oil and oil products:

$$A = M \times \frac{Q}{7{,}000},$$

where A is the fuel mass, tce;

M is the fuel mass, tonnes;

Q is the coal, crude oil and oil product calorific value, kcal/kg;

7,000 is the standardized fuel calorific value, kcal/kg.

The conversion of electricity units has been carried out according to the formula:

$$A = M \times K_1,$$

where A is the amount of electricity, tce;

M is the amount of electrcity, kWh;

K_1 is the factor equals to $3.14 \cdot 10^{-4}$ tce/kWh.

Fuel and energy resource costs originally expressed in rubles per natural unit have been converted into \$/tce. Gas cost is found as

$$C_s = \frac{7{,}000 \times K_2 \times C}{8{,}000 \times D},$$

where C_s is the gas cost in \$/tce;

C is the gas cost, rubles/thousand m^3;

7,000 is the calorific value of standardized fuel, kcal/kg;

8,000 is the gas calorific value, kcal/kg;

D is the gas density, 0.8 tonnes/thousand m^3;

K_2 is the factor equals to 1 \$/ruble.

For coal, crude oil and oil products cost converting the folowing formula has been used:

$$C_s = K_2 \times C \times \frac{7{,}000}{Q},$$

where C_s is the cost in the \$/tce;

K_2 is the coefficient = 1\$/ruble;

C is the cost, rouble/tonne;

Q is the coal, oil and oil product calorific value, kcal/kg;

7,000 is the standardized fuel calorific value, kcal/kg.

For the electricity cost converting the following formula has been used:

$$C_s = \frac{K_2 \times C}{K_1}$$

where C_s is the cost in \$/tce;

K_2 is the coefficient = 1\$/ruble;

C is the cost, rouble/kWh;

K_1 is the coefficient = $3.14 \cdot 10^{-4}$ tce/kWh.

Real energy sector data are summarized in Appendix A and Appendix B contains all the input data used for ENPEP model.

1.2.4 Comparison of Actual and Model Output for the Base Year

The completed full model data set (amount and cost of electricity, heat, fuel and oil products for all kinds of conversion processes) for the base year was calibrated to reflect official base year energy supply totals (see Table 1). It is assumed, that if simulation results for the base year are close enough to actual statistics, then the model will describe energy balance change adequately for the whole simulation period through the year 2020.

Table 1. Energy Balance Data and Model Outputs for the 1990 Base Year

Set of conversion processes	Produced heat, electricity and oil products (1000 tce)		Fuel price ($/tce)		Heat and/or power price ($/tce)	
	Actual	Calculated	Actual	Calculated	Actual	Calculated
Coal Condensed Power Plants	3,967.3 (e)	3,968.3 (e)	7.50	12.21	59.98 (e)	77.55 (e)
Oil Gas Condensed Power Plants	1,010.5 (e)	1,010.6 (e)	20.76	31.20	79.43 (e)	134.86 (e)
Coal Cogeneration Power Plants	3,551.5 (e) 7,361.2 (h)	3,550.9 (e) 7,360.9 (h)	13.69	12.21	75.93 (e) 36.14 (h)	147.41 (e) 70.16 (h)
Oil Gas Cogeneration Power Plants	364.8 (e) 1,822.4 (h)	364.9 (e) 1,822.5 (h)	19.78	31.20	86.09 (e) 46.39 (h)	172.78 (e) 93.14 (h)
Boilers	10,321.0 (h)	10,323.7 (h)	ND	21.12	ND	61.61 (h)
Hydro Power Plants	853.1 (e)	853.1 (e)	ND	1.00	16.67 (e)	33.25 (e)
Refineries	12,681.0 (gd) 7,504.0 (fo)	12,679.3 (gd) 7,504.6 (fo)	ND	23.97	83.26 (gd) 42.51 (fo)	84.17 (gd) 43.01 (fo)

Notes: e - electricity; h - heat; gd - gasoline and diesel; fo - fuel oil; ND - no data.

Table 1 shows that simulation results and actual statistics for production of power, heat and oil processing products for all types of conversional processes are practically the same. The differences vary from 0.1 to 2.7 thousand tce, that is no more than 0.3 % of parameter values.

The main differences are found on comparing calculated and actual price fuel parameters, and, therefore they are found on comparing calculated and actual price parameters of power electricity and heat. There is an overestimation of fuel cost characteristics for almost all capacity categories. The estimated fuel price is lower than the actual one by 11 % for Coal Cogeneration Power Plants. The estimated fuel price is above the actual one by 63 %, 50 % and 58 % for Coal Condensed Power Plants, Oil Gas Condensed Power Plants, and Cogeneration Power Plants respectively.

We assumed that the price overestimation can be explained by a high aggregation level in the Kazakstan model energy network (see Figure 2). It makes the model less adaptable and does not allow it to choose less expensive fuels when simulating power and heat production.

The influence of high aggregation level on the fuel price for Coal Condenced Power Plants can be demonstrated by the example. According to the accepted scheme all the blocks corresponding to the coal production at first are united into one set for representation in the energy system scheme, then the coal allocation for consumers including Heat Power Plants is described. The model uses weighted average price which is the same for all consumers. In practice, the Coal Condenced Power Plants in Kazakstan, for example, Kazakstan-Ermak and Ekibastuz-1 located close to the Ekibaztus coal stripping get coal at its costs. Therefore, the calculated weighted average coal price is substantially greater than the actual value.

Power and heat prices are automatically overestimated because of fuel price overestimation, but these discrepancies are significantly greater. So, calculated price values are more than actual. Discrepancies between cost indicators for power energy and heat are essentially greater; the estimated prices exceed the available cost data by 29 %, 70 %, 94 %, 107 % and by 99 % for Coal Condenced Power Plants, Oil Gas Condensed Power Plants, Coal Cogeneration Power Plants, Oil Gas Cogeneration Power Plants, and Hydro Power Plants respectively. Another reason of such overestimation, probably, is using as model input data the averaged for Kazakstan depreciation allocation value which is equal to 3 % of total production. In practice, the depreciation rate can be equal to zero, and we can see that now as a result of the government measures on price policy stabilization.

In reality, the energy resource price performs economic, social and political functions. Both nowadays and during the soviet period, the prices in Kazakstan (as well as in other republics of the former USSR) performed primarily a political function. The actual electricity and heat prices do not reflect the true costs. Therefore, the model gives economically more justified prices. The described situation involving discrepancies between actual and estimated values can be formulated as a calculated estimate of difference between available actual price data determining “mean political” cost and calculated results which can be interpreted as simulated forecast price of power and heat. The obtained result gives us an opportunity to assess the approximate economic imbalance in the energy sector of Kazakstan as it undergoes the transition to a market economy.

Therefore, the comparison of simulation results with the actual statistics on energy balance in Kazakstan for the base year allows us to conclude that the model adequately simulates heat and power production. The obtained results during the forecast period through 2020 can be considered as good approximation for power and heat production. However, the model overestimates actual price characteristics which should be taken into account in any future economic analysis.

1.3 Scenario Assumptions

This section presents main quality and quantity assumptions, which are necessary to simulate mitigation scenarios. Energetic development, energy efficiency, future electricity demand, and structure of its distribution are based on the projections of economic and population growth. Therefore, creation of energetic development scenarios should be based on sociodemographic and macroeconomic scenarios of the country development.

The dramatic current and future changes in the economy of Kazakstan and system over the next twenty years make any standard techniques of extrapolation of previous trends of little or no value. Policies and behavior are in the process of substantial change. Thus, scenario assumption presented in this chapter provide the initial framework by which to begin to estimate energy demand assuming different key premises.

1.3.1 Macro-parameters

Current rapid occurring in Kazakstan and the lack of reliable detailed data make it difficult to perform the kind of analysis normally undertaken in OECD countries to project long-term economic growth and energy demand. Trends based on historical data provide limited information about Kazakstan’s future as Kazakstan makes the transition to a market-based economy. There is great uncertainty surrounding macroeconomic and sectoral developments in the short and longer term. As a result, any projection of energy demand and potential energy savings at this time would be one of many possible outcomes.

The Republic of Kazakstan possesses a reasonable potential comprising accumulated national budget, and natural resources. There are substantial reserves of polimetallic and ferrous ores, oil, gas, coal and other valuable mineral resources on the territory of Kazakstan. It is one of the major regions to produce non-ferrous metals, it has developed branches of ferrous metallurgy, chemical industry, agricultural complex, and machine-building complex. However, the formation of its economic potential has been greatly influenced by certain peculiarities of the previous national economy development. For a long time the Kazakstan economy was developing as a part of the former USSR complex. The formation of the primary industrial structure was determined by both setting up extracting branches and removing of the USSR industrial enterprises to the East during the war, thus, it was completely aimed to satisfy the needs of the “center”. The economy of Kazakstan was characterized by essential structural distortions, irregularity and spottiness (a combination of big industrial giants with vast undeveloped regions), the lag in industrial and social infrastructure development, production of finished products, especially complex ones. This led to emergence of heated acute social problems in transition to the market economy and state independence. Based on the analysis of the most important problems and tendencies in the republic’s economic complex and taking into account the crisis situation, the following stages of the economy development were distinguished.

The first stage 1996-1998 is supposed to be characterized by overcoming the deterioration of standard of life and by creation real prerequisites of its growth on the basis of slowing down economic recession and stabilization of economic situation. Basically, during this period the issues of institutional transformations should be worked out, necessary elements of market infrastructure should be set up to ensure market regulation of economy.

In the second stage, 1999-2000, prerequisites for economic growth reanimation and structural reconstruction will be created, this will ensure the basis for substantial production growth in the following period. Thus, in 1999-2000 the branches, ensuring well-being and export-oriented production, will remain as top priorities. In the first place, they are qualities of branches of the fuel and energy complex, oil-chemical and metallurgical complex as well as communications.

During the period of 2001-2010 (third stage) it is predicted increase of economic growth rate under little exceeding rate of population growth.

The general direction of the economy in 2011-2020 (forth stage) will be setting up a new industrial system on the basis of resource saving technologies. Switching from an additional resource attraction concept to intensification of their use will take place. A general re-orientation forwards processing industry, science-intensive production development and as a result an improvement of the production technological level will occur.

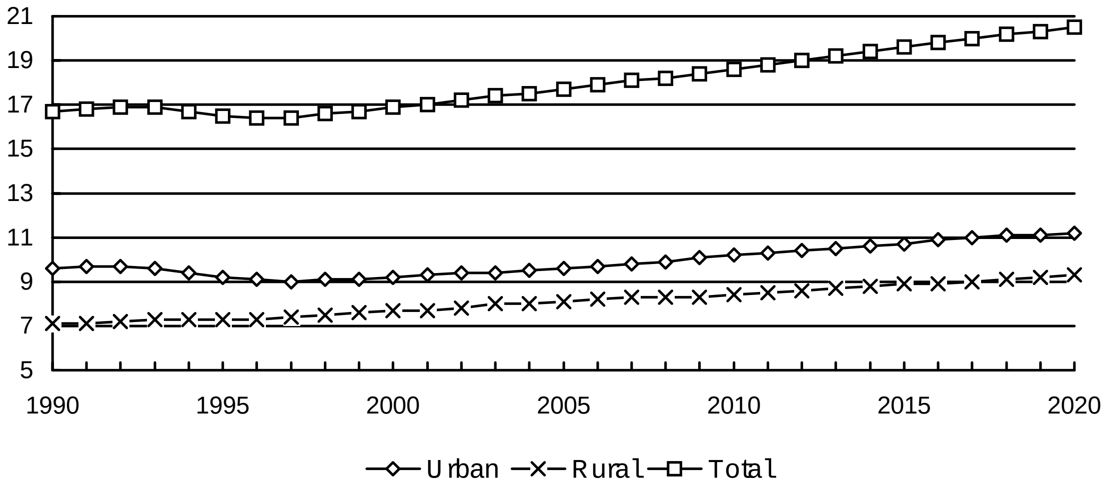
On the whole for the investigated period through the year 2020 the most rational development option relates to a gradual shift in the structural policy from initial priorities of traditional specialization branches to a higher extent of raw material processing, augmentation of existing export potential and providing conditions for its realization towards priorities in the field of processing industry and the technological and promising types of production.

The development of macroeconomic and sociodemographic scenarios is based on methodology designed at the Institute of Market Relations of the Republic of Kazakstan. Using this methodology the macroeconomic trends are obtained up to the year of 2020 for baseline and all mitigation scenarios.

The projections in sociodemographic, GDP growth and export, the main indicators of the development of the Republic of Kazakstan through the year 2000-2020 are presented below.

The population of Kazakstan was 16.7 in 1990 and the population density was 6.2 inhabitants per square kilometre. The serious socioeconomic problems that arose a few years ago and the recent emigration wave have resulted in a substantial decrease in population. The Kazakstan population is getting older as a result of a long-standing tendency of crude birth decrease mostly for urban population.

Figure 3. Population Projection (millions)

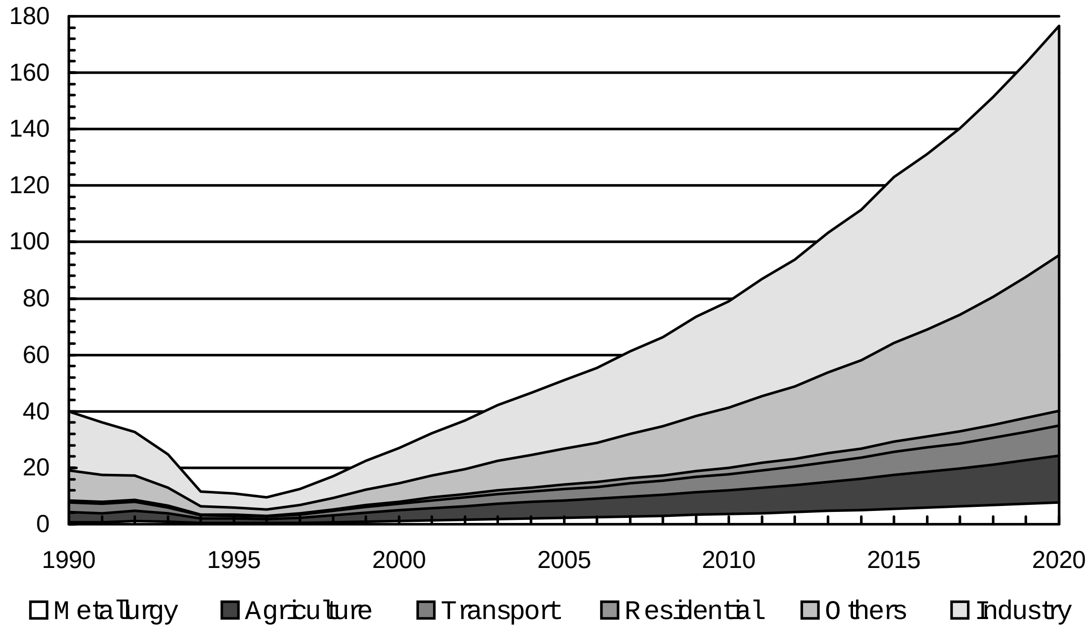


Using the demographic tendency analysis and the basic demographic indicators for 1990, a forecast was prepared for the period to 2020. It predicts a decrease of the Kazakstan population by about -3.0 % from 1992 to 1997 with an average annual rate of - 0.6 %. It should be noted that the total population decrease in 1992-1997 is caused by decrease in urban population which was about -7.2 % with an average annual rate of -1.4 %. The rural population is increased in the same period by 2.8 % with an average annual rate of 0.4 %. The total population increase is expected from 1997 to 2020. Annual growth rate is expected to be about 0.5 % in 1995-2000, 0.9 % in 2000-2005, 1.0 % in 2005-2010, 1.1% in 2010-2015, and 0.9 % in 2015-2020. As a whole for the period 1990-2020, the population growth can increase by 22.8 %.

At the Figure 4 GDP forecast is presented in constant 1995 prices and average exchange rate for 1995 ($1 = 60 tenge).

One of the key features of the economy of Kazakstan is a very large share of industry and agriculture in the overall economy. This is due to the political emphasis on heavy industry during the centrally planned era. Recent Wold Bank economic reports indicate that agriculture and industry shares of employment in 1992 were about 24 % and 30 % respectively. These are about the same shares as reported for 1980. The percentage of net material product originating in the agricultural and industrial sectors in 1993 were about 31 and 51, respectively.

Figure 4. GDP Growth Projections (billion US$)



It is foreseen that after 1996-1998 the economic decline will come to an end. An averaged annual GDP growth is expected within the range of -12.7 % in 1990-1996 to 46.2 % in 1996-2000. The GDP growth rate will temporary reduce after 1996 and will be equal to 17.8 % in 2000-2005, 11.3 % in 2005-2010, 9.0 % in 2010-2015. At the end of forecast period it will be 10.5 %. The six main economic sectors have been analyzed as follows: metallurgy, agriculture, transports, residential, industry and building and other sectors. The forecast assumes stable growth rates for all sectors after overcoming the drastic downfall of the 1990-1996 period. It is expected that the total GDP level of 1990 can be reached by 2003.

The level of the year 1990 will be reached in metallurgy, agriculture and residential sector in 1999-2000. For the other sectors the base level can be reached 5 years later in 2004-2005.

The future GDP structure can be characterized by the following main tendencies:

- The metallurgy production will have increased by the end of the period more than it was in 1990 by a factor of 10.7. Its GDP share temporarily increases from 3.0 % in 1990 to 4.8 % in 2015. At the end of forecasted period the share can be 4.4 %.
- Although the industry production will be more by the end of the period (year 2020) than it was in 1990 by a factor of 3.9, the industry production share will have decreased from 51.0 % to 45.9 %.
- The agriculture and residential shares will not changed considerably. They will increase from 9.0 % and 2.0 % in 1990 to 9.4 % and 3.0 % respectively. The production for agriculture and residential sectors by 2020 will be more by a factors of 4.6 and 6.6 respectively.
- The share of transport decreases from 8,0 % in 1990 to 6,0 % by the year 2020.

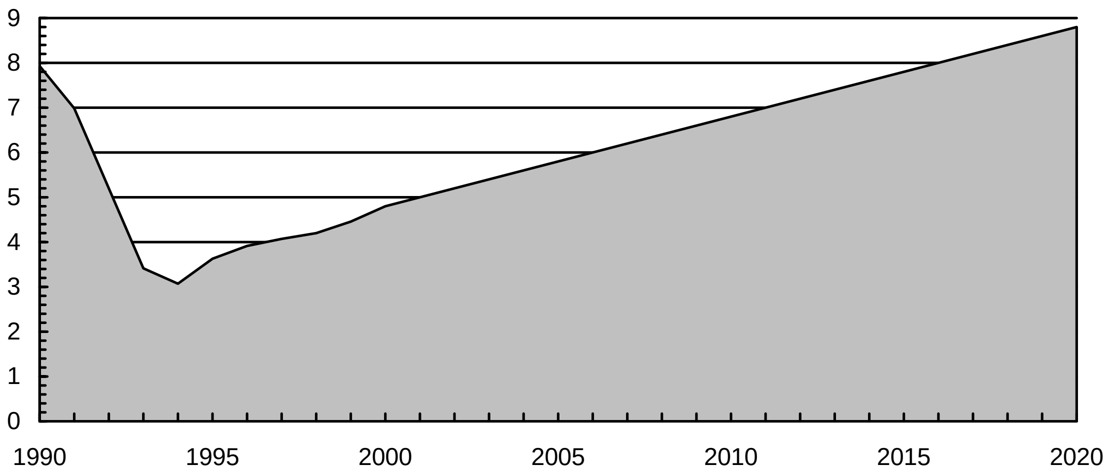
- The share of the other increases from 2,7 % in 1990 to 3,1 % by the year 2020. The production for this sector by 2020 will be more by a factor of 5.2.

We can conclude, that increase GDP part in metallurgy, agriculture, residential and the other sector will take place, it will be balanced by decrease in transport and industry production.

As a whole, the forecasted development trends are significant, in accordance with the rich indigenous resources, the foreign trade balance expectations, and the financial indicators.

Given the GDP forecast, relevant scenarios for exports and inflation indicators rate have been designed.

Figure 5. Projection of Export (billion US$)



Total exports scenario in US dollars is presented at Fig. 6. It is expected that exports growth rate will increase most considerable after 2000, but the base level of 1990 can be reached only by 2015.

To evaluate mitigation option costs it is necessary to take into account forecast of local currency inflation (tenge). Fig. 6 shows inflation forecast chart.

Figure 6. Projection of Inflation (%)

According to this scenario the inflation will reduce from 60 % in 1995 to 33 % in 1997. After 1997 it will gradually reduce and its stabilization is expected to be 3-5 % by 2005, that is close to average world value.

1.3.2 Price assumptions

Given GDP forecast and taking into account experts' estimates, relevant scenarios for energy resources price have been developed.

In Table 2 preliminary price guidelines though 2005 is presented. These projections are based on November 1994 real prices at a fixed exchange rate of 51.4 Tenge per US dollar.It is also assumed that there is no real increase in the world prices. Table 2 has been developed to provide the basic framework by which to project future price guidelines.

Table 2. Kazakstan Energy Price Guidelines

	1994 (1a)	1998 (1b)	2005 (1b)
Crude Oil $/million tonnes	31	78 (2)	85 (3)
Diesel Fuel, refinery $/million tonnes	105	106 (4)	114 (5)
Natural Gas, $/million tonnes	78	83 (6)	104 (7)
Coal, power plant $/million tonnes	4	8 (8)	14 (9)
Electricity, $/million tonnes	0.029	0.0704 (10)	0.0985 (10)

In our study, when fuel and energy resource prices forecast was developed it has been assumed that prices of domestic and imported fuel and energy resources will go up at the same pace. The prices of imported oil, sub bituminous coal, fuel oil and power will reach the world prices in the year 2000, for imported gas this will happen in 1995.

Table 3 presents expected annual price growth rate, in percent of price of previous year.

Table 3. Energy Resource Price Projections

	Expected price growth rate, %	
	1991-2000	2001-2020
Coal	5.71	1
Gas	21.08	3
Oil	12.14	2
Fuel oil	14.31	2
Electricity	2.54	2

These data were used as input for BALANCE model. Price projections are introduced in corresponding blocks of BALANCE for coal (blocks Ekib. coal-9, Karag.coal-10, Kuzn. coal-12), gas (blocks Dom.gas-6, Imp.gas-7), oil (blocks Dom.oil-1, Imp.oil-2), fuel oil (blocks Imp. petroleum-3, Imp.foil-5) and electricity (blocks Imp. elec-13).

The projection has not only been given for coal imported from the Middle Asia, since its price in 1990 was more than 2 times as high as world price, therefore it would not changed.

1.3.3 Energy Intensities

Kazakstan's energy intensity historically has been quite high. It has been comparatively high for a multitude of factors: the share of industry in the share of industry in the economy is quite high compared with other countries; wasteful use of materials as well as presence of old technologies result in the inefficient use of energy; the fuel mix in Kazakstan is heavily weighted towards coal which tends to be less efficient as a fuel in end-use applications; low energy prices provide few incentives for saving energy; and finally, energy is, to a large extent, inefficiently produced as mentioned in *(Richard Browning, et.al., 1995).* Projecting future long-term energy intensity in Kazakstan requires both a bottoms up and a top down approach. The bottoms up approach requires a detailed assessment of each factor and an assessment of how these factors are likely to change. The top down approach is to conduct comparative analysis of several countries over many years and of particular energy intensive sectors. This information will provide a range of values which will capture the likely future long-term trend in Kazakstan. Projecting in which part of the range Kazakstan is likely to fall requires a careful assessment of many structural and macroeconomic issues.

In this study as mentioned in Introduction section, we did not consider the energy consumption sector. The mitigation analysis has been conducted only for different options in energy production sector. It has been assumed that energy intensity in energy production sector is remind the same for the baseline scenario. The assumption about intensity for mitigation scenarios are presented in section 1.5.2.

1.3.4 Final Energy Demand Projection

The results obtained from the analysis in terms of GDP growth and structure, import-export and population growth serve to develop final energy demand projections. The approach using experts' estimates bottom up approach were used for developing this projection. The main problem in implementing the approach was the lack of reliable data concerning energy demand end-use categories. The available data was fragmentary or inadequate for the new economic conditions. According to this approach the energy demand depends on economic activities and social needs. Over the long term, energy demand will be influenced by socioeconomic development patterns (economic growth, lifestyle, society behavior), expected technology mix in all sectors of economy (influenced by new technology penetration rate), and energy price growth.

Four major economic sectors are addressed at this stage with emphasis on energy intensive subsectors. For each sector and sub sector, expert judgment is used to identify the long-term development of the sector that is consistent with the output of macroeconomics analysis and the potential for new technologies' penetration, the corresponding energy demand for industry, agriculture, transportation and residential sector. It was assumed also that electricity export will not change after the year 2000.

The final electricity demand and electricity export projections for the baseline scenario are given in Figure 7. These data have been used to calculate demand change rates as a percentage of the previous year. Expected rates of the change in power energy demand and exports are summarized in Table 4.

Figure 7. Final Electricity Demand and Electricity Export for the Baseline Scenario (billion kW)

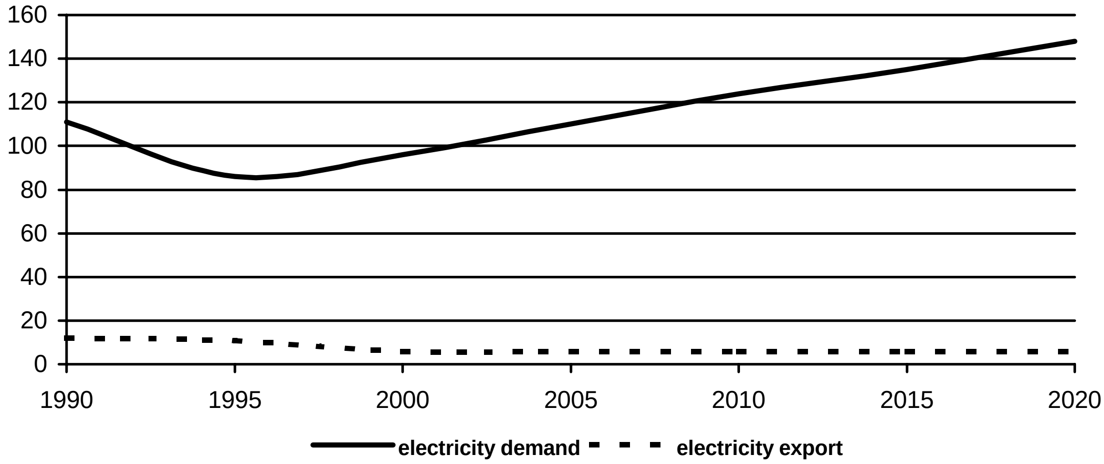


Table 4. Projected electricity demand and electricity export change rates

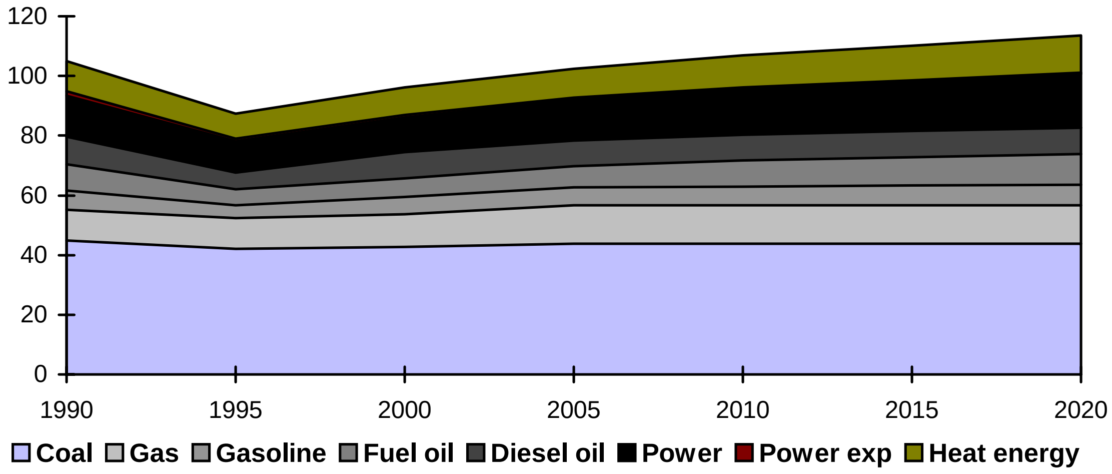
Electricity demand		Electricity export	
Time Period	Amount, %	Time Period	Amount, %
1991-1993	-4.1	1991-1993	-0.4
1994-1995	-6.9	1993-1994	-33.7
1996-1997	1.4	1994-1995	-33.7
1998-2000	2.7	1995-1996	-4.8
2001-2002	2.0	1996-1997	-8.6
2003-2005	3.5	1997-1998	-5.5
2006-2010	2.3	1998-1999	1.8
2011-2020	1.8	1999-2000	5.4

The result shows a growth in power energy demand of about 1.3 times by 2020 year compared to 1990 and a growth of about 1.6 times compared with 1996. Electricity demand downfall of the 1990 - 1997 period reflects the general decline of national production.

The project of electricity demand have been introduced for blocks: Metallurgy-9, Industry-10, Residential-11, Transport-12 and Agriculture-13.

Using macro economic trends, the other energy demand projection for the baseline scenario was obtained. In Figure 8 , projection of demand of different types of final energy is given.

Figure 8. Final energy demands for baseline scenario (million tce)



Analysis of the data from the Figure 8, shows that a growth of coal, gas, oil products and heat demand are about of 1.06, 1.2, 1.5, 1.6 and 1.3 times respectively in 2020 compared to 1995 can be expected. This growth compared to 1990 is insignificant, because of decline in period of 1990- 1998.

It should be noted that in calculations of demand change rates using the data of Figure 9, corrections (for gas and coal demanding 1991-1995) have been introduced since not only domestic consumption but also exports are taken into account in nodes: Gas demand-5 and Coal demand-6 in constructed BALANCE energy network (see Figure 2).

1.3.5 Energy resources and technologies

1.3.5.1 Fuel resource Extraction Forecast

A description of the resources for primary energy included in the analysis were presented in 1.1.2. To construct the energy development scenario a mineral resource extraction forecast for the period under consideration is required. It is assumed that by the year 2005 the oil and Ekibastuz coal extraction will be doubled and gas extraction can increase 4 times. The information summarized in Table 5 is introduced for corresponding blocks of resources.

Table 5. Mineral Resource Extraction Forecast

	Extraction in 1990, 1000 tce	Maximum possible extraction per year, 1000 tce/year		
		1991-1999	2000-2004	2005-2020
Ekibastuz coal	44,420	50,000	75,000	100,000
Oil	38,363	40,000	60,000	80,000
Gas	6,504	7,000	14,000	28,000
Karaganda coal	29,547	35,000	35,000	35,000

Coal import suspension has been taken into account as well. By 1995 Kuznetsk and Middle Asia coal imports were stopped.

1.3.5.2 Energy Supply Technologies

The model characterizes 88 electric generation options, including 33 existing and 11 new cogeneration plants. These are 2 existing and 11 new coal-fired plants, 1 existing oil-gas-fired, 27 existing and 3 new hydroelectric plants.

There are 27 processes characterized in the model: 14 distribution processes, 3 transportation processes, and existing and 7 new oil refineries.

Choice among different technologies of energy supply has been made to model electric system operation and planing. As it mentioned main types of energy supply technologies in Kazakstan are as follows: Coal Condensed Power Plants (CCN); Oil Gas Condensed Power Plants (GCN); Coal Cogeneration Power Plants (CCG); Oil Gas Cogeneration Power Plants (GCG); Boilers, Hydro Power plants (HYP); Refinary.

The main features for each of the options, such as capital variation, variable and fixed O&M costs, efficiency and instaled capacities for baseline scenario are presented below.

Capital expenditure and O&M costs projections are given in Tables 6 and 7. It is assumed that the annual rate growth is 3%.

Table 6. Capital Expenditure Variation in the Energy Sector in 1990-2020 ($/unit of capacity)

Capacity type	Year						
	1990	1995	2000	2005	2010	2015	2020
CCN	170	197	228	264	306	355	412
GCN	170	197	228	264	306	355	412
CCG	190	220	255	296	343	398	461
GCG	190	220	255	296	343	398	461
Boilers	50	58	67	78	90	104	121
HYP	180	209	242	281	326	378	438
Refinery	60	70	81	94	109	126	146
Project.HYP				604	700	811	940
Project. CCN			465	539	625	725	840
Project. CCG			255	296	343	398	461
Project. GCG		360	393	456	529	613	711
Project. refinery				94	109	126	146

Table 7. O&M Cost Variation in the Energy Sector in 1990-2020 ($ per unit of output)

Capacity type	Year						
	1990	1995	2000	2005	2010	2015	2020
CCN	26.39	40.18	46.58	54.00	62.60	72.57	84.13
GCN	34.95	53.22	61.70	71.52	82.92	96.12	111.43

CCG	21.60	32.89	38.13	44.20	51.24	59.40	68.86
GCG	23.32	35.51	41.17	47.72	55.32	64.13	74.35
Boilers	22.80	34.72	40.25	46.66	54.09	62.71	72.70
HYP	7.33	11.16	12.94	15.00	17.39	20.16	23.37
Refinery	19.77	30.10	34.89	40.45	46.89	54.36	63.02
Project.HYP				15.00	17.39	20.16	23.37
Project. CCN			46.58	54.00	62.60	72.57	84.13
Project. CCG			38.13	44.20	51.24	59.40	68.86
Project. GCG		35.51	41.17	47.72	55.32	64.13	74.35
Project. refinery				40.45	46.89	54.36	63.02

As it can be seen from Table 6, capital expenditures for projected Coal Cogeneration Power Plants (CCG) are taken to be the same as for existing plants because new plants will not be built during the period under consideration. Some of existing capacities will be increased at the expense of new block commissioning. Capital expenditures for projected Oil Gas Cogeneration Power Plants (GCG) are increased as compared to existing capacities, because in addition to expansion of several GCG, construction of the Aktobe Heat Power Plants (HPP) is anticipated.

Table 8 summarized data on installation of capacities in power generation through the year 2020. These data are partly based on (*Ministry of Energy and Coal Industry of Kazakstan*, 1995).

Table 8. Future Capacities (billion kWh)

Type of HPP	Number of units	Capacity, MW	Year						
			1997	2000	2002	2005	2010	2015	2020
Coal Cogeneration Power Plants									
Tselinograd - 2	4, 5	370	–	0.8	0.8	0.8	1.6	1.6	1.6
Karaganda - 2	5	185	–	0.8	0.8	0.8	0.8	0.8	0.8
Karaganda - 3	5	110	–	0.5	0.5	0.5	0.5	0.5	0.5
	6	140				0.2	0.8	0.8	0.8
Ust-Kamenogorsk	12	80	–	0.4	0.4	0.4	0.4	0.4	0.4
Oil Gas Cogeneration Power Plants									
Uralsk - 1	no data	no data	–	1.7	1.7	1.7	1.7	1.7	1.7
Guriev	8	150	–	–	–	0.6	0.9	0.9	0.9
	9	150	–	–	–	–	0.6	0.9	0.9
Actobe - 1	7	98	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Actobe	1	477	–	2.5	2.6	2.8	2.8	2.8	2.8
	2	477	–	2.8	2.8	2.8	2.8	2.8	2.8
Chimkent - 3	3	80	–	–	–	0.4	0.4	0.4	0.4
	4	300	–	2.0	2.0	2.0	2.0	2.0	2.0
	5	300	–	2.0	2.0	2.0	2.0	2.0	2.0
Coal Condensed Power Plants									
Southern Kazakstan	1	540	–	–	2.0	3.2	3.2	3.2	3.2
	2	540	–	–	–	1.3	3.2	3.2	3.2
	3	540	–	–	–	–	2.0	3.2	3.2

	4	540	–	–	–	–	–	3.2	3.2
	5	540	–	–	–	–	–	0.6	3.2
	6	540	–	–	–	–	–	–	3.2
Ekibastuz - 2	3	525	–	3.0	3.0	3.0	3.0	3.0	3.0
	4	525	–	2.5	3.0	3.0	3.0	3.0	3.0
	5, 6	1,050	–	–	–	6.0	6.0	6.0	6.0
	7, 8	1,050	–	–	–	–	6.0	6.0	6.0
		Hydro Power Plants							
Semey	no data	69	–	–	–	0.3	0.3	0.3	0.3
Maynak	1, 2	300	–	–	–	0.8	0.9	0.9	0.9
Kerbulak	1, 2	56	–	–	–	0.3	0.3	0.3	0.3

As it can be seen, in 2000-2010 a number of additional capacities in four Coal Cogeneration Power Plants (CCG) of Kazakstan are planned too. Power specialists only provided the planned capacity (in MW) and expected power output (in TWh) in new blocks. Next table presents some assumptions caused by the lack of the rest of the information necessary for modeling the future energy blocks. A special assumption is made about the heat output at CCG puting into operation. The following relationship between power and heat outputs was used for 1990:

28 % of power and 72 % of heat for Tselinograd CCG-2, 47 % and 53 % for Karaganda CCG-2, 37 % and 63 % for Karaganda CCG-3, 26 % and 74 % for Ust-Kamenogorsk CCG.

The data on new blocks of CCG have been summed up for corresponding years, converted into standard units and introduced in the Cogener (coal) - 4 node (see Figure 2).

From 1997 through 2015 new blocks in the four oil-gas cogeneration power plants (GCG) and a new heat power plants (HPP) in Actobe will be put into operation (see Table 8). The data after required transformations as well as data obtained on the basis of assumptions were introduced in the Cogener (oil-gas)-5 node. It should be noted that heat output computed for all future GCG power and heat output ratio in 1990 at the Shimkent GCG-3 were 30 % of power and 70 % of heat.

In 2000-2020 the Southern Kazakstan coal condensed power plants (CCN) and blocks 3-6 of the Ekibastuz CCN N 2 are planned to be commissioned. The data on new CCN are allowed for in the Condensing PP-9 block. The information on efficiency, capacity ratio, etc., obtained on the basis of assumptions, were introduced in this block as well. By the year 2005 the Semipalatinsk, Maynak and Kerbulak Hydro Power Plants (HYP) are expected to be commissioned. Necessary data related to these stations are introduced into the Hydraulic PP-8 node.

Future Capacities of Refineries**.** Existing refineries have capacities of 18.5 million tonnes per year. In the nearest future the Atyrau refinery is planned to be reconstructed, the Pavlodar and Shimkent refineries will be expanded, new refineries in Mangistau, Aksai and small refineries in Actobe will be built. The total capacity of refineries will amount to about 40 million th of oil per year. The future refineries are simulated by the Refinery - 6 block, they will be put into operation in 2005.

In Table 9 all data on capacities that will be instolled through the year 2020 according to the baseline scenario are presented.

Table 9. Data on Future Capacities for baseline scenario

Object (node in the network)	Year of commis-sioning	Heat output, 1000 tce	Electricity output, 1000 tce	Efficiency	Capacity factor	Ratio of output product costs	Capital costs, $/tce of output	O&M costs, $/tce of output	Assumptions used
HYP (Hydraulic PP-8)	2005	–	184.500	0.800	0.370	–	604.00	15.000	Only new-capacity capital costs change-increase more than 2 times
CCN (Condensing PP-9)	2000 2002 2005 2010 2015 2020	–	676.500 984.000 2,029.500 3,247.200 3,862.200 4,255.800	0.340	0.580	–	465.00	46.580	Only new-capacity capital costs change-increase more than 2 times
CCG (Cogener (coal)-4)	2000 2005 2010	608.738 650.624 1,029.312	determined by efficiency	0.190 (e) 0.390 (h)	0.570	1.000 (e) 0.476 (h)	190.00	38.130	There are no changes in comparison with existing capacities. To compute heat output the ratios of heat and power outputs at the Tselinograd CCG N2, the Karaganda CCG-2 and -3, the Ust-Kamenogorsk CCG in 1990 have been used
GCG (Cogener (oil-gas)-5)	1997 2000 2002 2005 2010 2015	143.500 3,286.150 3,329.200 3,673.600 3,931.900 4,018.000	determined by efficiency	0.170 (e) 0.410 (h)	0.630	1.000 (e) 0.539 (h)	360.00	35.510	Only new capacity capital costs change-increase more than 1.5 times. Capital costs are computed under the assumptions that costs amount to 604 $/tce of output for the new Actobe GCG and 190 $/ tce of output - for the rest of expanded capacities. O&M costs increase 1.5 times. To compute heat output the ratio of heat and power output in Shimkent GCG N3 in 1990 has been used
Refineries (Refinery-6)	2005	–	17,440.000 (op) 6,720.000 (fo)	0.47 (op) 0.28 (fo)	0.980	1.000 (op) 0.511 (fo)	67.00	40.450	Capital costs are assumed to be 100 $/tonne of oil processed

Notes: h - heat, e - electricity, op - oil products, fo - fuel oil.

The following conversion nodes are used for modeling future capacitites: Hydraulic PP-8 for future Hydro power Plants, Condense PP-9 for future Coal Condensed Power Plants (CCN), Cogener (Coal) - 4 for future Coal Cogeneration Power Plants (CCG), Cogener (oil-gas) - 5 for future Oil Gas Cogeneration Power Plants (GCG), Refinery - 6 for future refineries. They have been introduced to the scheme of the fuel and energy balance. The same information as for conversion blocks of existing capacities is required to put these blocks into operation. However, only capacity and output data for future HPP and HYP were available. Therefore in modeling future capacities we were forced to use the assumptions given below.

1.3.6 Emission Coefficients

After inputting the data required for the BALANCE module, we identified the capacities for which emissions in the IMPACTS module were computed. Fuel combustion technologies have been chosen out of the IMPACTS module data base which fit the simulation of emissions for units given in the BALANCE module. The option criteria are the type of technology, the type of fuel used and the type of output (heat or power).

The emission coefficients of the major plant types used in this study are presented in Table 10.

Table 10. Emission Factors for Major Plant Types (kg/GJ input)

	Coal Fired	Oil-Gas Fired
Particulate	0.212407	0.0202972
SO_2	1.01146	0.418942
NO_x	0.404585	0.222
CO	0.0202293	0.01631
NMVOC	2.36008E-03	1.38042E-03
Methane	1.01146E-03	4.4832E-04
CO_2	100.4	62.4
CO_2-Equivalent	100.4212	62.42228

It should be noted, that the data of emission coefficient for oil-gas fired plant type was missing in the IMPACTS module's database. Therefore we used the emission factors, which are given in (*IPCC Guidelines, 1995*) for fuel oil.

1.4 Screening of Mitigation Options

After the determination of the scenario assumption, a next step is the energy development scenarios for a base case as well as for the cases which taking into account introduction of mitigation options.

As mentioned the most significant contributor to GHG emissions in Kazakstan is the energy production sector, the main effort in our mitigation analysis addressed to this sector. Taking into account the availability of natural resources and the existing scientific and technical studies, we present here five main directions for GHG mitigation in the energy production sector of Kazakstan.

All the mitigation options assessed for the energy sector affect electricity generation. Preliminary estimation of the GHG mitigation potential was based on avoided fuel use for electricity generation. The calculations were completed according to the following formula:

$$RE = EG \cdot CF1 \cdot HR \cdot CF2 \cdot RA1 \cdot (CC/100) \cdot RA2$$

where RE is CO_2 reduction in Gg; EG is electricity generation (TWh); CF1 is conversion factor from TWh to kWh = 10^9; HR is heat rate in grams of coal equivalent per kWh, GCE/kWh = 160 GCE/kWh for cogeneration cycle at the HPP, 57 GCE/kWh for combined cycle at the HPP and 350 GCE/kWh for hydro, wind, solar and geothermal energy; CF2 is conversion factor from grams to Gigagrams; RA1 is a ratio standard net calorific value (7,000 kcal/kg) and Ekibastuz coal NCV (3,500cal/kg); CC is carbon content of Ekibastuz = 42 percent; RA2 is CO_2 and C molecular weights ratio = 3.67.

1.4.1 Increase in Fuel Utilization Efficiency at Heat Power Plants

For many years as well as at present the share of heat power plants (HHPs) in the total electricity generation has been 93-94 percent (*Mikhailovsky ,1993*). Thus, the most attractive options in the area of electricity generation are measures aimed either at increasing the efficiency of HHPs or at their replacement.

At present, the most efficient ways of decreasing electricity generation heat rates at HPPs are:

- further development of cogeneration instead of separate generation of electricity and heat, which can be implemented in three ways: construction of new cogeneration power plants; replacement of condensing turbines at existing plants by cogeneration turbines; modernization of condensing turbines; and
- enhancement of the thermal design of HPPs: and, in particular, the use of combined-cycle HPPs as both new construction and modernization of the existing steam turbine plants with the addition of gas-turbine units.

The cogeneration cycle allows a reduction in the electricity generation heat rate from 350 standardized gram of fuel/kWh (GCE/kWh) to 190 GCE/kWh; the CO_2 emission factor is reduced by 480 g/kWh.

The heat rates at combined-cycle HPPs that have a design efficiency of 42 percent is approximately 57 GCE/kWh lower than at usual HPPs, and the CO_2 emission factor is lower by 170 g/kWh. Table 11 presents the estimated electricity generation by new, more efficient HPPs according to the data of the Ministry of Energy of Kazakstan.

Table 11. Estimated Reduction of CO_2 Emissions for Heat Power Plants in Kazakstan

Parameters	Years				
	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020
Additional electricity generation by the cogeneration cycle (TWh)	3.10	7.70	10.20	14.70	18.20
Decrease in fuel consumption (tce)	496.00	1,232.00	1,632.00	2,352.00	2,912.00
Reduction in CO_2 emission (Gg)	1,529.00	3,798.00	5,031.00	7,251.00	8,977.00
Electricity generation by combined-cycle units in 5 years (TWh)	8.56	14.03	15.47	16.01	16.01
Decrease in the fuel consumption, (1000 tce)	488.00	800.00	882.00	913.00	13.00
Reduction in CO_2 emission, (Gg)	1,504.00	2,466.00	2,719.00	2,815.00	2,815.00
Total CO_2 emissions reduction, (Gg)	3,033.00	6,264.00	7,750.00	10,066.00	11,792.00
Cumulative CO_2 emissions reduction, (Gg)	3,033.00	9,297.00	17,047.00	27,113.00	38,905.00

In addition, the table shows the amount of avoided fuel in standardized tonnes. Proceeding from the Ekibastuz coal that is largely used in Kazakstan, and has 42 percent carbon content (*Ministry of Energy of USSR 1979*), the possible reduction in the CO_2 emissions was calculated in Gg and is also presented in Table 11. The heat rate is assumed to be 350 GCE/kWh (*State Statistical Committee 1991*).

By the year 2000 the construction of Aktyubinsk combined-cycle plant with the capacity of 954 MW and annual electricity generation of about 6 TWh is planned. The construction of similar plants of smaller capacity is expected in two more cities (by 2001-2005). A proposal to add gas-turbine units to the traditional steam-turbine units at the six largest cogeneration plants in Kazakstan is under consideration.

Electricity generation by combined-cycle technology can reach 8.5 TWh in 2000, 14 TWh in 2005 and 15.5 TWh in 2010. There are difficulties for further development of this option due to absence of natural gas resources.

1.4.2 Renewable Energy

Kazakstan has sufficient resources for the development of renewable energy sources such as hydro power, wind energy, solar energy and geothermal energy. On the basis of planned capacity inputs for the period through 2020, the reduction of CO_2 emissions for each of these sources is estimated.

Hydro Power. According to the assessments of the design organization of Kazakstan, several large hydro power plants are scheduled for construction. The program of the construction of new hydro capacities for the period 1996-2000 and the corresponding reduction in the CO_2 emissions are presented in Table 12.

Table 12. Estimated Reduction of CO_2 Emissions for Hydro Power

Parameters	Years				
	1995-2000	2001-2005	2006-2010	2011-2015	2016-2020
Total new hydraulic capacity (million W)	140.0	523.0	923.0	1,323.0	2,123.0
Electricity generation (TWh)	0.680	1.7	2.9	4.1	6.5
Amount of fuel replaced in the energy balance (1000 tce)	238.0	595.0	1,015.0	1,435.0	2,275.0
Replaced fuel recalculated in tonnes of Ekibastuz coal (1000 tonnes)	476.0	1,190.0	2,030.0	2,870.0	4,550.0
Reduction in carbon emissions (Gg)	200.0	500.0	853.0	1,205.0	1,911.0
Reduction in CO_2 emissions (Gg)	732.7	1,834.3	3,131.0	4,422.0	7,013.0

Wind Energy. The largest project for the use of wind energy in Kazakstan is the construction of the “Jungar Gate” wind power plant with a capacity of 300 MW and annual generation of 0.9 TWh. In addition, the construction of 6,650 small facilities is planned for the period from 1996 to 2020.

As a result, it is planned that the electricity generation from wind turbines will amount to 0.9135 TWh/year in 1996-2000, and 0.675, 0.750, 0.900 and 1.050 TWh/year in the subsequent five-year terms through 2020. This will result in reduction of the CO_2 emissions by 1132.9 Gg by 2020.

Solar Water Heating. Solar heaters can produce 80 liters of water heated by 40_C per 1 kW of heater power. Thus, one solar collector can produce 3,200 kcal/day, which means energy saving of 538 GCE. The usage of such collector for 200 days/year will save 107.6 skgf/year. The capacity of the demand market can be assessed between 1,000 and 5,000 heaters/year. Proceeding from the higher number, one can assess the resulting

CO_2 reduction as 331.7 tonnes/year. Solar electric power plants are also of great interest. By 2000, the construction of 1-2 such plants with the capacity of 50-100 MW in the south areas of Kazakstan is possible. The electricity generation of these plants can be assessed from 0.125 TWh/year in 1996-2000 to 0.500 TWh/year in 2016-2020, which will allow reduction in CO_2 emissions of up to 1,756 Gg.

Geothermal Energy**.** Due to the deepness of the deposits of geothermal water, use of already available drills for minerals is most reasonable. At the moment, there is no assessment of these resources. However, the lower estimate can be made as 100 thousand m^3 of water with the average temperature of 60^o C. This would result in the replacement of 1,020 standardized tonnes of fossil fuel /day (heat rate of 170 skgf/Gcal of heat is assumed). The annual reduction in the CO_2 emission would be about 1,150 Gg.

Roughly estimated (assuming gradual penetration of these resources), a reduction of 230 Gg of CO_2 per year can be reached.

1.4.3 Summary of screening of GHG mitigation options

The total potential of GHG mitigation in the energy sector for all options considered is shown in Table 13. The development and intensification of the traditional branches of the energy sector, the modernization of the existing CGP and the construction of new HYP, can produce the largest GHG reduction (see Table 13). Of the renewable options, the most attractive in terms of CO_2 reduction are the use of geothermal waters and wind energy. For the 1996-2020 period the implementation of all possible options in the energy sector would lead to a cumulative reduction of CO_2 emissions of 68,000 Gg.

Table 13. Potential Reduction of CO_2 Emissions in the Energy Sector of Kazakstan (Gg)

Option	Years				
	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020
Wind energy facilities	985.7	728.3	809.2	971.1	1,132.9
Hydro power facilities	732.7	1,834.3	3,131.0	4,422.0	7,013.0
Use of solar water heaters	0.3	0.3	0.3	0.3	0.3
Solar power plants	135.8	270.0	270.0	540.0	540.0
Use of geothermal energy	1,150.0	1,150.0	1,150.0	1,150.0	1,150.0
Decrease in cogeneration power plants heat rates	3,033 .0	6,264	7,750.0	10,066.0	11,792.0
Total CO_2 emissions reduction	6,037.5	10,246.3	13,110.5	17,149.4	21,689.6
Cumulative CO_2 emissions reduction	6,037.5	16,284.4	29,394.4	46,544.3	658,233.9

The calculations reflect rather optimistic assumptions. In reality the implementation of each measure would depend on many factors. The most important of these factors are reflected in the criteria presented in Table 14.

Table 14. Screening of Mitigation Options

Criteria	Cogeneration Modernization	Hydro Energy	Thermal Waters	Wind Energy	Solar Energy
Potential for large impact on CO_2, Gg	10,610	1,913	1,568	1,262	1,750
Indirect economic impacts:					
Increase in domestic employment	L	L	L	L	L
Decrease in import payments	H	H	M	M	H
Consistency with national environment goals:					
Reducing emissions of air pollutants	M	H	U	H	H
Effectiveness in limiting other environmental impacts	L	M	M	H	H
Potential effectiveness of implementation policies	M	M	U	M	L
Sustainability of option	H	H	U	L	U
Consistency with national development goals	H	H	U	M	U
Data availability for evaluation:					
Technology characterization	H	H	U	L	L
Cost of implementation programs	H	H	U	U	U

Notes: H-high; M-medium; L-low; U-uncertain

The development and intensification of the traditional branches of the energy sector, the modernization of the existing HHPs and the construction of new hydro power plants can produce the largest GHG reduction. Of the non-traditional options, the most promising in terms of CO_2 reduction are the use of geothermal waters and wind energy. For the 1996-2020 period, the implementation of all possible options in the energy sector would lead to a cumulative reduction of CO_2 emissions of 68,000 Gg.

From the viewpoint of the criterion of “indirect impacts”, one can note that the considered options will not affect the employment of the population, but some redistribution of human resources may occur. Also, one can note that the implementation of the majority of the options in the energy sector will somewhat reduce the imports of fuel and/or electricity.

In terms of the criterion of the correspondence to the environmental policy (criterion 4), the renewable energy resources, wind and solar energy in particular, and the utilization of biogas have the highest grade. These options will allow decrease in emissions of CO_2 and other harmful gases in the process of fuel combustion and also decrease other negative environmental impacts, e.g., the coal dumps will disappear. Hydro power has a lower rating according to this criterion because it affects water ecosystems.

From the viewpoint of highest support in Kazakstan (criterion 6), options for HPPs modernization and construction of new hydro power plants are most attractive, because this is the traditional technology of energy generation. Also, these options are most developed technologically and economically.

Thus, we can conclude that the main mitigation options in the energy production sector, according to the criteria of mitigation potential and feasibility, are the following:

1. modernization of HPPs aimed at increasing efficiency;

2. further expansion in the use of hydro power energy;
3. use of wind energy;
4. use of solar energy.

In addition instolation of nuclear power plant were considered. Developing a nuclear power has a good potential in Kazakstan because it has 25 percent of the world resources of uranium. Installation of the two units of nuclear turbine instead of putting into operation six coal units at the South Coal Power Plant, which is the main Nuclear Scenario assumption, and it is also includedin the plans of the Ministry of Energy (*Program for Urgent Measures on Energy Development*, 1996) .

Table 15 presents the estimated additional electricity generation by new, more efficient TPPs and possible produced electricity at the expense of installation of renewable and nuclear power plants according to the data of the Ministry of Energy and Coal Industry of Kazakstan (*Program for Urgent Measures on Energy Development*, 1996) .

Table 15. Electricity Generation for Different Mitigation Options (TWh)

Mitigation option	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020
Modernization of TPPs:					
Cogeneration cycle	3.100	7.700	10.200	14.700	18.200
Combined-cycle	8.560	14.030	15.470	16.010	16.010
Hydro Power Plants	0.680	1.700	2.900	4.100	6.500
Solar Power Plants	0.125	0.250	0.250	0.500	0.500
Wind Power Plants	0.914	0.675	0.750	0.900	1.050
Nuclear Power Plant	-	-	-	2.000	5.000

1.5 Scenarios of Energy Sector Development in Kazakstan

As general scenario assumptions have been defined and screening of possible mitigation options in energy production sector has been done, scenarios for energy sector long - term development has to be elaborated. To conduct the analysis of the most promising mitigation options the baseline and six alternative mitigation scenarios based on the BALANCE module of the ENPEP package has been developed. The definitions of all those scenarios are given below.

1.5.1 Baseline Scenario

A baseline scenario should represent a future in which there are no policies or programs designed to encourage or require actions that reduce GHG emissions or enhance carbon sink (*Sathaye and Mayers, 1995*).

Taking into account macro economic projections and general scenario assumptions (section 1.3); the baseline scenario of the energy sector development in Kazakstan for the period up to the year 2020 has been worked out. These key assumptions for the baseline scenario can be summarized as follows:

- Prices of imported oil, coal, fuel oil and power will reach the world prices in the year 2000; for imported gas this will happen in 1995;
- Prices of domestic and imported fuel and energy resources will go up at the same pace;
- Demand blocks for oil products, fuel oil, gas and coal comprise both domestic consumption and export;
- Identical rate changes in oil exports' and total fuel and energy resource consumption in Kazakstan are assumed;
- Heat and power production ratio in CGP plants will not change in the future;
- Gas and fuel oil consumption fraction will not change in GCG and GCN in the future;
- New boilers will not be built;
- When new capacity of CCG plants are introduced the capital expenditures will not change;
- Heat and electricity losses in networks will not change;
- The final energy use remains the same for every scenaro;
- Operating heat and power generation capacities will not be decommissioned

The baseline scenario of the Kazakstan's energy sector development in 1990-2020 has been constructed by inputting the following information in the Balance module:

- Data on the fuel and energy balance and capacities of the heat - and power generating sector for the base year 1990 (see section 1.2.3);
- Fuel and energy resource price projection (section 1.2.4).
- Final energy demand projection (section 1.3.4)
- Fuel resources extraction projection (1.3.5.1)
- Data on installed capacity projection for the heat and power generation sector (section 1.3.5.2)

1.5.2 Mitigation scenarios

A mitigation scenario reflects a future in which climate change mitigation is a primary motivation for adoption of technologies and practices that reduce GHG emissions. It may reflect only the technical potential for reducing GHG emission or storing carbon sinks, or it may incorporate estimates of what is achievable considering the many factors (institutional, cultural, legal, etc.) (*Sathaye and Mayers, 1995*).

The main objective of carrying out mitigation scenarios here is to evaluate the most attractive mitigation options, focusing on specific technologies in energy production sector.

In section 1.4 possible GHG mitigation options reduce in the energy production sector in 1996-2020 were considered. Only four of all mitigation options have been chosen for further analysis. There are: the rehabilitation of HPPs aimed at increasing efficiency; further expansion in the use of hydro power energy and the use of wind and solar energy.

The use of solar water heaters has not been evaluated since it does not make an essential contribution to the generated power capacity. The use of thermal water is rather uncertain in according to the most of criterion (see Table 11).

When the scenario with installation of hydropower capacity was elaborating we took into account, that an installation the large Hydro power stations has been taken into account in the baseline scenario, therefore only small once were involved in the mitigation scenario developing.

In addition the mitigation scenario where the capacity of nuclear power was installed, has been elaborated. When the scenario was developing, following information about possibility of developing nuclear power (NPP) in Kazakstan has been taken into account. According to the energy development plans the construction and commission of six blocks of the South Kazakstan CCN were projected beginning from 2002. However, in nowadays a possibility of introduction of only two of them and the construction of two Nuclear Power Plant blocks nearly is under considerations. Thus, an analysis of the GHG emissions reduction for this option the introduction of two Coal Condenced Power Plant and two Nuclear blocks - can be carried out.

At last, the mitigation scenario, that include all five mentioned options has been developed.

Thus, in addition to base case we ran following six alternative scenarios: (1) **Rehabilitation Cogeneration** scenario, which include the options on modernization of HPP; (2) **Small Hydro** scenario, which include hydropower plants installation; (3) **Wind** scenario, which include wind power plants installation; (4) **Nuclear** scenario, installation of nuclear capacities; (5) **Solar** scenario, including the use of solar energy and (6) **Integrated** scenario which include all mentioned mitigation options.

To run these mitigation cases related changes have been introduced in the BALANCE module. There are main assumptions and data for each mitigation scenario differ from baseline one below.

1.5.2.1 Rehabilitation Cogeneration scenario

As it was indicated in section 1.4, the specific fuel consumption reduction in the HPP can be achieved in two ways: the rehabilitation of power generation using introduction of district heating cycle and the introduction of cogeneration steam and gas technologies.

The main assumptions for Rehabilitation Cogeneration mitigation scenario differ from the baseline one are as follows: (1) the efficiency has been increased so that total fuel consumption reduction for the period 1990-2020 corresponded to data in Table 11, section 1.4.1; (2) capital expenditures have been increased by 20-50 % , as more perfect facilities are more expensive.

Capital expenditure projections for coal and oil-gas cogeneration power plants, according to plans of the Ministry of Energy and Coal Industry, for this scenario are given in Table 16.

Table 16. Capital Expenditure Projection for Cogeneration Power Plants ($/unit of capacity)

	Years					
	1995	2000	2005	2010	2015	2020
Coal-fired		638	740	858	995	1153
Oil-gas-fired	540	590	684	794	920	1067

To run the scenario it is assumed that an introduction of district heating plants are developed on the basis of new units of CCG and corresponding data has been indroduced to the node Cogener (coal) - 4 of the energy network (see Fig.2). Installation of steam and gas technologies are developed on the basis of new units of GCG and data introduced in the node Cogener (oil-gas) - 5. Table 17 gives the data on introduced changes in comparison to the base case.

Table 17. Changes Made for the Rehab.Cogen. Scenario

Type of Cogeneration	Efficiency		Capital Expenditures,$	
	Baseline Scenario	Rehab.Cogen. Scenario	Baseline Scenario	Rehab.Cogen. Scenario
Coal-fired	0.19 (e) 0.39 (h)	0.23 (e) 0.47 (h)	255.00	383.00
Oil-gas-fired	0.17 (e) 0.41 (h)	0.18 (e) 0.42 (h)	360.00	432.00

Notes: e -electricity; h - heat.

In Table 17 an increase in the efficiency of the CGP plants in the mitigation scenario as compared with the baseline scenario by 6 % for new GCG and 21 % for new CCG is explained by the following. In the mitigation scenario for new GCG an introduction of steam and gas turbines and for new CCG - an introduction of district heating are simulated. These technologies differ in the efficiency growth rate: for the former it is 3 times less than for the latter. It is this difference that is observed in the mitigation scenario when future CGP capacities are simulated. These changes are presented in corresponding tables of Appendix B. They are marked by the symbol (*).

1.5.2.2 Small Hydro, Wind, Solar and Nuclear scenarios

When *Wind* and *Solar* mitigation scenarios developed it was assumed, that additional energy capacity would be introduced through the year 2020 according to data, presented in Table 13, section 1.4.3.

In *Small Hydro* scenario it is assumed that 356.7; 504.3 and 799.5 tce will be avoided in 2010, 2015 and 2020 respectively due to small hydropower plants intstallation.

As mentioned, it was assumed in *Nuclear* scenario, that in year 2010 power generation at three units (blocks) at South Kazakstan Coal Condensation Power plant (CCN) would be replaced by power generation in Nuclear Power plant. In that case the amount of avoided fuel in the energy balance can reach 3,862 and 24,255 thousand tce by years 2015 and 2020 respectively. Fuel cost for NPP is assumed to be 150 $/ tce.

In Table 18 capital expenditure and O&M cost variations though the year 2020 for Nuclear (NPP) Wind (WPP) and Solar (Photovoltmatic) (PPP) power plants according to the mitigation scenarios are presented. For *Small Hydro* scenario it was assumed that capital expenditures and O&M costs per unit of capacity would be the same as for hydropower plants (HYP) for the baseline scenario (see Tables 6 and 7).

Table 18. Capital and O&M Costs Variations for Small Hydro, Wind, Solar and Nuclear scenarios ($/unit of capacity)

Scenario	Years				
	2000	2005	2010	2015	2020
			Capital Costs		
Nuclear			543	629	730
Wind	983	1,140	1,321	1,531	1,775
Solar	2,577	2,987	3,463	4,015	4,654
			O&M Costs		
Nuclear			54.00	62.60	72.57
Wind	222.00	257.36	298.35	345.87	400.96
Solar	75.00	86.95	100.79	116.85	135.46

To run *Nuclear*, *Wind* and *Solar* scenarios power generation at the expense of the nuclear, wind, solar and hydropower new convention process nodes were installed in the energy network (see section 1.2.2, Figure 2). They were Nuclear light water-PP-11, Wind turbine-12 and Photovoltaic-13 nodes respectively. Input for indicated nodes is presented in Table 19.

Table 19. Input Data for Nuclear, Wind and Solar Scenarios

Node	Efficiency	Capital costs per unit of capacity, $/tce	O&M costs, $/tce	Life expectancy, years	Capacity ratio	Electricity output, million tce				
						Year				
						2000	2005	2010	2015	2020
Nuclear light water-13	0.32	543.00	54.00	30.00	0.65	-	-	246.0	861.0	1,180.8
Wind turbine-14	1.00	983.00	222.00	20.00	0.35	112.4	195.4	287.7	398.4	527.6
Photo-voltaic-15	1.00	2,577.00	75.00	30.00	0.33	15.4	46.2	77.0	138.5	200.0

Fuel cost for NPP is assumed to be 150 $/tce. Data on efficiency, capacity ratio, O&M costs, capital expenditures, lifetime for the nodes Nuclear light water PP-13 for Nuclear Scenario, Wind turbine-14 for Wind Scenario, Photovoltaic-15 for Solar Scenario blocks have been drawn from the IMPACTS database for respect technologies. The procedure of new data inputting is shown in the corresponding tables of Appendix B (symbol *).

1.5.2.3 Summary of assumption for mitigation scenarios

In conclusion, let us to summarize inputs were introduced to the energy network of the Balance Module to run all considered mitigation scenarios. First of all the data for baseline case was taken as a basis for construction of the mitigation scenarios. Efficiency and capital cost data differ from the baseline scenario were introduced in the Cogener(coal)-4 and Cogener(oil-gas)-5 nodes for *Rehab. Cogen*. scenario. New nodes for *Nuclear, Wind* and *Solar* scenarios have been introduced. Data differ from the baseline ones were introduced to Condens (coal)PP-9 and Hydraulic PP-6 nodes for *Small Hydro* and *Nuclear* scenarios. Summary of the introduced data and assumptions are presented in table 20.

Table 20. Data and Assumptions for the Mitigation Scenarios

Scenario	Assumptions and data differ from the baseline scenario	Nodes, which data were introduced
Rehab. Cogen.	See sections 1.4 and 1.5.2.1	Cogener (coal)-4, Cogener (oil/gas)-5
Small Hydro	See section 1.5.2.2	Hydraulic PP-8
Nuclear	See section 1.5.2.2	Nuclear light water PP-13
Wind	See section 1.5.2.2	Wind turbine-14
Solar	See in section 1.5.2.2	Photovoltaic-15
Integrated	All above mentioned changes	All above mentioned nodes

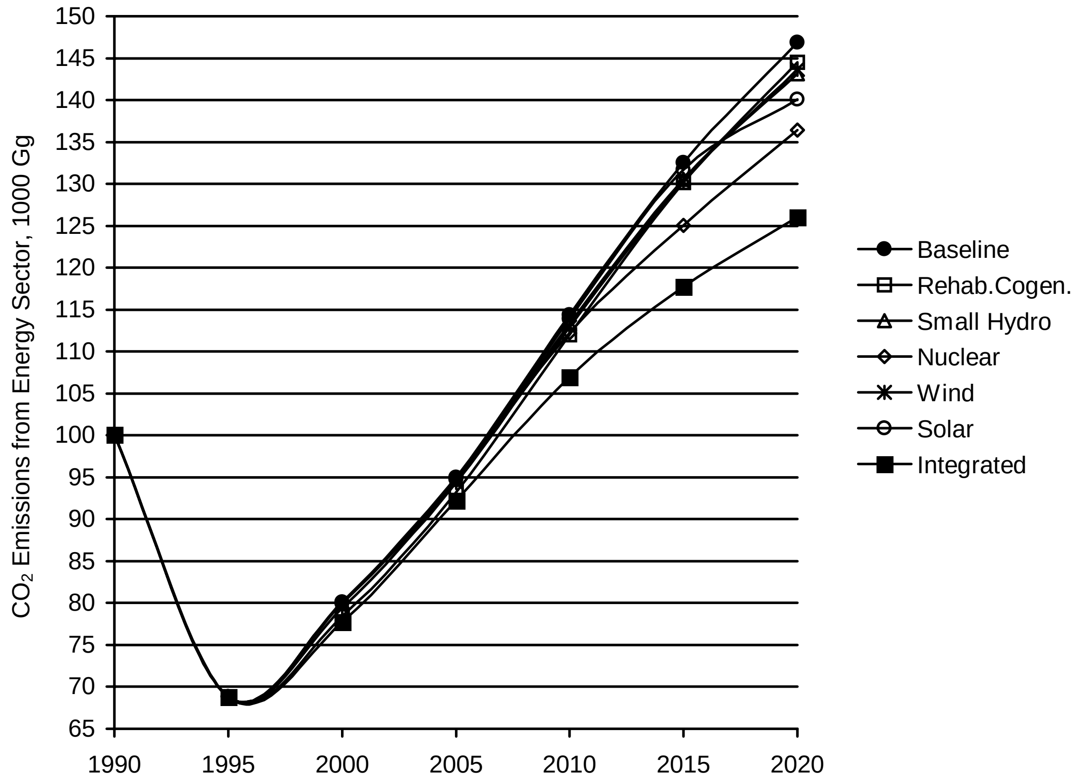
1.6 Results

1.6.1 GHG emissions

GHG emissions and their time changes are the most important features of every scenario. The GHG emissions are projected according to the baseline and mitigation scenarios using the IMPACTS module of ENPEP package. The projection is accomplished for CO_2, CH_4, NO_x, CO, and NMVOC, as well as for SO_2 and particles. All scenarios have the same emissions in the base 1990 year.

The results for CO_2, the most important GHG, is presented in Figure 9.

Figure 9. CO_2 Emissions Projection for the Baseline and Mitigation Scenarios



The difference between the base year CO_2 emissions estimates presented in Figure 9 and the National GHG Inventory (*Monocrovich* et. al., 1996) is not significant and amounted to about 5 percent. The results obtained for the baseline scenario indicate the following level of CO_2 emissions compared to the 1990 base year: 1995, 69 percent; 2000, 80 percent; 2005, 95 percent; 2010, 114 percent; 2015, 132 percent and 2020, 147 percent. Such a time run of CO_2 emissions reflects the general decline of economy at the first stage of a transition period.

The comparison between emission levels for the baseline and each mitigation scenario shows that the potential of CO_2 reduction considerably differs under different mitigation scenarios. Difference between baseline and each mitigation levels of CO_2 emissions (in Gg) is presented in Table 21. In Table 22 these data are expressed as percentage of the baseline CO_2 emissions level.

Table 21. CO_2 Emission Reductions from Baseline Level under Mitigation Scenarios (Gg)

Scenario	Year				
	2000	2005	2010	2015	2020
Cogen. Rehab.	1,609	1,763	2,308	2,330	2,330
Small Hydro		0,141	1,018	1,929	3,740
Nuclear			2,128	5,035	10,402
Wind	0,652	0,632	1,459	2,275	3,139
Solar	0,089	0,196	0,442	0,816	1,739

Integrated	2,351	2,739	6,351	11,629	16,277

Table 22. Annual CO_2 Emissions Reductions from Baseline Level under Mitigation Scenarios (% of baseline emissions)

Scenario	Year				
	2000	2005	2010	2015	2020
Cogen. Rehab.	2.0	1.9	2.0	1.8	1.6
Small Hydro		0.2	0.9	1.5	2.6
Nuclear			1.9	3,8	7.1
Wind	0.8	0.7	1.3	1.7	2.1
Solar	0.1	0.2	0.4	0.6	1.2
Integrated	2.9	2.9	5.6	8.8	11.1

According to Cogen.Rehab., Wind and Solar scenarios these measures can lead to emission reductions since 2000. Installation of small hydro power stations (Small Hydro mitigation scenario) can reduce emissions since 2005, and introduction of Nuclear power plant (Nuclear scenario) can reduce them since 2010.

As we can see from the Tables 21, 22 and Figure 10 development of nuclear energy can lead to the most considerable CO_2 emissions reduction. According to the Nuclear scenario, there are 1.9; 3.8 and 7.1 percents of annual emission reduction in 2005, 2010 and 2020 respectively in comparison with the baseline scenario. The rehabilitation of power generation (Rehab.Cogen. scenario) can reduce annual CO_2 emissions to 1,609 Gg by 2000 and about 2,330 Gg by 2020, that amounts to about 2 percent of the baseline level. The mitigation potential of the Small Hydro and Wind scenarios totals from 0.2 to 2.6 percents in 2000 and 2020 respectively. Total reduction potential of the all mitigation measures (Integrated scenario) suppose to be from 2.9 in 2000 to 11.1 percent in 2020.

In general, we can say that according to every considered scenario development of CO_2 emissions indicates that it most probably will not exceed 1990 level until 2005.

The difference between baseline and each mitigation scenario levels of the other GHG as well as SO_2 and particles expressed as percentage of the corresponding baseline emissions level is presented in Table 23. Emissions of NOx and CO were calculated in the GHG Inventory (*Kazakstan GHG Inventory for 1990, 1995*). The same emissions calculated with the use of the IMPACTS module for 1990 differs from them by about 40 %. The reason of these discrepancies can be explained by the possible difference between emission factors for NOx and CO in our previous inventory and those used in the IMPACTS module.

Table 23. GHG, SO_2 and Particles Emissions Reduction from the Baseline Scenario Level under Mitigation Scenarios (%)

GHG	Emissions Reduction, in percent of the baseline emissions				
	Year				
	2000	2005	2010	2015	2020

		Rehab. Cogen. scenario			
CH_4	1.9	1.7	1.9	1.6	1.5
NO_x	1.5	1.7	2.0	1.7	1.5
CO	2.1	2.0	2.1	1.9	1.7
NMVOC	2.0	1.8	2.0	1.7	1.6
SO_2	1.9	1.7	1.9	1.6	1.5
Particulates	1.4	1.2	1.5	1.3	1.1
		Small Hydro scenario			
CH_4	0.0	0.2	0.9	1.5	2.6
NO_x	0.0	0.2	0.9	1.5	2.6
CO	0.0	0.1	0.9	1.4	2.6
NMVOC	0.0	0.2	0.9	1.8	2.6
SO_2	0.0	0.2	0.9	1.5	2.6
Particulates	0.0	0.2	1.0	1.7	3.0
		Nuclear scenario			
CH_4	0.0	0.2	0.9	1.5	2.6
NO_x	0.0	0.0	1.9	5.8	7.2
CO	0.0	0.0	1.7	5.3	6.7
NMVOC	0.0	0.0	1.9	5.7	7.2
SO_2	0.0	0.0	2.0	6.0	7.4
Particulates	0.0	0.0	2.4	7.0	8.6
		Wind Scenario			
CH_4	0.9	0.7	1.3	1.8	2.2
NO_x	0.8	0.7	1.3	1.8	2.2
CO	0.8	0.6	1.2	1.6	2.0
NMVOC	0.8	0.7	1.3	1.7	2.2
SO_2	0.9	0.7	1.3	1.8	2.2
Particulates	1.1	0.8	1.5	2.0	2.6
		Solar Scenario			
CH_4	0.1	0.2	0.4	0.6	3.7
NO_x	0.1	0.2	0.4	0.6	4.2
CO	0.1	0.2	3.4	0.6	5.4
NMVOC	0.1	0.2	0.4	0.6	4.4
SO_2	0.1	0.2	0.4	0.6	3.8
Particulates	0.2	0.2	0.4	0.7	2.6
		Integrated			
CH_4	2.9	2.9	6.6	11.6	14.7

NO_x	2.9	2.9	6.5	11.3	14.4
CO	3.0	3.0	6.3	10.8	13.7
NMVOC	2.3	2.9	6.4	11.3	14.3
SO_2	2.3	2.8	6.6	11.5	14.7
Particulates	2.6	2.4	7.0	12.7	16.2

Level of CH_4, NO_x, CO and NMVOC emissions is incomparably less than level of CO_2 emissions. At the same time the relative changes of the other GHG emissions reductions, as well as of the SO_2 and particle emissions under the different Mitigation scenarios compared to the baseline scenario are similar to those for CO_2.

Comparison the CO_2 emission scenarios expert judgments of the development of CO_2 emissions

In addition to the assessment with the use of the IMPACTS module given above, baseline GHG emissions scenario was also developed by experts' assessments. Ten experts including the leading authorities and scientists in the energy sector, industry, transport, agriculture as well as experts in economics were questioned. The experts took into account the results of the last 4 years (official statistics) and the actual status of production in their respective branches of the economy.

Taking into account CO_2 emissions level for 1990, on the first step the experts determined the production ratio between 1991 and 1990. The comparison of data showed that in both production volumes and fuel consumption 1991, values are practically the same as for 1990. The year 1991 was one of stagnation: the production growth stopped while the decline had not yet started. Since 1992, there has been a decline first in industry and then in the other branches of the economy.

The experts noted the following four reasons for the decline:

1. Interruptions or cancellation of the supplies from the members of the former USSR due to severing of economic and financial links;
2. A high degree of equipment being worn out, a decrease in efficiency, and available capacity and as the result, an increase in energy consumption;
3. Difficulties in selling the major items of Kazakstan exports (non-ferrous metals, mineral fertilizers, etc.) - Kazakstan consumes only 8 percent - 20 percent of the production of such products while the former consumers (the members of the former Soviet Union) either can not buy products due to economic difficulties or prefer other suppliers;
4. Movement of human resources from the country and from the state industrial enterprises to other activities (retail stores, cooperatives etc.).

Due to these and other reasons the decline in production as compared to 1991 was 10 percent in 1992, 25 percent in 1993, and the 40 percent in 1994. For 1996 the experts projected further decline in production: 45 percent for the optimistic scenario and 50 percent for the pessimistic scenario. Stabilization is only expected in 1998; after that, some slow growth is expected to reflect up to 75-80 percent of the 1991 level by the end of the decade.

The forecast for the production volumes in industry for the second half of the decade is especially unreliable in comparison with similar forecasts for the other branches of the economy. The mentioned high degree of equipment depreciation, being a highly negative factor, will nevertheless become a stimulus for the restructuring of the industry.

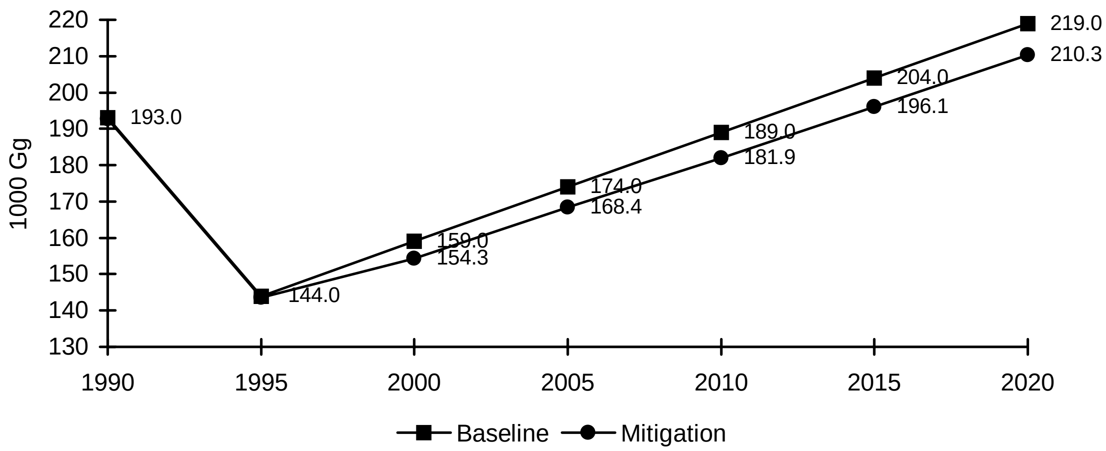
Another important factor - a high growth of the prices for energy sources - will also have a major impact. As energy consumption by industry in Kazakstan is high, the cost of industrial products will increase, which will worsen the problem of selling the products.

The decline in the energy sector is somewhat less than general decline in industry due to an increase in energy consumption because of aging equipment. In addition, residential electricity consumption, which is the second largest consumer of electricity, showed less changed. The residential consumption of energy in 1993 was 15 percent less than in 1991 level, as compared with 25 percent decline in industry. The stabilization of electricity generation is expected in 1996; after that, a growth is expected, reaching the level of 90 percent of the 1991 generation in 2000.

In agriculture, the total amount of cultivated land decreased by 2 million ha during the last three years. In the near future, a reduction by 1-2 million ha can be expected, with a total reduction of about 15 percent in comparison to the 1991 level. The specific energy consumption per hectare will increase by 10 percent - 20 percent due to modernization of the cultivation techniques. At present, many operations such as cultivation, water retention, snow retention are not implemented in full due to shortages in fuel and equipment.

On the basis of the expert assessments and data on specific fuel consumption in the major branches of the economy we developed a baseline scenario of the CO_2 emissions for the period 1990-2020 as well as one mitigation scenario. When developing the mitigation scenario, the most realistic options in energy sector that meet the key criteria (see Table 13, section 1.4.3) were accounted for. In this scenario the following options were integrated: modernization of HPPs aimed at increasing efficiency; further expansion in the use of hydro power energy and use of wind energy; use of the energy of geothermal waters and the use of solar energy.

Figure 10. CO_2 Emissions Projections for Baseline and Mitigation Scenarios According to the Expert Judgments



CO_2 emissions projections for the baseline and the mitigation scenario, according to the expert judgement are presented in Figure 10. As we can see from the figure, according to baseline scenario, CO_2 emissions decline sharply through 1996 and then gradually rise.

The total volume of CO_2 emissions in this decade amounts to 1,571,000 Gg. For the same period, the CO_2 absorption by forest can be assessed as 40,000 Gg. Thus, the net emission is 1,531,000 Gg. The GHG emissions in 2000 are 18 percent below the 1990 level. This result is in a good agreement with those, obtained from the IMPACTS module (Figure 9).

The annual reduction of the CO_2 emissions under expert assessment is amounted to 3 percent by the year 2000 and about 4 percent by 2020 in comparison with the baseline level. As it has been shown in section 1.6.1 the same parameters for Integrated mitigation scenario under IMPACTS module amounted for 2.9 and 11.1 percent respectively, because of including in the later analysis introduction of the nuclear plants.

1.6.2 Energy Use

GHG emission reduction connects with the changes in the composition of fuel-energy requirements that is decreasing use of traditional fossil fuel (coal, fuel oil and gas) and corresponding decrease of power generation by all types of Heat Power Plants. The fuel consumption and electricity generation changes under baseline and different mitigation scenarios obtained from the BALANCE are considered below.

1.6.2.1 Primary Energy

The total fuel consumption and shares of different fuel types under baseline scenario by energy production section in conditional units (tce) and in per cent of the value of the year 1990 are presented in Tables 24 and 25.

Table 24. Fuel Consumption by Heat Power Plants under the Baseline Scenario (1000 tce)

Fuel Type	Year						
	1990	1995	2000	2005	2010	2015	2020
Coal	30,366	20,441	20,071	24,206	30,063	36,031	40,865
Fuel Oil	2,807	2,272	5,480	6,195	6,754	6,912	6,942
Gas	3,084	2,496	6,021	6,807	7,420	7,594	7,627
Total	36,257	25,209	31,572	37,208	44,237	50,537	55,434

Table 25. Fuel Consumption by Heat Power Plants under the Baseline Scenario (% of 1990)

Fuel Type	Year						
	1990	1995	2000	2005	2010	2015	2020
Coal	100	67	66	80	99	119	135
Fuel Oil and Gas	100	81	195	221	241	246	247
Total	100	70	87	103	122	139	153

According to the baseline scenario the coal consumption on all types of Heat Power Plants totally for the years 1995-2000 is to be decreased by 33% - 34 % compared to its level in 1990. The coal consumption is to be reached its level of the year 1990 after the year 2010 and will increase by 35 % in the year 2020. More considerable changes under the baseline scenario are expected to occur in the consumption of gas and fuel oil. The using of these fuels can increase twice, and twice and a half compared to the year 1990 by the end of the years 2000 2020, respectively. The total fuel consumption fell by 30 % in 1995. It would reached the 1990 level in the period 2000-2005 and increased by 53 % by the year 2020.

The character feature of the fuel balance of Heat Power Plants under the baseline scenario is suppose to be an increase of the proportion of gas and fuel oil and decrease of the coal share (Tables 24 and 25). In Table 26 the fuel balance, that is proportions of different fuel types in percentage of the total consumed fuel under the baseline scenario is presented.

Table 26. Fuel Balance of Heat Power Plants under the Baseline Scenario (% of the total consumed fuel)

Fuel Type	Year						
	1990	1995	2000	2005	2010	2015	2020
Coal	83	81	74	75	78	71	73
Fuel Oil	8	9	17	17	15	14	13
Gas	9	10	19	18	17	15	14
Total	100	100	100	100	100	100	100

Table shows that under the baseline scenario, by 2000 the fuel oil and gas share will increase from 8% to 17 % and from 9% to 19 % respectively, and a specific weight of coal will decrease from 83% to 74 % (Table 26). The fuel oil and gas share will decrease and the coal share will increase further by the year 2020. The share of fuel oil and gas will change from 17% to 13 % and from 19% to 14 % for the period 2000-2020, respectively. The share of coal will rise from 74% to 78 % by 2010 and then will decrease to 73% by the year 2020. Such changes in fuel balance are determined by installation of large gas and fuel oil units in the year 2000 and the largest in the country South Kazakstan CNP in the years 2002-2005.

The reduction of fuel consumption in thousand tce and percentage of the year 1990 under different Mitigation Scenarios are presented in Table 27.

Table 27. Reduction of Coal Consumption at HPP in Mitigation Scenarios as Compared with Baseline Scenario (1000 tce/percentage)

Mitigation Scenario	Year									
	2000		2005		2010		2015		2020	
	1000 tce	%	1000 tce	%	1000 tce	%	1000 tce	%	1000 tce	%
					Coal					
Rehab. Cogen.	272	1.4	294	1.2	454	1.5	454	1.3	454	1.1

Small hydro			43	0.2	316	1.1	612	1.7	1,218	3.0
Nuclear					7,254	2.4	2,532	7.0	3,537	8.7
Wind	222	1.1	192	0.8	465	1.5	731	2.0	1,047	2.6
Solar	30	0.1	60	0.2	135	0.4	259	0.7	413	1.0
Integrated	525	2.6	592	2.4	2,096	7.0	4,589	12.7	6,625	16.2
Fuel oil and gas										
Rehab. Cogen.	441	3.8	491	3.8	533	3.8	544	3.7	544	3.7
Small Hydro			7	0.03	50	0.4	70	0.5	86	0.6
Nuclear										
Wind			36	0.3	52	0.4	68	0.5	32	0.2
Solar										
Integrated	441	3.8	545	4.2	650	4.6	720	5.0	729	5.0
Total										
Rehab. Cogen.	713	2.3	785	2.1	987	2.2	998	2.0	998	1.8
Small Hydro			50	0.1	366	0.8	682	1.3	1,304	2.4
Nuclear					7,254	1.6	2,532	5.0	3,537	6.4
Wind	222	0.7	228	0.6	517	1.2	799	1.6	1,079	1.9
Solar	30	0.1	60	0.2	135	0.3	259	0.5	413	0.7
Integrated	966	3.1	1,137	3.1	2,746	6.2	5,309	10.5	7,354	13.3

As one can see, introduction of hydro power plants (Small Hydro Scenario) offers predominantly reduction of coal consumption and slight reduction of oil-gas fuel consumption.

Under the other renewable scenarios replacements of power generation on coal fuel take place as well as. In case of the Solar Scenario the amount of forced out coal is minimum. The only coal ousts from fuel balance by putting into operation the nuclear power plants (Nuclear Scenario). This reduction is rather significant because of large plants capacity.

There are not significant changes in structure of fuel balance under Integrated mitigation scenario. Summarized reduction of traditional fossil fuel consumption by all types of HPP accounts for from 3,1% to 13,3%. As we can see CO_2 emissions is decreased with the same rate. Therefore coal consumption decrease has principal contribution to emission reduction. Coal combustion, among other things, leads to the most CO_2 emissions that are more than oil and gas ones by 30% and 80% respectively.

Thus, as we can see from the analysis above the most replacement of fossil fuel is taken to arrive under Nuclear and Rehab. Cogen. Scenarios. Almost none of proposed measures lead to reduction of oil-gas fuel consumption. Explanation of this fact will be offered in following section devoted by power generation structure.

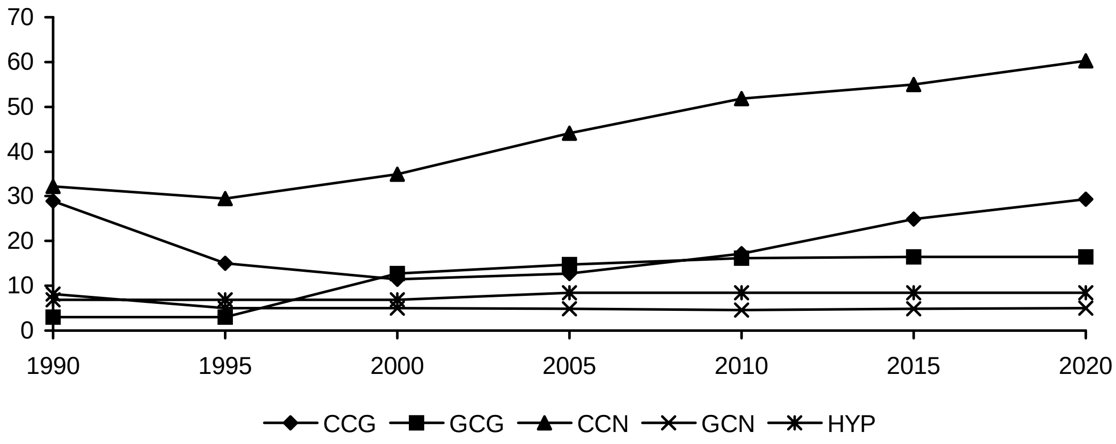
1.6.2.2 Electricity Generation

Let us consider here the development of capacity expansion of the power electricity system by different types of Heat Power Plants being used in the various scenarios.

Note, that in this study we discuss only annual electricity requirements. These values were obtain from the BALANCE Module.

Electricity generated by main types of technologies: (CCG - Coal Cogeneration Power Plants, GCG - Oil Gas Cogeneration Power Plants, CCN - Coal Condensed Power Plants, GCN - Oil Gas Condensed Power Plants, HYP - Hydro Power Plants) under the baseline scenario is presented in Figure 11.

Figure 11. Electricity Generation under the Baseline Scenario (million kWh)



The share of electrcity producing by different types of technologies under the Baseline Scenario is given in Table 28.

Table 28. Share of electricity generated by different types of technologies under the Baseline Scenario (%)

Technology type	Year						
	1990	1995	2000	2005	2010	2015	2020
CCG	36	25	16	15	18	23	25
GCG	4	5	18	17	16	15	14
CCN	41	50	49	52	53	50	50
GCN	10	8	7	6	5	4	4
HYP	9	12	10	10	8	8	7
Total	100	100	100	100	100	100	100

It is immediately apparent from the Table 28, that in the base year the main technology in energy production sector was coal condensed power plants (CCN), where 50% of all amount of electricity was produced, followed by coal cogeneration power plants (CCG), where 36% was produced, oil gas condensed power plants (GCN) and oil gas cogeneration power plants (GCG), with shares of energy production of 10 and 4 % respectively. The share of hydro power energy (HYP) was minimum and amounted for 9 %.

Table 28 and Figure 11 indicate that according to baseline scenario, the share of CCN has been increasing slightly through the year 2020, while those for GCG increase significantly from 4 to 14 per cent. With the later fact the significant fact of increase of oil and gas consumption (that has been indicated in section 1.6.2.1) is connected. The shares of CCG, GCN, HYP is suppose to be decrease by the year 2020.

Figure 11 shows that, according to the baseline scenario, electricity generation at all type of Power Plant, except CCN, decreased during the period 1990-1995. The total electricity generation drops by almost a quarter in 1995 compares to 1990. It is projected, that after the year 1995 electricity generation will grow steady to almost 120 kWh by the year 2020, that are almost 1,5 times more that those for the base year.

Amount of electricity generation is connected with a share of import of electricity. The information about import of electricity according to baseline scenario is presented in Table 29.

Table 29. Import of Electricity According to Baseline Scenario

Unit	Year						
	1990	1995	2000	2005	2010	2015	2020
million kWh	29,203	19,154	15,130	13,911	11,480	10,081	10,789
(%) for 1990	100	66	52	48	39	35	37

Import of electricity is likely to fall to less than 40 per cent of its 1990 level by the 2020.

Let us consider the changes in power generation balance under different mitigation scenarios. In our study we assumed that total electricity demand under all mitigation scenarios is the same as for the baseline scenario. That is, summarized value of consumed power is remaining as for the baseline case. In addition, when we had run the mitigation cases following two main assumptions were accepted. Firstly, we set a priority for new technologies under mitigation scenarios to allow them to produce all planned power (electricity) as it has been given in Table 15, not taking into account economical effectiveness of proposed measures. Secondly, power electricity produced by new capacities oust electricity produced by only CNP. Power generation on CGP can not be decreased, because they produce mainly heat, and proportion of heat and electricity generation are constant (see section 1.5.1).

Therefore, Rehabilitation Cogeneration scenario, which include the options on modernization of HPP, is only scenario that has no any changes in power generation. Under this scenario energy efficiency and cost of electricity are increased.

In Table 30 changes of electricity generated by different power plants under different mitigation scenarios in percentage of respect amount of electricity under baseline scenario are presented. As expected, all mitigation measures lead to decreasing share of electricity generation at traditional fuel plants (i.e. Heat Power Plants) - oil-gas and coal condensed plants compared to baseline conditions**.** Table 30 shows that this decrease at Coal Condensed Plants reached maximum under Nuclear scenario by 2020, where the share of electricity supposed to be amounted for about 16 per cent of baseline level. Small Hydro, Wind, Solar scenarios allow to decrease the share by 5.6, 4.8 and 1.9 % by the year 2020 respectively. The largest decrease of the share of electricity generated by oil-gas condensed plants is suppose to be under Small Hydro scenario (about 5 % by 2020), followed by Wind (about 4.0 %) scenario.

Table 30. Changes of Power Generation at Different Power Plants (difference in percentage of baseline)

Type of power plant	Year				
	2000	2005	2010	2015	2020
		Small Hydro scenario			
Hydro		+ 2.4	+16.6	+30.9	+59.4
Oil-gas		-0.5	-3.0	-4.2	-4.9
Coal		-0.3	-1.7	-3.1	-5.6
		Nuclear scenario			
Coal	-	-	-3.9	-12.7	-16.2
		Wind scenario			
Oil-gas	0.0	-2.2	-3.2	-4.0	1.8
Coal	-1.7	-1.2	-2.5	-3.7	-4.8
		Solar scenario			
Coal	-0.2	-0.4	-0.7	-1.3	-1.9
		Integrated scenario			
Oil-gas	0.0	-3.2	-7.3	-10.5	-10.6
Coal	- 2.0	-1.9	-8.7	-20.8	-28.2
Hydro	0.0	+2.4	+16.6	+30.9	+59.4

In comparison with baseline scenario, reduction of power generation at CCN accounts for from 2% in 2000 to 28% in 2020. At the same time reduction for GCN comprises from 3% to 11%. Decreasing electricity generation at Heat Power Plants compensates by increasing of the share of electricity produced by Nuclear and renewable power plants.

As a result, the proportion of this types of energy in the national energy system is increasing. Table 31 shows proportion of electricity produced by different types of power plants, in case if all considered mitigation measures implemented (Integrated scenario).

Table 31. Structure of Power Generation under Integrated Scenario (%)

Type of Power Plants	Year					
	1990	2000	2005	2010	2015	2020
Coal Cogeneration	36	16	15	17	22	24
Oil Gas Cogeneration	4	18	17	16	15	13
Coal Condensed	41	48	50	48	39	36
Oil Gas Condensed	10	7	5	4	4	4
Hydro	9	10	10	10	10	11
Nuclear	0	-	-	2	6	8
Wind	0	1	2	2	3	3
Solar	0	0.2	0.4	1	1	1

Total	100	100	100	100	100	100

As one can see, share of nuclear, wind, hydro and solar energy is increasing by 6%, 2%, 1% and 0.8% respectively. The share of CCN,GCN and GCG is decreasing. Share of electricity generated by CCG (Coal Cogeneration Power plants) suppose to be increased as the result of measures on increasing energy efficiency at HPP (Heat power plants).

Changes in electricity generation and fuel consumption under considered mitigation scenarios lead to decrease of import of electricity that can also cause GHG emissions reduction. From above Table 29 we can see changes in electricity import according to the baseline scenario. Table 32 presents decrease of electricity import under different mitigation cases compare to the base case.

Table 32. Decrease of Electricity Import under Different Mitigation Scenarios

Mitigation Scenario	Year									
	2000		2005		2010		2015		2020	
	%	10^9 kWh	%	10^9 kWh	%	10^9 kWh	%	10^9 kWh	%	10^9 kWh
Small Hydro	-	-	0.4	57	3.5	398	7.1	715	13.0	1407
Wind	2.0	301	6.9	959	8.0	919	10.2	1033	12.2	1317
Solar	0.2	41	1.3	179	1.9	220	3.3	333	4.6	496
Integrated	2.3	341	8.5	1187	13.2	1512	20.5	2065	27.5	2967

Under Integrated scenario decrease of electricity import can reach more than 27% of the baseline level by the year 2020. The most significant increase of import reduction (from 0.4-2% in 2000 to 12 -13% in 2020) can be achieved under Wind and Small Hydro scenarios.

1.6.3 Cost of Emission Abatement

Determination and analysis of the cost of emission abatement of different mitigation measures are both the most important steps for evaluation of mitigation scenarios. The presentation of the costs of emission abatement depends on the model used in the analysis, on level of aggregation and degree of assurance and completeness of the input data. As it has been shown in section 1.2.4, our cost analysis supposes to be mainly of qualitative nature because of rather high level of aggregation of the energy network and high level of uncertainties of costs data. Nevertheless, we suppose that even such analysis is useful for initial assessment of costs of emission abatement for every considered mitigation scenario and allows to compare different mitigation measures on their additional energy system costs. Since our cost analysis is qualitative, we do not present here the total impacts of foreign exchange, however it is obviously that implementation of considered energy efficiency measures in transition country like Kazakstan would require sufficient foreign investments.

1.6.3.1 Additional Energy System Costs

To compare the total costs of energy system under different mitigation and baseline scenarios we used cost output of the BALANCE module (link number 40, see Figure 2, section 1.2.2). This cost figure, that has been named in BALANCE module as “Energy price”, expresses energy prices by energy producer and reflects following elements of cost figures: investment costs to replace and expand stock in energy supply (through introducing or increasing Capital expenditures and O&M costs for new capacities); fuel supply costs, and other costs like capital expenditures and operating and maintenance costs.

In Table 32 energy prices under different mitigation and baseline scenarios are presented.

Table 32. Producer Energy Prices under Different Mitigation Scenarios (cents/kWh)

Scenario	Year						
	1990	1995	2000	2005	2010	2015	2020
Baseline	2.00	2.32	2.96	3.11	3.31	3.62	3.95
Rehab. Cogen.	-	-	3.00	3.15	3.35	3.64	3.96
Small Hydro	-	-	-	3.11	3.30	3.58	3.87
Nuclear	-	-	-	-	3.41	3.95	4.38
Wind	-	-	3.00	3.15	3.38	3.73	4.10
Solar	-	-	2.98	3.12	3.33	3.65	4.00
Integrated	-	-	3.04	3.20	3.52	4.07	4.53

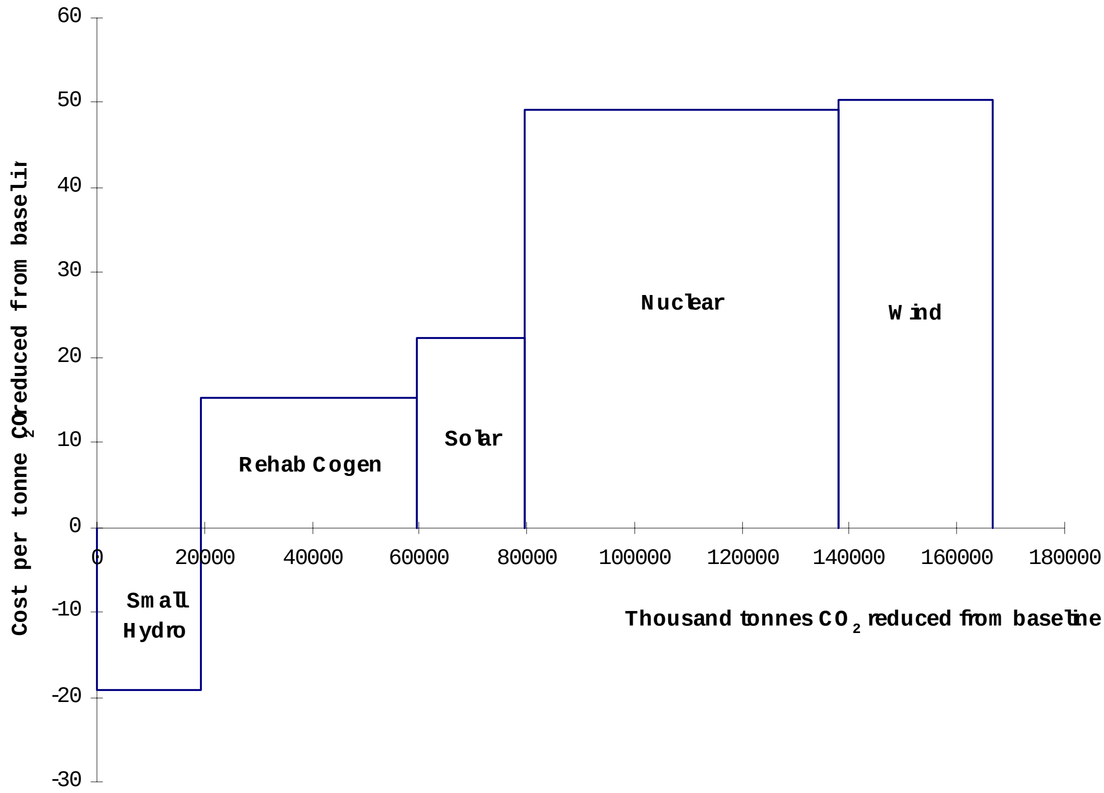
As we can see, energy costs under almost all mitigation scenarios higher than the baseline one. Exception is Small Hydro scenario where energy prices are lower than the baseline one during whole considered period. In the year 2020 energy price under Small Hydro scenario is suppose to be 2 % lower than the baseline one. The most considerable increase of energy price to compare with the baseline one gives Nuclear scenario, where difference from the baseline reaches 11 % of the baseline price by 2020. Energy prices under Cogen. Rehab. Scenario tend to reach the baseline level and in 2020 suppose to differ from it only by 0.3 %. By the same time period Wind scenario lead to increase of energy prices by about 4 % and Solar scenario — by 1.3 %. The same value for Integrated scenario is amounted to almost 15 %.

Thus, we can conclude, that the most “expensive “ mitigation scenario, that is scenario which require the most additional investments is Nuclear scenario, followed by Wind, Solar and Rehab. Cogen. Scenarios in order to price decreasing.

1.6.3.2 Cost Curve

Cost curves for emission abatement express the cost per unit of emission reduction as a function of the quantity of GHG reduced *(J. Sathaye and S. Meyers,* 1995). The curves can be establish in different ways, depending on which model is used and the level of detail in study. The Figure 12 presents Discrete Step CO_2 - Reduction Cost Curve, which we chose for our study to compare different mitigation scenarios.

Figure 12. Discrete Step CO_2 - Reduction Cost Curve



In the Figure 12 the blocks such curves correspond to individual mitigation scenarios with the widths representing the potential GHG reduction and the heights representing the cost per unit GHG reduction. In our analysis we analyzed average costs which reflect the difference in total energy system costs, expressed in sum of difference of Producer Energy Prices under mitigation and baseline scenario when a specific mitigation scenario is compared to baseline, divided by the difference in emission between the two scenarios. The cost curve in Fig. 12 is developed for all considered time period and presents cumulative reduction over the time horizon studied.

As we can see from the Figure, the Wind scenario has the highest cost of emissions abatement, which amounted about 50$ per tonne of reduced CO_2. It followed by Nuclear scenario, which has a bit lower cost of emissions abatement. It is interesting that the cost under Integrated scenario lower than under Wind and Nuclear ones. That can be because the integration of different mitigation options is not simple addition of them and aggregates different mitigation options, which cause different structural and technical changes in the energy system, many of which are interdependent. Rehab. Cogen scenario has the lowest cost of emissions abatement amounted less than a half of those for Wind scenario. Small Hydro is the only scenario which lead to saving of funds, because the installation of Small Hydro plants lead to decreasing of total energy system cost.

From the other side, from the point of view of amount of CO_2 reduction the Integrated mitigation scenario is potentially a very attractive, because it allows to reduce the most CO_2 emission and the cost of emission abatement is not maximum. Small Hydro and Rehab. Cogen. Scenarios look also very attractive, because allow to reduce emissions with the minimum expenditures. Nuclear scenario is the most potentially reduced, but the costs of emission abatement is very high.

1.6.4 Summary of Mitigation Scenarios

Preliminary access (screening) of the number of possible mitigation options by some criteria has been done in section 1.4.3. Let us consider here all developed mitigation scenarios from the point of view major of criteria and using the results of above analysis (see Table 34). Consider them in descending order of GHG saving potential.

Table 34. Summary of Mitigation Scenarios

Criteria	Nuclear	Rehab. Cogen.	Wind	Small Hydro	Solar	Integrated
GHG reduction CO_2 (1000 tonnes):						
Cumulative over the period	58,288	40,083	28,622	19,421	18, 022	157,851
Annual average	10.40	2.33	3.14	3.74	6.74	20.82
Methane (net annual average change, tonnes)	104	20	31	37	52	206
Cost of emission abatement, $/tonne	49.05	15.26	50.33	-19.96	22.35	31.21
Reduced import (average annual value, US $)	Uncertain	Uncertain	64,606	68,793	24,088	145,522
National environmental impacts (net annual reduction, tonnes):						
Sulfur oxides	745	148	224	265	375	1466
Particulates	863	112	256	297	106	1619
Potential impacts implementation policies	Low	High	Medium	High	Low	-
Sustainability of option	Medium	High	Medium	High	Low	-
Consistency with national development goals	High	High	Medium	High	Medium	-
Uncertainty of data :						
Technology performance and costs	Low	Low	High	Low	High	-
Costs of implementation programs	Low	Low	High	Low	High	-

As one can see from the Table 34, Nuclear scenario has the most GHG and the other pollutants reduction potential. It suppose to be from about 1.5 to 3 times more than those for the other scenarios and totaled approximately 4 % of annual GHG baseline emissions. At the same time the cost of emission abatement of the scenario is suppose to be the highest and exceeded those for the rest scenarios in 2-3 times. However, it should be noted that we assumed price of nuclear fuel twice more that the most expensive type of fuel (mazut) to take into account expenditures for utilization of nuclear waste.

Developing a nuclear power has a good potential in Kazakstan because it has 25 percent of the world resources of uranium. Installation of the two units of nuclear power instead of putting into operation six coal blocks at the South Coal Power Plant, which is the main Nuclear Scenario assumption, has been planned by Ministry of Energy. But the main legislation act about developing nuclear energy in Kazakstan—the “Low about Use of Nuclear Energy”—is still under consideration by the Kazak Government. Therefore, assessment of this option from the point of view of sustainability and potential impacts implementation policies is rather uncertain in the nearest future, in spite of the fact that developing nuclear energy meet national goals in general.

Rehabilitation of Cogeneration mitigation scenario looks as one of the most attractive one. Firstly, modernization of Heat Power Plants has a big potential for saving GHG emissions, taking second place after Nuclear scenario.It accounted for more than 40 thousand metric tons or about 1.9 million or 1.7% of annual level of baseline emissions. At the same time this scenario has rather low cost of emissions abatement. We can say that reducing 1% of GHG emission “costs” about half of percent of increasing price of electricity. For comparison, this value for Nuclear and Wind scenarios amounted to about 2 %; for Small Hydro and Solar scenarios — 0.7% and 1.5% respectively. According this study, the scenario does not lead to change in import of electricity. Secondly, this option has been included in the National Electric Energy-Saving Program (*Program on Energy Saving in the Republic of Kazakstan*, 1996) as the main priority of the Medium - and Short - Term Measures in Power Production Sector. This Program recently has been approved by the Government of Kazakstan.Therefore, this option has good possibility of implementation, this option is quite sustainable and consist with national development goals. At least, data about technology and implementation costs of this measures are the most accurate and complete and included in mentioned Program on Energy Saving as well.

Developing wind energy in Kazakstan (Wind scenario) is one of the most supported and sustainable option for long term program of energy development in Kazakstan (*Program on Energy Saving in the Republic of Kazakstan*, 1996). According to this study Wind scenario allows to reduce about 1.2% of annual baseline GHG emissions. From the other hand, it suppose to be the most “expensive” scenario. Expenditures for this scenario totales about 0.4 billion dollars. At the same time scenario has the most reducing import possibility. As mentioned, it appears that favorable wind resources exist in Kazakstan. But at the same time for Kazakstan conditions special systems need to be designed that will not only withstand the strong winds but also cope with the frequent reversal of wind direction. Therefore data about costs and technology implementation is of high level of uncertain.

The next in the order of descending order of GHG saving potential is Small Hydro Scenario. The lead-in of the Small hydro power plants are planning since 2005, so the suitable scenario lasts 16 years. It was obtained, that under the scenario reduction of CO_2 emissions during this period suppose to be 1 % of annual baseline level. As showed our analysis, the introduction of HYPs is the most profitable option. It is the only option that leads to reduce the price of power electricity and therefore saves funding -- $0.4 billion in 2005 - 2020 or $24 million of annual as comparison to baseline scenario. Moreover under Small Hydro scenario it was obtained that expenses in import decrease $ 0.4 billion or on the average $ 22 million per year. The introduction of SHY have a good chance from the point of view of technology availability, as far as a production of SHY has good organized in Kazakstan. At least, developing hydro power in Kazakstan would have a very positive social effect because it will permit to improve electric power supply in the South and South-East of Kazakstan, where the largest deficit of electricity is experienced.

Reducing GHG emission under Solar scenario can amounted for about 0.9% annually of the baseline level. Introduction of Solar power plants leads to GHG reduction twice less than modernization HHPs (Rehab. Cogen. Scenario), but the expenditures are twice more. However, at the same time installation of solar plants, according to the scenario, can cause reducing import by approximately $10 million annually.

Integrated scenario combains rehabilitation cgeneration power plants, introduction of solar, wind and nuclear power plants. All measures listed here have different times and chances for implementation.Under Integrated Scenario Rehabilitation Cogeneration Plants, Wind and Solar Plants are putting into operation since 2000; Small Hydro Power Plants - since 2005 and Nuclear Plants - since 2010. All separated mitigating measures in general keep their own peculiarities in Integrated Scenario, however we can not consider this scenario as additional collection of options. The Integrated Scenario is considered as scenario where all measures are interdependent and its effect on energy system differs from simple addition of every considered option effect. That is why CO_2 emissions reduction is 5 % less than value obtained from summation of appropriate reducing quantity of separated scenarioes. Total CO_2 emissions reduction potential under Integrated scenario is suppose to be 158 million tons or, in average, 5.7 million tons annually. Expenditure for the reduction is about $ 4.9 billion, and for considering scenario every percent of CO_2 emissions reduction lead to 1 % of the increase of energy power cost. Taking into account that those values for Wind and Nuclear scenarios suppose to be almost twice more, we can say that in a sense developing all measures together is more favorably than introduction every of them separately.

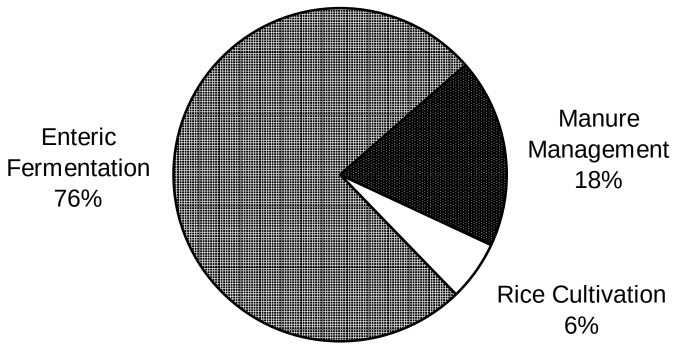
2. NON-ENERGY SECTOR

2.1 GHG Emission in Non-Energy Sector

As it has mentioned in section 1.1.5, according to recent GHG emission inventory non-energy sector emitted about 13 MMTCE in 1990 (*Monocrovich et. al.*, 1996). The most important sources in non-energy sector are agriculture and coal mines and refineries (Fugitive Fuel Emissions).

Agricultural activities produced 5.564 MMTCE, or approximately 8 percent of total GHG emissions in Kazakstan. The most significant gas emitted by agricultural activities is CH_4. The agriculture sector produces more than 770 Gg or 45% of total CH_4 emissions in Kazakstan, from sources such as domestic livestock, manure management, and rice cultivation. As it can be seen from Figure 13 enteric fermentation and manure management together were responsible for about 94 percent of methane emissions from agricultural activities.

Figure 13. Methane Emissions from Agriculture



Methane emissions from rice cultivation make a relatively small contribution to total CH_4 agricultural emissions, representing approximately 5.7 percent.

Other GHG emissions from the agriculture include nitrous oxide (N_2O) totaled about 1.1 Gg and nitrogen dioxide (NO_2) totaled 10 Gg.

The extraction of the coal in the country is about of 114 million tonnes/year, while the deposit of coal are assessed as 64 billion tonnes. The fugitive methane emissions from coal mines and refinery enterprises were evaluated using the data about the coal, oil, and gas extraction and the IPCC emission factors (*IPCC/OECD*, 1994). Methane emissions from coal mines in 1990 accounted for 751 Gg or about 5 MMTCE that was about 49% of total methane emissions in Kazakstan.

The net carbon dioxide flux from land-use and forest management was estimated to have been an uptake 1.1 MMTCE. This amounts to approximately 2% of the total CO_2 emitted, or approximately 1.7% of the total GHG emissions in Kazakstan.

2.2 Estimating the Potential of Greenhouse Gas Mitigation

2.2.1 Agriculture

One of the important mitigation option in agriculture can be implementation of the technologies of biogas utilization. This measure allows reduction of methane emissions in agriculture and it also allows replacement of some coal-fired capacities in the energy balance. According to expert estimations the annual generation of organic wastes in the agriculture of Kazakstan is estimated to be 40 million tonnes. The processing of already existing wastes with biogas technologies would allow generation of about 18 billion m^3 of biogas, which is equivalent to 14-15 million standardized tonnes of fuel. Even partial utilization of these resources could reduce the demand for centralized supplies to the rural areas and remote consumers and the consumption of electricity generated by coal-fired plants for space heating, thus reducing CO_2 emissions.

Biogas contains 55-80 percent methane and 20-45 percent CO_2. If we assume that by 2010 only 10 percent of the available resources of biogas are utilized, and by 2020 this share amounts to 20 percent, the total methane emissions reduction can be about 800 Gg in 2010 and 1,600 Gg in 2020. Thus, the implementation of this option is potentially very effective. According to expert assessments (Monokrovich, et al. 1996), the implementation of this measure could decrease methane emissions by 5-6 percent of the base year emissions from agriculture annually.

2.2.2 Land-use change and forestry

Among the options in the non-energy sector related to forestry, the most promising mitigation measure is increase of carbon absorption by expanding the planted area and preserving of existing absorbers. Currently forest area totals about 3.7% (9.6 million ha) of the Kazakstan territory. Based on data of 1990 annual CO_2 uptake from forest exploitation was evaluated as 4,627 Gg CO_2. Taking into account the CO_2 emissions from forest fires, the net CO_2 flux in 1990 from land-use change and forest management activities was estimated to have been a sequestration of 4,011 Gg CO_2.

Studies of the Kazak Scientific and Research Institute of Forestry showed that, on the basis of natural and economic conditions and the depleted condition of land, the optimal share of forested territory for Kazakstan is 5.1 percent. According to the Program “Forests of Kazakstan” the forest area of the country should be increased up to 4.6% of the whole Kazakstan territory by 2010 and up to 5.1% - by 2020. The areas (about 3.8 million hectare) are to be planted mostly with mixed softwoods forest. According to the IPCC recommendations annual increment in biomass should be taken as 14.5 tonnes/ha. Taking into account that carbon fraction of dry matter is equal 0.45 (*IPCC/OECD*..., 1994), annual carbon uptake increase is equal to 2,140 Gg/year. Because of the uncertainty about the magnitude and direction of the soil carbon change in plantation systems, this is ignored in our calculations. This analysis is to be done in further investigation.

Therefore if the forested area increases to 5.1 percent of the territory of Kazakstan, the CO_2 uptake by forests will increase from 1.7 to about 2.7 percent of the total CO_2 emissions. The cost of implementation of this option is assessed as $3.5 billion. To implement such measures foreign investments are necessary.

Planting of perennial herbs and bushes on available land after the decrease in the area of cultivated fields is another emission mitigation measure. In 1991, crops were cultivated on 24 million ha. In 1997, it is planned to use only 18-19 million ha: in the future this use of land may decrese to 16-18 million ha. Perennial herbs would be planted in the territory thus freed, which would increase the absorption of CO_2. In the near term, the implementation of this measure would cost 1.2 million USD.

2.2.3 Coal Mining

Methane supplies in coalbed are significant. Every year about 200 million m^3 of methane are extracted by degasation in the mines of Karagandy coal basin, 12-15 million m^3 of which are utilized in boilers to generate heat. The rest of methane goes irretrievably into the atmosphere thus polluting it. Emissions of 170-180 million m^3 Me are equal to 240,0 tonnes CO_2.

At present methane practically is not used as a feedstock for oil industry but is burnt out in various energetic installations. Being a secondary power resource in the processing of coal layers, methane can be used both as an power supply source and as a feedstock for chemical industry. The mitigation option from coalbed methane utilization may be very attractive from the viewpoint of criteria of consistency with national environment goals and indirect economic impacts.

That is why creating new technologies of methane processing into valuable chemical compounds is of great scientific, practical, economic and ecological importance.

The number of well developed technologies and pilot projects are exist. For example there are the scientific and technical program “Methane-Acetilene-Artificial Liquid Fuel” developed in Combustion Problem Institute of the Republic of Kazakstan. The project aim is to create an equipment for complex processing of natural gas (methane) to obtain valuable compounds for chemical industry. The project budget is to be $ 400,000. Successful implementation of the project will allow to decrease significantly coalbed methane emissions in Karagandy basin.

CONCLUSIONS AND LIMITATIONS

- The results of the Kazakstan mitigation assessment in energy sector include evaluation the most attractive mitigation options, focusing on specific technologies in energy production, which is the main source of GHG emissions in Kazakstan. GHG emissions for baseline and six mitigation scenarioes, as well as costs and impacts of different mitigation scenarioes for the period from 1990 to 2020 were estimated. Model of the Kazakstan energy sector were created using ENPEP model.
    - Possibilities of GHG mitigation in agriculture, land use and forestry based on expert judgments are considered.
- GHG emissions will not exceed the 1990 level until 2005, and Kazakstan will have no difficulties in fulfilling the commitments of the UN FCCC.
- The main mitigation options in the energy production sector, according to the criteria of mitigation potential and feasibility, are as follows: rehabilitation of thermal power plants aimed to increasing efficiency; use of nuclear energy; further expansion in the use of hydro power energy on the basis of small hydro power plants introduction; use of wind and solar energy. All these measures have been included in sustainable national plans for energy development.
- The maximum potential for CO_2 emission reduction in energy production is about 21 % of the base year 1990 emission level.
- Potential of annual reduction in CO_2 ranged from 3 % in 2000 to 11 % in 2020 can be achieved due to implementation of new technologies, renewable and nuclear energy sources together, i.e., under Integrated mitigation scenario. The maximum reduction potential has Nuclear scenario, followed by Rehabilitation, Wind, Small Hydro and Solar scenarioes. Implementation of these measures would result in reduction of coal and oil utilization as well as reduction of import of electricity.
- Small hydro introduction and rehabilitation of thermal power plants are the most cost effective and promising measures. Nuclear energy development is the most expensive one, but it has a great energy and GHG emissions saving potential.
    - The main mitigation options in agriculture and the forestry sector are the following:

        1. biogas utilization; the potential of this measure to mitigate agricultural methane emissions is 5-6 percent of the base year emissions,
        2. expansion of forested areas and planting of perennial herbs in the lands removed from agricultural uses; the mitigation potential is 5 percent of the base year emissions of CO_2

Current rapid changes occurring in Kazakstan and the lack of reliable detailed data made it difficult to perform analysis which would be detailed and accurate enough. The main limitations of the study are as follows:

- The level of aggregation was rather high, so the developed energy network was not detailed enough;
- The analysis was focused only on heat and electricity production sector. End-use technologies were not considered.
- Cost analysis has mostly qualitative nature because of high level of aggregation and high level of uncertainties of costs data. Since our cost analysis is qualitative, we do not present here the total impacts of foreign exchange, however it is obviously that implementation of considered energy efficiency measures in a transition country like Kazakstan would require foreign investments.
- There is a great uncertainty surrounding macroeconomic and sectoral developments in the short and longer term. As a result the projections of GDP, population and energy demand are need to be refined, at least several scenarioes should be presented.

LESSONS LEARNED AND MITIGATION PLANS

Mitigation strategies in the energy sector of Kazakstan are directly connected with the general national strategy of the energy sector development. All considered in the mitigation analysis measures were included in sustainable energy development plans.

At the same time it has been said that Kazakstan is confronted with a severe economic crisis which has dramatically limited the Government's financial capacity to address critical problems in the energy sector. Preparation of implementation strategies is the most difficult problem in realisation of such programs, because of a lot of barriers. The most important of them are strong storage of funds, absence of proper control system, weak institutional structure and legislative framework. The main sustainable energy development programs in Kazakstan are as follows:

Program for Urgent Measures on Energy Development, 1996.

National Program for Energy Saving, 1995

Program on Involving Renewable Sources of Energy in Energy Saving Until the Year 2020, 1995

The energy development and energy saving programs focus initially on policies and programs achievable in a timely and effective manner during the next three years as the country progresses to a market-based economy, and then considers policies and programs that will yield energy savings in the longer term. Taking into account priority, has been set in the energy development plans and our mitigation analysis we can identify the following priority of considered mitigation options:

Rehabilitation of cogeneration, which includes the options on modernization of Thermal Power Plants;

Small hydroelectric power plants installation;

Installation of nuclear power plant;

Wind power plants installation;

Use of a solar energy.

Next step on developing further mitigation analysis is in-depth evaluating all relevant energy saving measures and technologies, which have been included in the Energy Saving Program, from the point of view of their mitigation potential and cost effectiveness to include them in National Action Plan. Main policy measures include increasing energy prices. Within the industrial sector, this program focuses on energy savings in electric power, district heating, nonferrous metals - specifically copper, and fertilizers. Approximately 30-40 percent of the total electric energy could be saved if a comprehensive energy savings program is implemented. One the production and distribution side, improvements in efficiency could achieve savings of almost 20 percent. As before, we plan base our further mitigation analysis on the ENPEP model. Therefore, the main needs for further analysis include at least one more ENPEP training and ENPEP expert site visit, consultations and refining the equipment. Next steps in the analysis include: refining our current mitigation and cost analysis, using more accurate data and assumptions; expanding energy analysis and energy network; conducting a more detailed analysis of the energy consumption sector; expanding environmental analysis and refining macro-economical projections.

There are the number of programs and strategies in agriculture and forestry sectors and in environment protection that can have greenhouse gas emissions mitigation effect in non-energy sector of Kazakstan. The following programs to be integrated in National Climate Change Action Plan:

1. “Conceptual Program of Development of Agricultural and Industrial Complex of Kazakstan until the Year 2000”;
2. National Program “Forests of Kazakstan”;

According to the conception of development of agricultural and industrial complex of Kazakstan until the year 2000 and conception of forestry development considerable changes in planted area structure, livestock population and amount of phitomeliorative works should be done It is planned in our non-energy mitigation analysis to evaluate mitigation effect of measures and technologies included in these programs.

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Appendix A. ENERGY SECTOR DATA

Table A1. Energy Resources Data for 1990

Type of fuel and energy resources	Quantity, tonnes	Price, rubles/tonne	Calorific value, kcal/kg	Quantity, tce	Price, $/tce
Domestic oil	25,821,500	34.00	10,400	38,363,371	22.88
Imported oil	13,244,471	38.76	10,400	19,677,500	26.09
Imported gasoline and diesel oil	4,357,880	139.60	10,295	6,409,295	94.92
Imported fuel oil	1,306,000	66.11	9,550	1,781,757	48.46
Domestic gas	7,113,300 (1000 m^3)	10.00	8,000	6,503,589	10.94
Imported gas	12,558,731 (1000 m^3)	17.50	8,000	11,482,269	19.14
Ekibastuz coal	81,762,000	5.65	3,803	44,420,127	10.40
Karaganda coal	48,746,000	7.88	4,243	29,547,040	13.00
Middle Asian coal	1,000,000	28.00	3,162	451,714	61.99
Kuznetsk coal	10,761,000	11.86	4,935	7,586,505	16.82
Imported electricity	$29.2 \cdot 10^9$ (kWh)	$3.14 \cdot 10^{-2}$ (rubles/kWh)	$1{,}23 \cdot 10^{-4}$ (tce/kWh)	3,591,600	255.29

Table A2. Power Plants Data for 1990

Plant	Electric capacity, MW	Heat capacity, Gcal/h	Electricity output, million kWh	Heat output, thousand Gcal	Specific standardized fuel rate per electricity output, g/kWh	Specific standardized fuel rate per heat output, kg/Gcal	Mass of consumed fuel, tce	Cost of generated electricity, kopeks/kWh	Cost of generated heat, rubles/10Gcal
Coal condensed power plants (CCN)									
Ekibastuz CCN-1	4,000	–	17,129.9	103.0	363.0	179.5	6,236,643	8.93	107.68
Ermak CCN	2,400	–	15124.8	357.3	357.4	176.5	5,486,667	5.62	29.24
Total for coal CCNs	6,400	–	32,254.7	460.3	–	–	11,723,310	–	–
Coal cogeneration power plants (CCG)									
Almaty CCN	173	223.5	1073.0	459.4	484.7	194.2	609,298	17.71	70.27
Almaty CCG-2	510	1,042	2,316.8	3,258.4	262.1	183.6	1,205,475	11.39	68.52
Sogrin CCG	50	216.0	381.7	770.7	289.3	176.5	246,454	11.23	65.04
Karaganda CCN-2	658	325.5	4,955.4	887.7	404.5	184.3	2,168,062	8.17	34.50
Karaganda CCG-2	435	812.0	2,629.4	2,591.5	301.8	185.7	1,274,794	10.64	51.33
Karaganda CCG-3	440	700.0	1,844.0	2,756.2	257.1	184.1	981,509	7.35	51.69
Pavlodar CCG-1	350	920.0	2,287.9	5,963.8	221.5	175.0	1,550,435	3.78	28.90
Pavlodar CCG-2	110	332.0	665.2	1,829.8	250.7	180.8	497,593	7.94	50.99
Pavlodar CCG-3	500	926.0	2,171.6	3,282.6	361.4	182.0	1,382,249	7.07	37.96
Petropavl CCG-2	380	858.8	2,620.0	3,541.0	362.7	189.4	1,620,939	7.57	34.39
Kizil-Orda CCG-6	146	346.4	440.8	1,036.8	574.5	188.7	448,884	35.72	119.34
Leninogorsk CCG	57	179.0	342.3	1,234.6	329.5	187.4	344,152	10.33	63.80
Ust-Kamenogorsk CCG	241.5	596.0	1,251.3	3,084.9	237.9	178.8	849,264	7.54	53.79
Balkhash CCG	120	250.0	791.1	1270.6	408.7	189.4	563,974	14.12	47.70
Dzezkazgan CCG	227	554.0	1,090.7	1,531.2	405.3	193.8	738,807	13.90	60.57
Karaganda CCN-1	177	342.0	594.4	1,317.2	454.0	206.2	541,464	17.15	45.38

Plant	Electric capacity, MW	Heat capacity, Gcal/h	Electricity output, million kWh	Heat output, thousand Gcal	Specific standardized fuel rate per electricity output, g/kWh	Specific standardized fuel rate per heat output, kg/Gcal	Mass of consumed fuel, tce	Cost of generated electricity, kopeks/kWh	Cost of generated heat, rubles/10Gcal
Karaganda CCG-1	32	160.0	137.0	1,311.6	183.0	200.5	288,047	7.35	51.69
Almaty CCG-1	145	503.0	765.1	3,963.6	162.0	173.3	810,838	5.51	54.49
Rudny CCG	131	305.0	547.6	2,071.4	304.5	174.8	528,825	9.57	39.80
Kostanai CCG	12	86.0	71.6	1,130.5	171.0	163.4	196,967	9.14	39.62
Tselinograd CCGs 1 and 2	266	706.0	1,628.9	3,547.9	263.2	185.7	1,087,572	6.21	48.88
Semipalatinsk CCG	6	27.1	35.7	1,141.0	186.9	184.6	217,301	–	72.87
Tentek CCG	18	102.0	84.8	872.2	183.2	186.9	178,550	15.71	78.10
Ekibastuz CCG	12	60.0	46.2	1,980.0	235.0	177.6	362,505	–	74.28
Kentau CCG-5	28	136.0	101.2	693.7	196.7	179.9	144,703	10.44	104.06
Total for CCGs	4,606.5	8,783.2	25,592.6	36,128.0	–	–	15,311,400	–	–
Oil-gas cogeneration power plants (GCG)									
Gurjev GCG	239	596.0	1138.1	1,499.3	336.6	171.1	639,615	12.94	51.07
Chimkent GCG	160	570.0	700.5	1,438.7	349.5	178.0	500,913	11.20	83.79
Actobe GCG	79	344.8	406,8	3,219.4	282.9	168.2	656,587	10.93	57.00
Arkalyk GCG	6.5	41.0	40.9	997.0	173.7	164.6	171,211	8.28	58.55
Chimkent GCGs-1,2	42	264.0	178.4	1,831.4	201.4	167.5	342,689	5.96	48.04
Uralsk GCG	32	195.0	168.0	2,178.4	169.6	167.0	392,286	4.92	46.56
Jambyl GCG4	60	254.0	333.0	1,592.8	160.1	167.1	319,470	5.83	122.65
Total for GCGs	618.5	2,264.8	2,965.7	12,757.0	–	–	302,271	–	–
Oil-gas condensed power plants (GCN)									
Jambyl GCN	1,230	–	8,215.8	38.3	348.3	175.0	2,868,266	9.77	74.39
Boilers									
Boilers	–	37,520	–	72,225	–	NA	13,299,000	–	74.02

Plant	Electric capacity, MW	Heat capacity, Gcal/h	Electricity output, million kWh	Heat output, thousand Gcal	Specific standardized fuel rate per electricity output, g/kWh	Specific standardized fuel rate per heat output, kg/Gcal	Mass of consumed fuel, tce	Cost of generated electricity, kopeks/kWh	Cost of generated heat, rubles/10Gcal
				Hydroelectric plants					
Hydroelectric plants	2,129.4	–	6,935.8	–	–	–	–	2.05	–

Appendix B. ENERGY NETWORK DATA

Table B1. Depletable Resource and Import Fuel Process Node Data

Node name	Energy resource	Output link	Price projection set	Price, $/tce	Base-year quantity, 1000 tce	Annual capacity, 1000 tce/year
Dom. oil-1	Domestic crude oil	1	3	22.88	38,363.371	40,000
Imp. oil-2	Imported crude oil	2	3	26.09	19,677.500	1E+10
Imp. light-3	Imported gasoline and diesel fuel	3	4	94.92	6,409.295	1E+10
Imp. foil-5	Imported fuel oil	5	4	48.46	1,781.757	1E+10
Dom.gas-6	Domestic gas	7	2	10.94	6,503.589	7,000
Imp. gas-7	Imported gas	8	2	19.14	11,482.269	1E+10
Ekib.coal-9	Ekibastuz coal	9	1	10.40	44,420.127	50,000
Karag. coal-10	Karaganda coal	10	1	13.00	29,547.040	35,000
Asian coal-11	Middle Asian coal	11	0	61.99	451.714	1E+10
Kuzn.coal-12	Russian coal	12	1	16.82	7,586.505	1E+10
Imp. elec.-13	Imported electricity	13	5	255.29	3,591.600	1E+10
Nuclear-14	Nuclear Resource	81	0	150.00	0.000	1E+10

Table B2. Depletable Resource Price Projections

Projection number	Projection name	Fractional Growth Rates 1	2	3	4	5	6	7	8	9	10
1	Coal	0.057 0.010 0.010	0.057 0.010 0.010	0.057 0.010 0.010	0.057 0.010 0.010	0.057 0.010 0.010	0.057 0.010 0.010	0.057 0.010 0.010	0.057 0.010 0.010	0.057 0.010 0.010	0.057 0.010 0.010
2	Natural Gas	0.211 0.030 0.030	0.211 0.030 0.030	0.211 0.030 0.030	0.211 0.030 0.030	0.211 0.030 0.030	0.030 0.030 0.030	0.030 0.030 0.030	0.030 0.030 0.030	0.030 0.030 0.030	0.030 0.030 0.030
3	Crude Oil	0.121 0.020 0.020	0.121 0.020 0.020	0.121 0.020 0.020	0.121 0.020 0.020	0.121 0.020 0.020	0.121 0.020 0.020	0.121 0.020 0.020	0.121 0.020 0.020	0.121 0.020 0.020	0.121 0.020 0.020
4	Petroleum Products	0.143 0.020 0.020	0.143 0.020 0.020	0.143 0.020 0.020	0.143 0.020 0.020	0.143 0.020 0.020	0.143 0.020 0.020	0.143 0.020 0.020	0.143 0.020 0.020	0.143 0.020 0.020	0.143 0.020 0.020
5	Electricity	0.025 0.010 0.010	0.025 0.010 0.010	0.025 0.010 0.010	0.025 0.010 0.010	0.025 0.010 0.010	0.025 0.010 0.010	0.025 0.010 0.010	0.025 0.010 0.010	0.025 0.010 0.010	0.025 0.010 0.010
6	Nuclear Fuel	0.000 0.000 0.010	0.000 0.000 0.010	0.000 0.000 0.010	0.000 0.000 0.010	0.000 0.000 0.010	0.000 0.000 0.010	0.000 0.000 0.010	0.000 0.000 0.010	0.000 0.000 0.010	0.000 0.000 0.010

Table B3. Renewable Resource Process Node Data

Node Name	Energy Resource	Output link	Steps in production	Price, $/tce	Base-year quantity,	Annual capacity,

			cost curve		1000 tce	1000 tce
Hydro-1	Hydro Energy	15	1	1E-10	1,066.379	1E+10
Wind-2	Wind Energy	77	1	1E-10	0.000	1E+10
Solar-3	Solar Energy	79	1	1E-10	0.000	1E+10

Table B4. Decision / Allocation Node Data

Node Name	Input links	Priority links	Premium multipliers	Output links	Base-year splits	Price sensitivity	Lag parameter
AL-1	1, 2			16 17 57	0.5354 0.4646 0.0000	10	0.5
AL-2	3, 18, 58, 74			44	1.0000	1	0.5
AL-4	5, 20, 60			46 47 48	0.3511 0.3466 0.3023	7	0.5
AL-5	7, 8			21	1.0000	1	0.5
AL-6	22			23 24 25	0.2066 0.1470 0.6464	1	0.5
AL-7	9, 10, 11, 12		9 (link 10)	26 27 28 29 63 68	0.1430 0.2273 0.0962 0.5335 0.0000 0.0000	5	0.3
AL-8	24, 28, 47			30	1.0000	1	0.5
AL-9	23, 48			6 31 71	0.4869 0.5131 0.0000	0	0.0
AL-10	32, 33, 35, 62, 69, 72	72, 69, 32		39	1.0000	1	0.5
AL-11	34, 70, 36, 73, 76	73, 36, 70, 34, 76		40	1.0000	1	0.5
AL-12	41			49 50	0.5000 0.5000	1	0.5
AL-13	42			51 52 53 54 55 56	0.1204 0.2476 0.3490 0.1414 0.0559 0.0857	1	0.5
AL-14	15			65 66	0.0000 1.0000	1	0.5
AL-15	37, 64, 38, 67, 13, 14, 82, 78, 80	67, 64, 38, 80, 78, 82		76	1.0000	1	0.1

Table B5. Conversion Process Node Data

Node Name	Input link	Output link	O&M cost, $/tce	Efficiency	Total capital investment, 1000 $	Capacity of a single plant, 1000 tce/year	Capacity factor	Life expectancy of plant, years	Interest rate fraction	Capacity of all plants, 1000 tce/year
T-1	21	22		0.8300						
T-2	39	41		0.9779						
T-3	40	42		0.9113						
Condens (coal) PP-5	26	37	26.39	0.3384	170	1	0.5761	30	0.03	3,967.328
Condens (oil-gas) PP-10	6	14	34.95	0.3523	170	1	0.7635	30	0.03	1,010.543
Boilers-4	30	32	22.80	0.7761	50	1	0.2199	30	0.03	10,320.950
Hydraulic PP-6	66	38	7.33	0.8000	180	1	0.3723	30	0.03	853.103
Hydraulic PP-8	65	67	11.16	0.8000	604	1	0.3723	30	0.03	0.000
Condens (coal) PP-9	63	64	40.20	0.3400	465	1	0.5800	30	0.03	0.000
Nuclear PP-13	81	82	54.00	0.3200	543	1	0.6500	30	0.03	0.000
Wind Turbine-14	77	78	222.00	1.0000	983	1	0.3500	20	0.03	0.000
Photo-voltaic-15	79	80	75.00	1.0000	2,577	1	0.3300	30	0.03	0.000

Table B6. Multiple-Output (Refinery) Process Node Data

Node Name	Input link	Output sizing link	Output links	Output ratios	Price links	Price ratios	Excess demand links	O&M cost, $/tce	Total capital investment, 1000 $	Capacity of a single unit, tce/year	Capacity factor	Life expectancy, years	Interest rate	Profit factor	Capacity of all plants, 1000 tce/year
Cogener (coal)-2	27	33	33 34	0.3949 0.1905	33 33	1.000 2.101	76	21.60	190	1	0.5735	30	0.03	0.1	18,638.660
Cogener (oil-gas)-3	31	35	35 36	0.6029 0.1207	35 35	1.000 1.855	70	23.32	190	1	0.6257	30	0.03	0.1	3,022.771
Refinery-1	17	20	18	0.4702	18	1.000		19.77	60	1	0.9800	30	0.03	0.1	26,966.540

			20	0.2783	18	0.511									
Cogener (coal)-4	68	69	69	0.3900	69	1.000	34	34.22	255	1	0.5700	30	0.03	0.1	1E+08
			70	0.1900	69	2.101									
Cogener (oil-gas)-5	71	72	72	0.4100	72	1.000	36	35.53	360	1	0.6300	30	0.03	0.1	1E+08
			73	0.1700	72	1.855									
Refinery-6	57	60	58	0.4700	58	1.000		22.00	94	1	0.9800	30	0.03	0.1	1E+08
			60	0.2800	58	0.511									

Table B7. Demand Process Node Data

Node Name	Input Link	Demand Growth Projection Set
Oil Export-1	16	1
Oil Prod.-2	44	4
Fuel Oil-4	46	5
Gas Dem.-5	25	6
Coal Dem.-6	29	7
Industry-7	49	2
Residential-8	50	2
Export-9	51	8
Metallurgy-10	52	3
Industry-11	53	3
Residential-12	54	3
Transport-13	55	3
Agriculture-14	56	3

Table B8. Energy Demand Growth Data

Projection set number	Fractional Growth Rates									
	1	2	3	4	5	6	7	8	9	10
1	-0.014 0.012 0.007	-0.014 0.012 0.007	-0.014 0.012 0.007	-0.083 0.012 0.007	-0.081 0.012 0.007	0.012 0.007 0.007	0.012 0.007 0.007	0.012 0.007 0.007	0.012 0.007 0.007	0.012 0.007 0.007
2	-0.008 0.012 0.019	-0.008 0.012 0.019	-0.008 0.012 0.019	-0.121 0.012 0.019	-0.045 0.012 0.019	0.019 0.019 0.010	0.019 0.019 0.010	0.019 0.019 0.010	0.019 0.019 0.010	0.019 0.019 0.010
3	-0.041 0.020 0.018	-0.041 0.020 0.018	-0.041 0.035 0.018	-0.069 0.035 0.018	-0.069 0.035 0.018	0.014 0.023 0.018	0.014 0.023 0.018	0.027 0.023 0.018	0.027 0.023 0.018	0.027 0.023 0.018
4	0.004 0.004 0.004	0.004 0.004 0.004	0.004 0.004 0.004	-0.375 0.004 0.004	-0.178 0.004 0.004	0.081 0.004 0.004	0.081 0.004 0.004	0.081 0.004 0.004	0.081 0.004 0.004	0.081 0.004 0.004
5	0.011 0.025 0.042	0.011 0.025 0.042	0.011 0.025 0.042	-0.426 0.025 0.042	-0.205 0.025 0.042	0.034 0.042 0.042	0.034 0.042 0.042	0.034 0.042 0.042	0.034 0.042 0.042	0.034 0.042 0.042
6	-0.020 0.031 0.000	-0.030 0.031 0.000	-0.010 0.031 0.000	0.000 0.031 0.000	-0.322 0.031 0.000	0.009 0.000 0.000	0.009 0.000 0.000	0.009 0.000 0.000	0.009 0.000 0.000	0.009 0.000 0.000
7	0.000 0.005 0.000	-0.090 0.005 0.000	-0.150 0.005 0.000	-0.190 0.005 0.000	-0.200 0.005 0.000	0.004 0.000 0.000	0.004 0.000 0.000	0.004 0.000 0.000	0.004 0.000 0.000	0.004 0.000 0.000
8	-0.004 0.000 0.000	-0.004 0.000 0.000	-0.004 0.000 0.000	-0.337 0.000 0.000	-0.337 0.000 0.000	-0.048 0.000 0.000	-0.086 0.000 0.000	-0.055 0.000 0.000	-0.018 0.000 0.000	0.054 0.000 0.000

Table B9. Capacitated Links

Link Number	Decision/Allocation Node	Link Capacity, 1000 tce/year
60	4	0

69	10	0
72	10	0

Table B10. Special Events

	Process		Data Item	
Year	Type	Number	Type	Value
1991	RS	12	CAPL	6000,000
	RS	11	CAPL	360,000
	PR	14	CAPL	850,000
1992	RS	12	CAPL	4500,000
	RS	11	CAPL	270,000
	PR	14	CAPL	700,000
1993	RS	12	CAPL	3000,000
	RS	11	CAPL	180,000
	PR	14	CAPL	565,800
1994	RS	12	CAPL	1500,000
	RS	11	CAPL	90,000
	PR	14	CAPL	565,800
1995	RS	12	CAPL	0,000
	RS	11	CAPL	0,000
	PR	14	CAPL	615,000
	PR	5	TCI	197,000
	PR	5	OM	40,180
	PR	10	TCI	197,000
	PR	10	OM	53,220
	RE	2	TCI	220,000
	RE	2	OM	32,890
	RE	3	TCI	220,000
	RE	3	OM	35,510
	PR	4	TCI	58,000
	PR	4	OM	34,720
	PR	6	TCI	209,000
	PR	6	OM	11,160
	RE	1	TCI	70,000
	RE	1	OM	30,100
1997	CA	72	CAPL	143,500
2000	PR	9	CAPL	676,500
	CA	69	CAPL	608,738
	RS	6	CAPL	14000,000
	RS	10	CAPL	50000,000
	*PR	13	CAPL	15,400
	CA	72	CAPL	3286,150
	RS	1	CAPL	60000,000
	RS	9	CAPL	75000,000
	*PR	12	CAPL	112,400
	PR	5	TCI	228,000
	PR	5	OM	46,580
	PR	10	TCI	228,000
	PR	10	OM	61,700
	RE	2	TCI	255,000
	RE	2	OM	38,130
	RE	3	TCI	255,000
	RE	3	OM	41,170
	PR	4	TCI	67,000
	PR	4	OM	40,250
	PR	6	TCI	242,000
	PR	6	OM	12,940

Year	Process		Data Item	
	Type	Number	Type	Value
	RE	1	TCI	81,000
	RE	1	OM	34,890
	RE	5	TCI	**393,000
				*511,000
	RE	5	OM	41,170
2002	PR	9	CAPL	984,000
	CA	72	CAPL	3329,200
2005	PR	8	CAPL	**184,500
				*209,100
	CA	69	CAPL	650,624
	CA	60	CAPL	6720,000
	RS	6	CAPL	28000,000
	RS	10	CAPL	70000,000
	*PR	15	CAPL	46,200
	PR	9	CAPL	2029,500
	CA	72	CAPL	3673,600
	RS	1	CAPL	80000,000
	RS	9	CAPL	100000,000
	*PR	14	CAPL	195,400
	PR	5	TCI	264,000
	PR	5	OM	54,000
	PR	10	TCI	264,000
	PR	10	OM	71,520
	RE	2	TCI	296,000
	RE	2	OM	44,200
	RE	3	TCI	296,000
	RE	3	OM	47,720
	PR	4	TCI	78,000
	PR	4	OM	46,660
	PR	6	TCI	381,000
	PR	6	OM	15,000
	RE	1	TCI	94,000
	RE	1	OM	40,450
	PR	9	TCI	539,000
	PR	9	OM	54,000
	RE	4	TCI	**296,000
				*473,000
	RE	4	OM	44,200
	RE	5	TCI	**456,000
				*592,000
	RE	5	OM	47,720
	*PR	14	TCI	1140,000
	*PR	14	OM	257,360
	*PR	15	TCI	2987,000
	*PR	15	OM	86,950
2010	PR	9	CAPL	**3247,200
				*3001,200
	CA	72	CAPL	3931,900
	*PR	15	CAPL	77,000
	*PR	8	CAPL	356,700
	CA	69	CAPL	1029,312
	*PR	14	CAPL	287,700
	*PR	13	CAPL	246,000
	PR	5	TCI	306,000
	PR	5	OM	62,600
	PR	10	TCI	306,000
	PR	10	OM	82,920

Year	Process		Data Item	
	Type	Number	Type	Value
	RE	2	TCI	343,000
	RE	2	OM	51,240
	RE	3	TCI	343,000
	RE	3	OM	55,320
	PR	4	TCI	90,000
	PR	4	OM	54,090
	PR	6	TCI	326,000
	PR	6	OM	17,390
	RE	1	TCI	109,000
	RE	1	OM	46,890
	PR	8	TCI	700,000
	PR	8	OM	17,390
	PR	9	TCI	625,000
	PR	9	OM	62,600
	RE	4	TCI	**343,000
				*548,000
	RE	4	OM	51,240
	RE	5	TCI	**529,000
				*687,000
	RE	5	OM	55,320
	RE	6	TCI	109,000
	RE	6	OM	46,890
	*PR	14	TCI	1321,000
	*PR	14	OM	298,350
	*PR	15	TCI	3463,000
	*PR	15	OM	100,790
2015	CA	72	CAPL	4018,000
	*PR	15	CAPL	138,500
	*PR	8	CAPL	504,300
	*PR	14	CAPL	398,400
	*PR	13	CAPL	861,000
	**PR	9	CAPL	3862,200
	PR	5	TCI	355,000
	PR	5	OM	72,570
	PR	10	TCI	355,000
	PR	10	OM	72,570
	RE	2	TCI	398,000
	RE	2	OM	59,400
	RE	3	TCI	398,000
	RE	3	OM	64,130
	PR	4	TCI	104,000
	PR	4	OM	62,710
	PR	6	TCI	378,000
	PR	6	OM	20,160
	RE	1	TCI	126,000
	RE	1	OM	54,360
	PR	8	TCI	811,000
	PR	8	OM	20,160
	PR	9	TCI	725,000
	PR	9	OM	72,570
	RE	4	TCI	**398,000
				*636,000
	RE	4	OM	59,400
	RE	5	TCI	**613,000
				*796,000
	RE	5	OM	64,130
	RE	6	TCI	126,000

Year	Process		Data Item	
	Type	Number	Type	Value
	RE	6	OM	54,360
	*PR	13	TCI	629,000
	*PR	13	OM	62,600
	*PR	14	TCI	1531,000
	*PR	14	OM	345,870
	*PR	15	TCI	4015,000
	*PR	15	OM	116,850
2020	*PR	14	CAPL	527,600
	*PR	13	CAPL	1180,800
	*PR	15	CAPL	200,000
	*PR	8	CAPL	799,500
	**PR	9	CAPL	4255,800
	PR	5	TCI	412,000
	PR	5	OM	84,130
	PR	10	TCI	412,000
	PR	10	OM	111,430
	RE	2	TCI	461,000
	RE	2	OM	68,860
	RE	3	TCI	461,000
	RE	3	OM	74,350
	PR	4	TCI	121,000
	PR	4	OM	72,700
	PR	6	TCI	438,000
	PR	6	OM	23,370
	RE	1	TCI	146,000
	RE	1	OM	43,020
	PR	8	TCI	940,000
	PR	8	OM	23,370
	PR	9	TCI	840,000
	PR	9	OM	84,130
	RE	4	TCI	**461,000 *737,000
	RE	4	OM	68,860
	RE	5	TCI	**711,000 *923,000
	RE	5	OM	74,350
	RE	6	TCI	146,000
	RE	6	OM	43,020
	*PR	13	TCI	730,000
	*PR	13	OM	72,570
	*PR	14	TCI	1775,000
	*PR	14	OM	400,960
	*PR	15	TCI	4654,000
	*PR	15	OM	135,460

Notes: * - for Mitigation scenarios; ** - not included in Mitigation scenarios

Appendix C. INITIAL DATA VALIDITY EVALUATION

The need for initial data validity evaluation dictated by heterogeneity of data and assumptions which allow to consider a number of data only as provisional. Table C1 explains criteria used for validity assessment.

Table C1. Initial Data Validity Evaluation Criteria

Validity	Meaning
Good	Data are presented in the state statistical reports
Satisfactory	There are alternative data sources
Bad	There are no data for that year; different assumptions are made

The data validity is evaluated in Table C2 on the basis of criteria listed in Table C1.

Table C2. Data Validity

Type of Data	Source	Assumptions Made	Data Validity
The mass of extracted domestic oil and gas condensate	[9]	–	Good
Cost of extracted domestic oil and gas condensate	[10]	Export price is taken as selling price of producer for domestic market	Satisfactory
Imported oil and gas condensate mass	[10]	–	Satisfactory
Imported oil and gas condensate cost	[10]	Cost of imported oil and gas condensate is taken 14 % higher than selling price	Bad
Imported gasoline mass	Experts' data	–	Satisfactory
Imported gasoline cost	[10]	Cost of imported gasoline 14 % higher than selling price of domestic producers	Bad
Imported diesel oil mass	Experts' data	–	Satisfactory
Imported diesel oil cost	[10]	Cost of imported diesel oil 14 % higher than selling price of domestic producers	Bad
Imported fuel oil mass	Experts' data	–	Satisfactory

Type of Data	Source	Assumptions Made	Data Validity
Imported fuel oil cost	[10]	Cost of imported fuel oil on 14 % higher than selling price of domestic producers	Bad
Extracted domestic gas mass	[9]	–	Good
Extracted domestic gas cost	[10]	Export price is selling of producer for domestic market	Satisfactory
Imported gas amount	[10]	–	Satisfactory
Imported gas cost	[10]	–	Satisfactory
Extracted Ekibastuz coal mass	Experts' data	–	Good
Extracted Ekibastuz coal cost	[10]	–	Satisfactory
Extracted Karaganda coal mass	Experts' data	–	Good
Extracted Karaganda coal cost	Experts' data	–	Satisfactory
Mass of coal imported from Middle Asia	[10]	–	Satisfactory
Cost of coal imported from Middle Asia	[10]	–	Satisfactory
Imported Kuznetsk coal mass	Experts' data	Determined as difference between total mass of imported coal and that imported from Middle Asia	Bad
Imported Kuznetsk coal cost	[10]	–	Satisfactory
Imported electricity	Experts' data	–	Satisfactory
Imported electricity cost	[10]	–	Bad
Hydroresources	Experts' data	Determined by division of generated electric power by HPS efficiency	Bad
Mass of oil and gas condensate processed at Kazakstan refineries	[10]	18 % of Kazakstan oil and gas as well a total amount of	Satisfactory

Type of Data	Source	Assumptions Made	Data Validity
		imported oil and gas have been processed	
Mass of fuel oil produced by refineries	Experts’ data	Determined as the difference between consumption and import	Bad
Cost of fuel oil produced by refineries	”Kaznefteproduct” Concern data	–	Good
Mass of gasoline produced by refineries	[9]	–	Good
Cost of gasoline produced by refineries	”Kaznefteproduct” Concern data	–	Good
Mass of diesel oil produced by refineries	[9]	–	Good
Cost of diesel oil produced by refineries	”Kaznefteproduct” Concern data	–	Good
Mass of fuel used for boilers	[7]	For 1990 the data of the year 1985 have been used	Bad
Fracture of coal, gas and fuel oil for boilers	[7]	For 1990 the data of the year 1985 have been used	Bad
Mass of gas consumed by the Ministry of Energy of Kazakstan	[8]	All gas is assumed to be used at oil-gas thermal electric power stations	Satisfactory
Specific consumption of standardized fuel for electricity and heat supply to 38 HPP	[8]	–	Good
Electric power output and heat supply to 38 HPP	[8]	–	Good
Nominal electric and heat capacity for 38 HPP	[8]	–	Good
Cost of electric and heat power supplied to 38 HPP	[8]	For 7 HPCs the data of 1988 have been used for 1990	Good
Electric power cost for HYP	[8]	–	Good
Capacity of HYP	[8]	–	Good

Type of Data	Source	Assumptions Made	Data Validity
Electric power output at HYP	[8]	–	Good
Capital investments to HYP	[7]	Capital investments in HPSs and HPCs are assumed to be equal	Bad
Capital expenditures for boilers	[7]	-	Bad
Capital expenditures for CNP and CGP	Experts' data	As data refer to 1991, the rate 0.45 $/tce is used	Satisfactory
Heat and electricity losses in networks	[10]	–	Good
Heat consumption fractures in industry and residential sector	[7]	Data of 1995 are used for 1990 under an assumptions that all heat produced is only consumed by this sectors	Satisfactory
Heat consumption fractures in metallurgy, industry, residential sector, transportation and agriculture	[7]	Data of 1995 are used for 1990 under an assumptions that all electricity produced is only consumed by these sectors	Satisfactory
Projected power generation capacities of HPP and HYP	[11]	–	Good
Maximum possible extraction rates of fossil fuel for a number of years	Experts' data	Fuel extraction in 1990-2020 will not exceed given values	Bad
Data on fuel and energy resource prices in late 80s in the USA	[12]	The US prices are considered as world averages; imported fuel and resources prices in Kazakstan will reach this level in 1996-2000; the same pace will be characteristic of domestic fuel and resource price rise	Satisfactory

Type of Data	Source	Assumptions Made	Data Validity
Rate of fuel and energy resource price change in 2000-2020	Experts’ data	–	Bad
Fuel and energy resource consumption levels in 1990-2020	Experts’ data	–	Bad
Capital costs and O&M costs in energy in 1990-2020	Experts’ data	Capital and O&M costs increase 1.5 times in 1995 and will further go up by 3 % annually	Bad
Data on inputting new blocks under reduction scenarios	Experts’ data	–	Good
Data on Rehab.Cogen. scenario	Experts’ data	New HPCs will be modernized	Good - for qualitative characteristics and bad - for costs
Data on imports and output reduction in Jambyl GCN	Experts’ data	–	Good

Notes: [7] - Chokin, 1990; [8] - Ministry of Energy and Electrification of Kazakstan, 1991; [9] - State Statistical Committee, 1991; [10] - Sartaev, 1991; [12] - Schipper and Meyers, 1992.