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ELECTRICAL ENGINEERING, MINING ENGINEERING D45

Analysis of Energy Development Perspectives

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Declaration:
Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology has not been submitted for any academic degree.

Arvi Hamburg…………….

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ENERGEETIKA. ELEKTROTEHNIKA. MÄENDUS D45

Energeetika arenguperspektiivide analüüs

ARVI HAMBURG

TTÜ KIRJASTUS

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ABBREVIATIONS AND SYMBOLS

Bbl	barrel		
bcm	billion cubic meters		
b/b	barrels per day		
Boe	barrel of oil equivalent		
CHG	compressed natural gas		
CHP	combined heat and power		
Cf	cubic feet		
CPP Coal	coal-fired condensing power plant		
CV	calorific value		
EU	European Union		
EUR	European momentary unit euro		
GDP	gross domestic product		
GHG	greenhouse gas		
GT	gas turbine power plant		
Gt	gigatonnes		
IPS/UPS	Independent Power Systems and unified power System		
J	joule		
kJ	kilojoule	(10^3 J)	Thousand
MJ	megajoule	(10^6 J)	Million
GJ	gigajoule	(10^9 J)	Milliard
TJ	terajoule	(10^{12} J)	Billion
PJ	petajoule	(10^{15} J)	Billiard
EJ	eksajoule	(10^{18} J)	Trillion
ZJ	zettajoule	(10^{21} J)	Trilliard
YJ	youtta joule	(10^{24} J)	Quadrillion
GJ/t	giga joule per tonne		
LNG	liquefied natural gas		
LPG	liquefied petroleum gas		
MJ/m^3	megajoule / cubic meter		
Mm^3	million cubic meters		
NORDEL	Nordic Transmission System Operators		
PP	power plant		
RES	renewable energy source		
tce	ton of goal equivalint = 29,31GJ		
toe	ton of oil equivalint = 41,87GJ		
tU	uranium t		
TPP	thermal power plant		
TSO	transmission system operator		
TUT	Tallinn University of Technology		

LIST OF ORIGINAL PAPERS

The main results of doctoral thesis have been published in the following papers and book:

I **Hamburg, A.** Energy situation and its development in independent Estonia, Baltic- Finnish conference: Energetic: From research to innovation, Estonian Academy of Sciences and Finnish Academies of Technology, Proceedings, 2001, pp. 53-57.

II **Hamburg, A.** The role of the state in forming the energy policy. – Scientific Proceedings of Riga Technical University. Power and Electrical Engineering. Vol. 14. Riga, 2005, pp. 61-66.

III **Hamburg, A.** Estonian National Energy Strategy, Oil Shale, 2007, Vol. 24, No. 2 Special, pp. 332-336

IV **Hamburg, A.** Innovation in energy supply, Oil Shale, 2009, Vol. 26, No. 3 Special, pp. 200-2007

V **Hamburg, A., Valdma, M.** Energy supply problems and perspectives.Oil Shale, 2010. Vol. 28, No. 2S (In publishing)

VI **Hamburg,** A., Köörna, A. Innovatsioon: teooria ja praktika, Euroülikool, 2009 (In Estonian)

In the Appendix A, copies of these publications are included.

Author’s own contribution

The contribution by the author to the papers included is as follows:

I. Arvi Hamburg is the author of the paper. He is responsible for literature overview, data collection and calculations.
II. Arvi Hamburg is the author of the paper. He is responsible for literature overview, data collection and calculations.
III. Arvi Hamburg is the author of the paper. He is responsible for literature overview, data collection and calculations.
IV. Arvi Hamburg is the author of the paper. He is responsible for literature overview, data collection and calculations.
V. Arvi Hamburg participated in writing of the paper. He was responsible for gata collection and some of the calculations. He had min. or role in writing
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I devote this work to keep alive the memory of Kristjan.

Arvi Hamburg

1. INTRODUCTION

1.1. Energy supply problems

Energy consumption in the world has increased very rapidly over the last 50-60 years mainly due to increasing population and economic development. In 2008, total worldwide energy consumption was 474 EJ [1]. This is equivalent to the continued power consumption 15 TW over the year.

The main sources of primary energy used in the world are the fossil fuels: oil, coal, natural gas and oil shale. About 80-90% of the energy consumption is derived from the combustion of fossil fuels.

The first problem on energy supply is that the resources of fossil fuels are limited and they are decreasing every year.

The second problem of fossil fuels is the pollution of environment that concur with combustion of organic fuels.

The growth of energy consumption in the world will continue. In 2050 the consumption of energy in the world may be over 2 times more and in 2100 over 3 times more than nowadays. Therefore the resources of fossil fuels will rapidly decrease and pollution of the environment will increase.

The decreasing of environmental pollutions is a traditional strategic objective of energy development. But in the last decades the movement for defending of environment has become more active. The environmental movement is based on the assertion that human-induced carbon dioxide emissions are the cause of the global climate warming. For that reason it is necessary to reduce the greenhouse gases emission, to use more wind power and to close the fossil fuels burning power plants.

In 1997 the climate conference in Kyoto took place. Several developed countries agreed with Kyoto protocol for cutting their emissions of greenhouse gases. European environmental policy is very active, using the quotas and taxing of CO_2 emissions.

Nowadays in many works [2, 3] the energy supply perspectives are looked also only from the climate warming positions. But many authors do not agree with the climate ideology [4, 5]. In their opinion the effect of human-induced carbon dioxide emissions on climate is negligible.

Actually the energy supply of consumers is an extremely important service that must continue and develop always in the future. Especially important and complicated is the consumers supply with electricity, as electricity is the most widely used form of energy and unlike gas and water, electricity cannot be stored.

The works about energy supply problems may be divided into 2 parts:

1) short-term energy supply problems (up to 10-20 years forward)
2) long-term energy supply problems (up to 50-70 years forward).

Short-term energy supply problems are usually solved by comparing concrete variants for concrete countries considering energy strategy and also political directions of the country.

There are a lot of papers and books about strategy and planning of short-term energy supply development [6, 7, 8 and 9].

The long-term energy supply problems are more complicated and these topics have not been studied sufficiently.

The current thesis is concentrated on the analysis of problems and long-term perspectives of energy supply. Time horizon of this thesis is 50-70 years forward.

1.2. Purpose and contents of the dissertation

The purpose of the dissertation was:

1. To analyze the main problems of energy supply in the world in a long-term perspective.
2. To make proposals for improving energy supply systems and processes.
3. To analyze energy supply problems of Estonia in a long-term perspective.
4. To make proposals for improving energy supply systems and processes in Estonia.

The dissertation belongs to the domain of energy strategy and energy policy. The topic of the dissertation is connected with the research area of power system cybernetics in the Department of Electric Power Engineering of the Tallinn University of Technology.

Contents of the dissertation:

The dissertation consists of 5 chapters:

1. Introduction
2. Energy resources and consumption
3. Electricity generation and consumption
4. Innovation in energy
5. Energy development perspectives in Estonia.
6. Conclusions

The main results of doctoral thesis are published in [1-VI].

2. ENERGY SOURCES AND CONSUMPTION

2.1. Introduction

The humankind will consume more and more electricity, heat and motor fuels and will constantly need more energy sources.

The energy sources are divided into two groups [1]:

- Non-renewable energy sources
- Renewable energy sources

Non-renewable energy sources are: fossil fuels (coal, oil, gas, oil shale and others) and nuclear fuels. They cannot be renewed or regenerated quickly.

Renewable energy sources are: solar power, wind power, hydro power, tidal power, geothermal power, biomass and others.

The energy sources are also divided into two groups:

- primary energy sources
- secondary energy sources.

Primary energy sources are energy sources in their original form. Primary energy sources include coal, oil shale, natural oil, natural gas, uranium, solar, hydro, wind, wave, wood, geothermal and others sources.

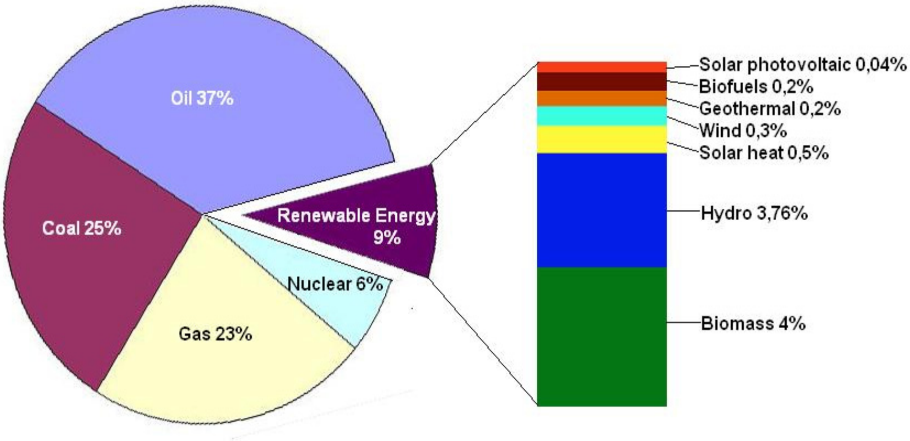
Secondary energy sources are produced from primary energy sources using energy-converting technologies. Electricity is a secondary energy source. Heat, produced by burning the fuels, is also the secondary energy source. The motor fuels are secondary energy sources too.

Analogically the primary and secondary energy are defined.

Primary energy is energy found in nature that has not been subjected to any conversion or transformation process. Primary energy is used as source (input) for producing secondary or converted energy. Primary energy may be non-renewable or renewable.

Secondary energy is energy that comes from the transformation of primary or secondary energy.

The structure of the world energy sources consumption in 2006 is shown in Figure 2.1.



Fig*ure 2.1 Structure of energy sources consumption in the world (2006) [10]*

The largest share of the world's energy consumption belongs to the oil fuels. The majority of this goes to the transport vehicles.

World energy consumption has grown over the last 100 years more than 15 times. The reserves, consumption and energy contents of fuels are presented in Table 2.1[11].

Table 2.1 Fuels reserves, consumption and energy contents

Fuels	Reserves	Consumption	Energy contents	
	(Gtce)	(Gtce/y)	GJ/t	MWh/t
Coal	2717	4,49	20-25	5,6-6,9
Oil	211;	5,2;	40-43	11,1- 11,9
Natural gas	167	3,0	46-47	12,8- 13,1
Peat	70	0,02	7,0-9,0	1,9-2,5
Oil shale	590	0,02	8,0-11,5	2,2- 3,2

The biggest oil shale user is Estonia.

The chemical composition of fuels that influences the energy contents and quantities of atmospheric emissions of fuels is presented in Table 2.2.

Table 2.2 Elemental composition of solid fuels and of organic matter of oil shale *(percent)* [11]

Fuel	C	H	O	N	S
Coal	75-85	3,5-5	3-5	0,8-1,2	<1
Wood	48-50	6-6,5	38-43	0,5-2,5	0,05
Peat	50-57	5-7,5	35-40	1,3-3	<0,3
Oil Shale	77,45	9,70	10,01	0,33	1,76

2.2. Fossil fuels

2.2.1. Coal

Coal is a readily combustible black or brownish-black sedimentary rock. Coal is composed primary of carbon along with variable quantities of other elements – sulfur, hydrogen, oxygen and nitrogen. The main types of coal are: lignite, flame coal, gas flame coal, gas coal, fat coal, forge coal, non baking coal and anthracite The heat content for different types of coal is usually in the interval 25 - 35 GJ/t (20-25GJ/t).

Coal is primarily used as a solid fuel to produce electricity and heat for consumers. About 40% of the world's electricity comes from coal. World coal consumption was 6,74 billion tons in 2006 and is expected to increase 48% to 9,98 billion tons by 2030.

China produced 2,38 billion tons in 2006. 68,7% of China's electricity comes from coal. India produced about 447,3 million tons in 2006. USA consumes about 14% of the world total, using 90% of it for generation of electricity.

When coal is used for electricity generation, it is pulverized and then burned in the boilers. The traditional pulverized combustion technology is nowadays too old. On this technology separates to atmosphere too much harmful emissions (nitrogen oxides, sulfur oxides and others). The future technologies of combustion are circulating fluidized bed combustion (CFBC) and pressurized fluidized bed combustion (PFBC) [12]. On these technologies of combustion the emissions of harmful gases will be sufficiently small.

Most of the coal reserve (up to 955) is located in Europe and Eurasia, North America and Asia Pacific as seen in Table 2.3.

Table 2.3 Coal reserves at the end of 2008 *(billion tons)* [10]

Year	Middle East	S .and Cent. America	Africa	North America	Asia Pacific	Europe/ Eurasia	Total
2008	1,4	15,0	32,0	248,1	259,3	272,2	828

The biggest coal reserves (Gt) by countries: United States 240 Gt , Russia 153 Gt, China 112 Gt [13].

Coal is and will remain the main energy source of for the electricity generation. From coal it is possible to produce the liquid fuels and gas.

2.2.2. Oil fuels

The oils have a high carbon and hydrogen content. All oils are burned in aerosol form generating heat, which can be used directly, or converted into other forms of fuels by various means. The oil that is pumped from the ground is then shipped via oil tanker to an oil refinery. There, it is converted from crude oil to diesel fuel, ethane, fuel oils, gasoline (petrol), jet fuel, kerosene and liquefied petroleum gas [14].

Two thirds of proven crude oil reserves are located in the Middle East and North Africa. More than half of the world's oil reserves are located in Middle East, as presented in Table 2.4 [13].

Table 2.4 Proved oil reserves at end of 2008 *(thousand million barrels)*

Year	Asia-Pacific	North-America	S. & Cent-America	Africa	Europe & Eurasia	Middle East	Total
2008	43,0	76,9	123,2	125,6	142,2	754,1	1265

Over the past twenty years, there has been an increase in the stock ¼ points. (1988- 988,4; 2008- 1265 thousand million barrels. Oil production and consumption regions are different. Asia Pacific, North America and Europe & Eurasia are deficit oil-importing regions.

Oil stocks have risen over the past 20 years, 1988th from 988.4 thousand million barrels 1265 thousand million barrels in 2008.

Around the world, only seven countries are rich in terms of its oil resources and determine politics of using liquid fuels today and in near future. It is important to own the stocks and production, and thus owning a strong market position. Major crude oil reserves are concentrated in relatively few countries. Oil reserves and production by countries are shown in Table 2.5 [15].

Table 2.5 Proved oil reserves and oil productions (Gt) by countries

Country	S-Arabia	Iraq	Iran	Kuwait	Emi-rates	Vene-zuela	Russia	Others	World
Reserves	35,7	15,1	14,7	13,3	12,9	10,1	6,7	40	148
Production Year (Gt)	0,497	0,063	0,182	0,104	0,123	0,138	0,400	2,125	3,632
Reserves Year	71	240	81	128	105	73	17	18,8	41

Fuel oil covers about 37% of total world energy consumption. About 10% of electricity is generated from fuel oil. Heat contents of oil fuels is 40-43 GJ/t.

The special oil fuels (petrol and diesel) are used in the transport vehicles. Heavy oil fuel (40-41GJ/t) used for ships and plants. Light oil fuels are used for boilers.

Heating oils (except motor oil) are the most used in electricity generation. Only a small percentage of oils are used in other industries, as illustrated in Figure 2.2 [14].

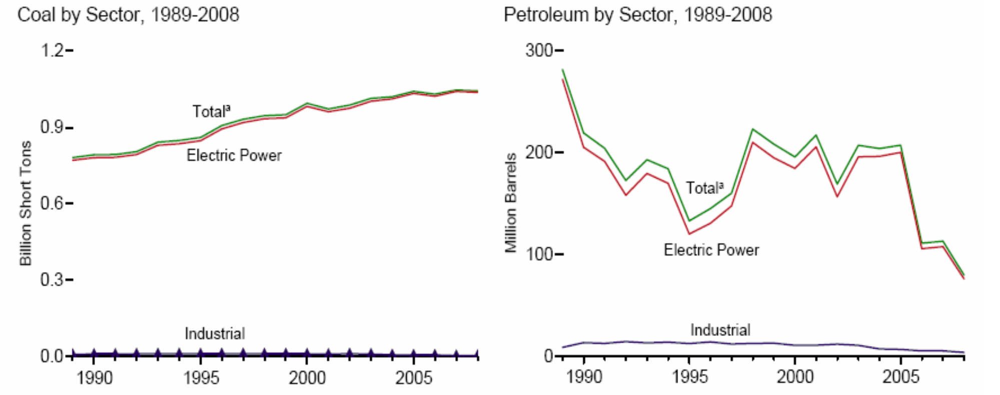


Figure 2.2 Consumption of selected combustible fuels (coal and petroleum) for electricity generation

World oil consumption fell by 420000 b/d, the largest decline since 1982. China again recorded the worlds largest incremental growth, rising by 260000 b/d. Consumption growth was above the 10-year average in the exporting regions of the Middle East, South and Central America, Africa and the Former Soviet Union.

Oil prices are assumed to fall from the 2008 level of $97 per barrel to around $60 per barrel in 2009, but then rebound with the economic recovery to reach $100 per barrel by 2020 and $115 per barrel by 2030 (in year-2008 dollars). As a result, OECD countries as a group are projected to spend on average close to 2% of their GDP on oil and gas imports until 2030. The oil price has been historically linked to the economic situation as seen in Figure 2.3 [13].

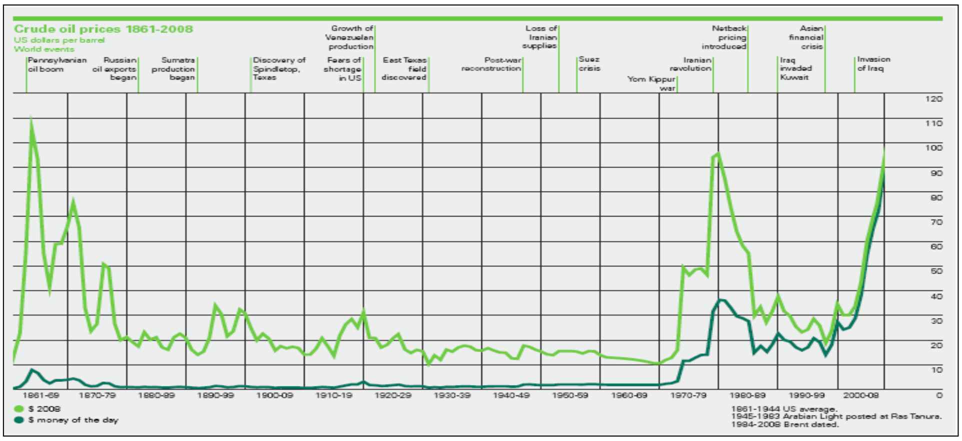


Figure 2.3 Crude oil prices in 1861-2009

Surge increase of the oil price 150 years ago was caused by the rapid development of motor vehicles and deployment. In 2008 the price increase was preceded by a leap in the price that was caused by oil crisis at the end of 1970 and at the beginning of 80s. Price change within large intervals. Oil price is sensitive economic parameter. The reserves of oil fuels will continue for 40 years only.

2.2.3. Natural gas

Natural gas is a gas consisting primarily of methane. It is found associated with other fossil fuels, in coal beds and is created by methanogenic organisms in marshes, bogs and landfills. The degree of security of supply of natural gas consumption is determined by the following factors: proved reserves, production of gas-based stocks, storage options as seen in Table 2.6 [16].

Table 2.6 Proved reserves, Production and Consumption at end of 2008 */Trillion cubic meters/*

Year	North America	South and Central America	Europe/ Eurasia	Africa	Middle East	Asia Pacific	Total
Proved reserves	8,87	7.31	62,89	15,39	76,91	14,65	186,02
Production	0,78	0,15	1, 075	0,19	0,36	0,39	2, 94
Consumption	0,80	0,13	1, 155	0,08	0, 30	0,45	2, 92
Stocks continuity	11,4 years	48,7 years	58,5 years	81 years	213,6 years	37,6 years	63,3 years

Proved gas reserves have increased substantially over the past 20 years, from the 109.72 trillion m³ in 1988 to 186.02 trillion m³ in 2008, which is 68.6% or 2/3 respectively. 41.3% of natural gas reserves are located in the Middle East and only 2.8% in Europe. 90.7% of the world natural gas reserves are located in 20 countries, the leader is the Russian Federation with 26.9% [17]. The reserves of natural gas by countries are shown in Table 2.7.

Table 2.7 Natural gas reserves by country

Country	Reserves (Trillion Cubic Feet)	Percentage of World Total	Reserves (Year)
World	6,254	100,0	60
Top 20 Countries	5,674	90,7	
Russia	1,680	26,9	76
Iran	992	15,9	370

Qatar	892	14,3	270
Saudi Arabia	258	4,1	91
United States	238	3,8	9
United Arab Emirates	214	3,4	138
Nigeria	184	2,9	230
Venezuela	171	2,7	127
Algeria	159	2,5	46
Iraq	112	1,8	
Indonesia	106	1,7	
Turkmenistan	94	1,5	
Kazakhstan	85	1,4	
Malaysia	83	1,3	
Norway	82	1,3	
China	80	1,3	
Uzbekistan	65	1,0	
Kuwait	63	1,0	
Egypt	59	0,9	
Canada	58	0,9	
Rest of World	581	9,3	

Over half of these reserves are located in just three countries: Russia, Iran and Qatar.

Natural gas accounts for 24,1% of world energy use and about 15% of electricity generation. It is the most frequently used ecologically clean fossil fuel. Natural gas is a major source of electricity generation through the use of gas turbines and steam turbines. Most grid peaking power plants and some off-grid engine-generators use natural gas. Natural gas burns more cleanly than other fossil fuels and produces less carbon dioxide per unit energy released.

Use of natural gas has increased very significantly in power generation (about 50%) as illustrated in Figure 2.4 [14].

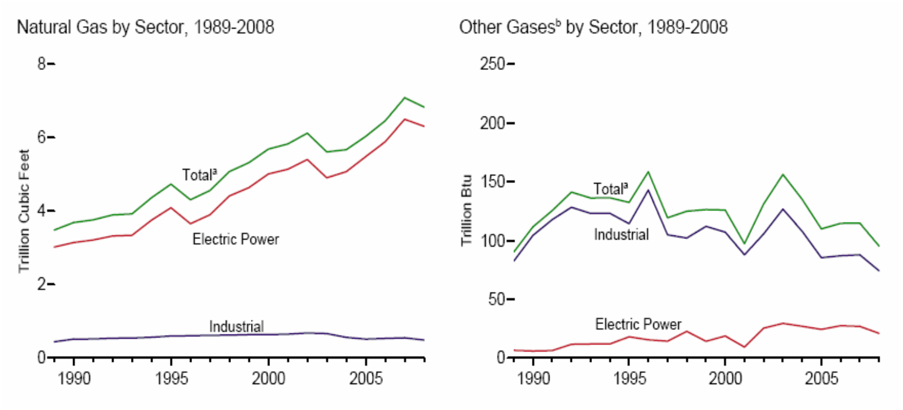


Figure 2.4 Natural gas by sector, 1989-2008

Small amounts of other gases are used in the electricity sector, the area of their use is mainly in other economic sectors. Consumption of natural gas is high in Europe and North America. In OECD, Europe and the Asia-Pacific region, oil-indexed gas prices rose more rapidly and consumption growth was below average. Chinese consumption grew by 15,8%, and China accounted for the largest incremental growth in world gas consumption. Natural gas produces less carbon dioxide when it is burned than does either coal or petroleum. Governments implementing national or regional plans to reduce greenhouse gas emissions may encourage its use to displace other fossil fuels.

The industrial sector currently consumes more natural gas than any other end-use sector and is expected to continue that trend through 2030, when 40 percent of world natural gas consumption is projected to be used for industrial purposes.

In the electric power sector, natural gas is an attractive choice for new generating plants, in particular, to ensure the energy balance and the creation of an emergency reserve. Electricity generation accounts for 35 percent of the world's total natural gas consumption in 2030, up from 32 percent in 2006.

In the IEO2009 reference case, natural gas consumption in the non-OECD countries grows more than twice as fast as consumption in the OECD countries, with 2.2 percent average annual growth from 2006 to 2030 for non-OECD countries, compared with an average of 0.9 percent for the OECD countries. The non-OECD countries account for 74 percent of the total world increment in natural gas consumption over the projection period, and the non-OECD share of total world natural gas consumption increases from 50 percent in 2006 to 58 percent in 2030. The OECD countries accounted for 38 percent of the world's total natural gas production and 50 percent of natural gas consumption in 2006, making them dependent on imports from non-OECD sources for 25 percent of their total consumption. In 2030, the OECD countries account for 31 percent of production and 42 percent of consumption, with their dependence on non-OECD natural gas only slightly higher than in 2006, at 27 percent. In the non-OECD regions, net exports grow more slowly than total production. In 2030, 17 percent of non-OECD production is consumed in OECD countries, down from 19 percent in 2006 [18].

Natural gas in European Union

The use of natural gas is intensive in the Member States of European Union and in the hole EU's energy balance primary energy demand will rise from 23,9% in 2005 to 29.9% in 2030 (18% in 1990). The natural gas used by the European Union members was 530 mrd /m³ in 2005, of which 42% was EU domestic product and 58% imports. Today, it can basically be assumed that for the European gas industry, which is becoming ever more dependent on imports, there are sufficient gas reserves available in the long run in countries which are accessible in terms of transmission distances. These countries include Russia, countries on the Gulf and in North and West Africa.

The projected increase of natural gas by year 2025 is 629 mrd/m³ in year, of which the EU domestic production is only 19% and 81% for imports. This is justified by the EU special attention to the increased security of supply of natural gas [19].

Europe's dependence on natural gas is increasing as presented in Table 2.8. It is especially important to ensure the security of supply.

Table 2.8 European (including Norway) total gas supply import from outside Europe [19]

Year	2005	2010	2015	2020	2025	2030
Dependency (%)	41	48	60	68	71	74

Today European production (incl. Norway) accounts for 59 % of supplies to EU gas markets and is expected to drop to a third by 2020 and to a quarter by 2030. Biggest supplies of natural gas are in Russian Federation, Europe depends of Russian gas are presented in Table 2.9.

Table 2.9 Russian gas export markets */mrd m³/year/* [20]

	2010	2015	2020	2025	2030
Total export	220	235	250	275	275
Export to EU/ incl. to the Baltic States and Finland	125/ 13	125/ 15	130/ 17	140/ 17	140/ 18
Export outside the EU	95	110	120	135	135
Contracts for the supply of Russian and EU	151	176	172	170	105
Difference between agreement and need	26	51	42	30	-35

Consumption of natural gas in different sectors of EU Member States is quite various. Using the gas for power generation is smallest in Estonia, the largest in Greece as presented in Table 2.10 [19].

Table 2.10 Natural gas is the main fuel in district heating in our country

	Power generation	House-holds	Industry	Services	District heating	Other	Gas as % of total primary fuel mix
Austria	29%	18%	37%	7%	2%	7%	21
Belgium	29%	22%	39%	10%	0%	0%	26
Bulgaria	26%	1%	46%	3%	7%	17%	15
Czech Republic	6%	28%	35%	18%	7%	5%	15
Denmark	39%	15%	18%	7%	3%	16%	20
Estonia	4,9%	6%	36%	6%	39%	1%	13
Finland	55%	1%	27%	1%	8%	9%	10
France	15%	34%	28%	21%	0%	2%	14
Germany	23%	37%	27%	14%	1%	0%	23
Greece	73%	5%	16%	3%	0%	2%	10
Hungary	32%	30%	15%	16%	4%	3%	40
Ireland	64%	14%	15%	8%	0%	-1%	27
Italy	40%	23%	24%	10%	0%	3%	38
Latvia	46%	8%	21%	10%	15%	1%	29
Lithuania	31%	5%	49%	4%	10%	1%	32
Luxembourg	41%	26%	34%	0%	0%	0%	26
Netherlands	33%	20%	23%	19%	1%	4%	40
Poland	8%	26%	40%	13%	2%	12%	13
Portugal	59%	6%	27%	5%	0%	4%	15
Romania	28%	16%	32%	9%	4%	11%	32
Slovakia	9%	22%	26%	19%	9%	16%	28
Slovenia	10%	9%	74%	1%	5%	0%	12
Spain	44%	12%	30%	9%	0%	5%	22
Sweden	31%	4%	40%	13%	1%	12%	2
United Kingdom	33%	33%	14%	9%	2%	8%	37
EU27	31%	26%	25%	12%	1%	4%	24

31% of natural gas is used for electricity generation in European Union. Around the world natural gas transportation takes place as pipeline transport and in liquefied form as maritime transport.

Security of natural gas supply can be enhanced by interconnections and the construction of natural gas terminals. Liquefied Natural Gas (LNG) currently represents the most exciting aspect of the international gas landscape.

LNG is simply an alternative method to transport methane from the producer to the consumer. Methane (C_1H_4) gas is cooled to –161.5° C (–260° F), converting its gaseous phase into an easily transportable liquid whose volume is approximately 600 times less than the equivalent volume of methane gas.

The "LNG chain," shown below, consists of discrete sections: upstream, midstream liquefaction plant, shipping, regasification, and finally, gas distribution.

Worldwide trade in LNG has steadily increased since the first delivery of LNG from the United States to the United Kingdom in 1959. In 1964, Algeria became the site of the first commercial LNG plant, initially exporting its product to the United Kingdom. It is very important in the aspect of the security of equipment to cover the winter load maximum. Consumption of natural gas is seasonal, before the winter high consumption the maximum storage are stored in stocks and the supply contracts will be reviewed. EU capacity and demand balance in winter 2009/2010 is seen in Table 2.11.

Table 2.11 EU capacity and demand balance in winter 2009/2010 [21]

TOTAL	GWh/day
Total capacity connected with import	12,931
Total capacity connected with LNG	4,834
Total national production	8,450
Total storage	13, 417
Total	39, 417
Total Market (Normal cold conditions)	28,668
Total market (Exceptional cold conditions)	35,621

EU natural gas daily production covers only 23.7% of gas consumption in a very cold winter day. There are two measures to safeguard the security of supply:

- dissolving the gas in the storage facility,
- buying the LNG.

EU has 127 Natural Gas Storages, total capacity 75 282 Mm^3, at 1 January 2007. EU27 countries National gas imports from non-EU countries are 87% by pipeline and 13% by LNG. In the long term LNG could represent 25% of the total EU supplies.

Over the period, it is estimated that 221 Billion euro of investments will be needed in the European gas sector. These investments need to exist at all stages of the supply chain: exploration and development, transmission systems incl. LNG infrastructure as well as storage capacity. LNG supplies are presented in Table 2.12.

Table 2.12 LNG Supplies in EU27 [19]

Countries	LNG Supplies (PJ)
Belgium	205,10
France	564,40
Greece	17,80
Italy	120,00
Portugal	73,00
Spain	1023,40
United Kingdom	135,00
EU	2138,70

LNG suppliers are areas where due to the large distances the establishment of gas pipeline is not economically justified. The supply of LNG is mainly from Algeria. Supplies of LNG breakdown of EU27 are shown in Table 2.13 [20].

Table 2.13 LNG supplies for EU

Country	LNG Supplies
Algeria	34%
Egypt	15%
Nigeria	18%
Middle East	12%
Trinidad, Tobago	8%
Others	13%

In the world's natural gas market LNG is a fast growing sector. Global LNG shipments rose by 12% last year to approximately a 181 mtoe/y. In 2006 LNG imports in Europe rose to almost 52 mtoe/y, representing a share of 11% of the total gas market – it is illustrated in Figure 2.5 [21]. The share of LNG is growing in the future.

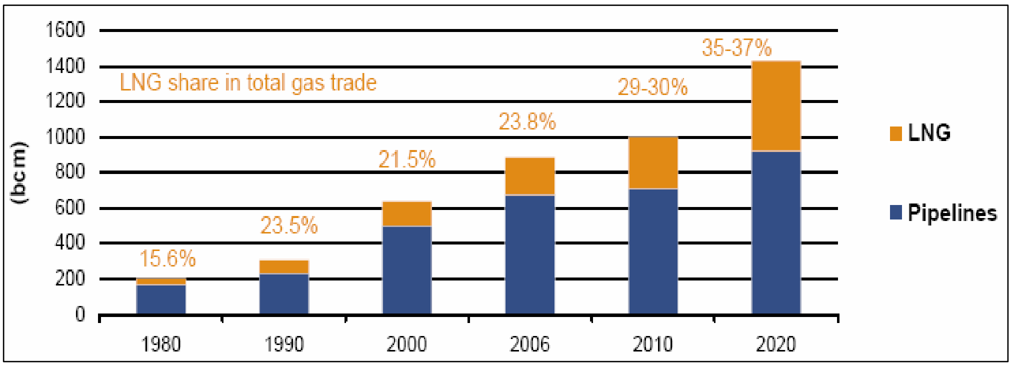


Figure 2.5 The increasing role of world gas trade

2.2.4. Oil shale

Oil shale is an organic-rich fine-grained sedimentary rock containing relatively large amounts of organic matter known as kerogen. Oil shale is combustable, but contains a lower percentage of organic matter than coal. At the same time, the organic matter in oil shale has an atomic ratio of hydrogen to carbon (H/C) approximately 1,2 to 1,8 times lower than for crude oil and about 1,5 to 3 times higher than for coals [23].

A 2005 estimate set the total world resources of oil shale at 411 gigatonnes enough to yield 2.8 to 3.3 trillion barrels (520×10^9 m^3) of shale oil. This exceeds the world's proven conventional oil reserves, estimated at 1.317 trillion barrels (209.4×10^9 m^3), therefore, the oil shale reserves are 2.5 times higher than oil stocks [24]. As the production and use of oil shale in the world is underdeveloped, and at an early stage, the stock has not been adequately studied. Actual reserves may exceed many times the quantity of tested stocks. By far the largest known oil shale deposit in the world is the Green River oil shale in the western part of the United States, which contains a total estimated resource of nearly 1.5 trillion barrels.

The deposits in the United States, Russia, Congo, Italy, Brazil and Morocco account for 95% of the world's resources in terms of shale-oil content. The oil shale resource in the Estonia deposit is 4,975 Gt. According to the given criteria, the active mineable oil shale resource in the Estonian deposit is 1,167 Gt.

Energy productivity of the layer is over 35 GJ/m3, sufficiently studied, which accounts for about 23 percent of the total resource [12].

Production of oil shale in Estonia (Estonia deposit), Russia (Leningrad and Kashpir deposits), United Kingdom (Scotland, Lothians), Brazil, China, and Germany from 1880 to 2000 is shown in Figure 2.6.

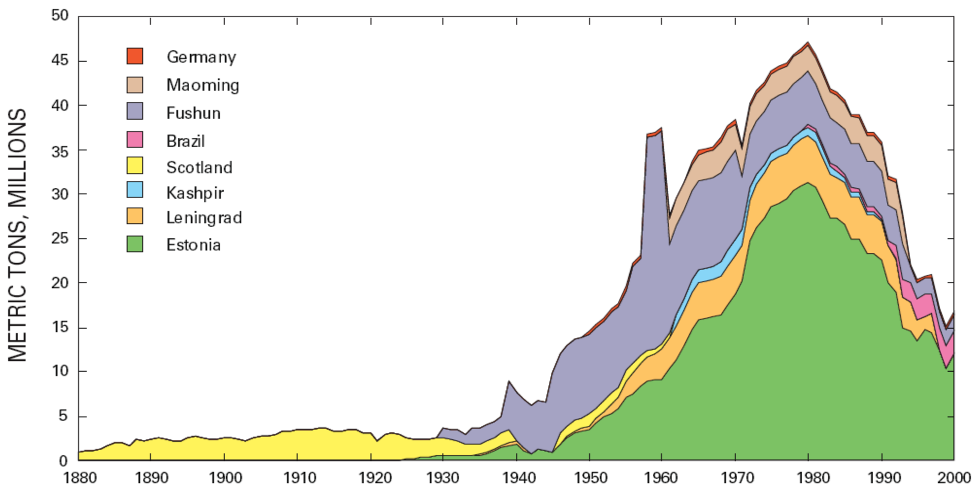


Figure 2.6 Production of oil shale [24]

Oil-shale power plants are in Estonia, which has an installed capacity of 2,967 (MW), Israel (12.5 MW), China (12 MW), and Germany (9.9 MW) [24].

Oil shale reserves exist in many countries (Table 2.14), particularly in the United States, Russian Federation, and also in Estonia. About 80% of oil shale used globally is extracted in Estonia (2009).

Oil shale as an energy source is used:

- for electric power generation in Estonia, China, Israel and Germany;
- for oil production in Estonia, Brazil, and China;
- for cement production in Estonia, Germany, and China;
- in chemical industries in China, Estonia, and Russia.

Table 2.14 Oil shale resources and production at the end of 2005 [25]

Country	In-place shale oil resources Million Barrels	Resources (%)	In-place shale oil resources Million tones	Production in 2005 Thousand tones oil
Egypt	5700	0,20	816	
Congo	100 000	3,55	14 310	
Madagascar	32	0,001	5	
Morocco	53 381	1,91	8 167	
South Africa	130	0,005	19	
Total Africa	159 243	5,68	23 317	
Canada	15 241	0,51	2 192	
United States of America	2 085 228	75,09	301 566	
Total North America	2 100 469	75,60	303 758	
Argentina	400	0,01	57	
Brazil	82 000	2,76	11 734	159
Chile	21	0,0007	13	
Total South America	82 421	2,77	11 794	159
Armenia	305	0,01	44	
China	16 000	0,39	2 290	180
Kazakhstan	2 837	0,10	400	
Mongolia	294	0,01	42	42

Myanmar (Burma)	2 000	0,07	286	
Thailand	6 400	0,15	916	
Turkey	1 985	0,07	284	
Turkmenistan	7 687	0,18	1 100	
Uzbekistan	8 386	0,25	1 200	
Total Asia	45 894	1,20	6 562	180
Austria	8	0,0003	1	
Belarus	6 988	0,21	1 000	
Bulgaria	125	0,004	18	
Estonia	18 686	0,66	2 494	345
France	7 000	0,21	1 002	
Germany	2 000	0,07	286	
Hungary	56	0,002	8	
Italy	73 000	2,31	10 446	
Luxembourg	675	0,02	97	
Poland	48	0,002	7	
Russian Federation	247 887	8,79	35 470	
Spain	280	0,01	40	
Sweden	6 114	0,21	875	
Ukraine	4 193	0,14	600	
United Kingdom	3 500	0,11	501	
Total Europe	368 156	12,39	52 845	345
Israel	4 000	0,1	550	
Jordan	34 172	1,1	5242	
Total Middle East	38 172	1,2	5792	
New Zealand	19	0,0006	3	
Australia	31 729	1,1	4531	
Total Oceania	3 1 748	1,1	4534	

TOTAL WORLD	2 826 103	100	408 602	684

Romania and Russia have in the past run power plants fired by oil shale, but have shut them down or switched to other fuel sources such as natural gas. Jordan and Egypt plan to construct power plants fired by oil shale, while Canada and Turkey plan to burn oil shale along with coal for power generation.

The resources of oil shale are very high in the world. If the stocks of oil and natural gas are decreasing, the importance of oil shale will increase.

Large quantities of oil shale have been produced and used in Estonia for a long time. We have scientific solutions for using our own oil shale and years of successful practical experience.

The priority is a concentration of scientific studies of oil shale in Estonia. We have the scientific and practical competence, the value of which increases with the increasing use of oil shale in the world.

2.2.5. Peat http://en.wikipedia.org/wiki/Peat

Peat is an accumulation of partially decayed vegetation matter. Peat is harvested as an important source of fuel in certain parts of the world. By volume there are about 4 trillion m³ of peat in the world covering a total of around 2% of global land mass (about 3 million km3) and containing about 8 billion TJ of energy [26].

Peat reserves are only in few countries, and they have not yet been sufficiently studied. Peat production and consumption by countries is presented in Table 2.15.

Table 2.15 Peat production and consumption in 2004 *(thousand tones)*

Country	Production	Consumption
Burundi	5	5
Total Africa	5	5
Falkland Islands	13	13
Total South Africa	13	13
Austria	1	1
Belarus	1 993	2 122
Estonia	279	299
Finland	3 200	8 724
Germany	133	11
Ireland	4 395	2 706

Latvia	13	9
Lithuania	50	47
Romania	8	10
Russian Federation	1 487	1 405
Sweden	1 276	1 276
Ukraine	707	653
United Kingdom	20	20
Total Europe	13 562	17 283
TOTAL WORLD	13 580	17 301

The resources of peat are not big in the world and it has only a local significance. Oil shale has the biggest reserve of fossil fuels as seen in Table 2.16.

Table 2.16 Reserve of fossil fuels

Fuel	Quantity	Continuity
Oil	1,119-1,317 billion barrels (178-209 billion m³)	43 years
Gas	1,161 billion barrels oil equivalent (BBOE), (175-181 trillion m³)	61 years
Coal	4,416 BBOE; 997,748 million short tons (905 billion tonnes) [13]	148 years
Oil shale	2,826 BBOE	100 years

2.3. Nuclear fuels

Nuclear fuel is any material that can be consumed to derive nuclear energy. Nuclear fuels are the most dense energy sources available to humans. The most common type of nuclear fuel contains heavy fissile elements that can be made to undergo nuclear fission chain reactions in a nuclear reactor. The most common fuels are 235U and 239Pu.

The International Atomic Energy Agency estimates the remaining uranium resources to be equal to 2500 ZJ. Nuclear power accounted for 6.3% of world’s total primary energy supply. The nuclear power production in 2006 accounted 2 658 TWh (23.3 EJ), which was 16% of world’s total electricity production. In November 2007, there were 439 operational nuclear reactors worldwide, with total capacity of 372 002 Mwe.

Despite the environmental lobby, the USA has grown its nuclear power production/consumption over the long term. France’s production has also expanded significantly – they are now the second biggest producers in the world. Japan's production was hit in 2003 by maintenance issues – though these plants are now back online. South Korea's production has increase significantly – because they do not have any indigenous coal, gas or oil –power is generated mainly from nuclear fuels and imported LNG.

Economically used stocks of nuclear fuels are large in Australia and Kazakhstan, the largest manufacturer is Canada (more than a quarter of the world's nuclear fuel production) and then Australia [27]. See figures 2.7 and 2.8.

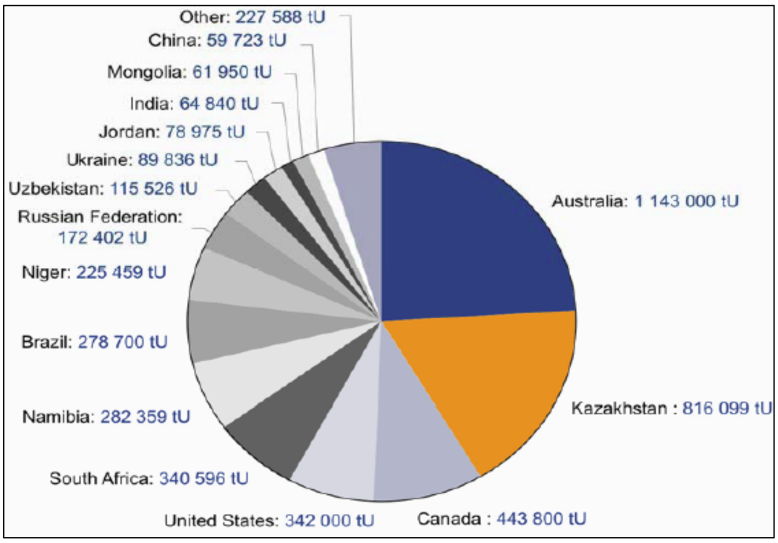


Figure 2.7 Distribution of identified producers resources at US$ 130/kgU in 2005

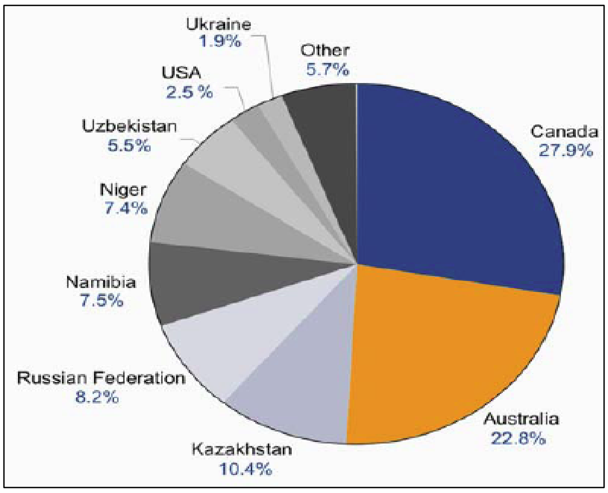


Figure 2.8 Top ten uranium

In 2005 the total production was 41 699 tU. Only 3% of the uranium used in European nuclear reactors was mined in Europe.

Russia, Canada, Australia and Niger were the largest suppliers of nuclear materials to the EU, supplying more than 75% of the total needs in 2007 [28].

2.4. Hydro power

Hydro power is a significant renewable energy source for electricity production. About 16% of global electricity in the world comes from hydro energy. Especially essential is the existence of large hydro power plants that have the great water reservoirs (storage plants). Hydro power plants with great water reservoirs enable to control the frequency and generating power in power system. Depending of the size of water reservoir the cycle of power regulation may be a day, week, one or several years. By the large hydro power plants also small hydro power plants (run-of-river plants) are used in the world. Their capacity is usually up to 10 MW. The small hydro power plants have not or may have very small water reservoirs [29]. In 2005, hydro power accounts for 6.1% of total primary energy consumption

Hydro accumulation plants are needed in power systems with nuclear power plants to produce the power for peak hours. Economically, they are justified to secure constant load for nuclear power stations [30].

2.5. Renewable energy

Using renewable energy sources is justified by the existence of their recording possibility. Renewable energy sources and waste can be classified into three broad groups:

- renewable sources and technologies,
- Renewable sources without stock changes,
- Renewable sources with stock changes.

In 2004, renewable energy supplied around 7% of the world's energy consumption. The renewables sector has been growing significantly since the last years of the 20th century. This resulted in an additional 35 GW of capacity during the year. Distribution and balance of renewable energy sources is presented in Figure 2.9 [31].

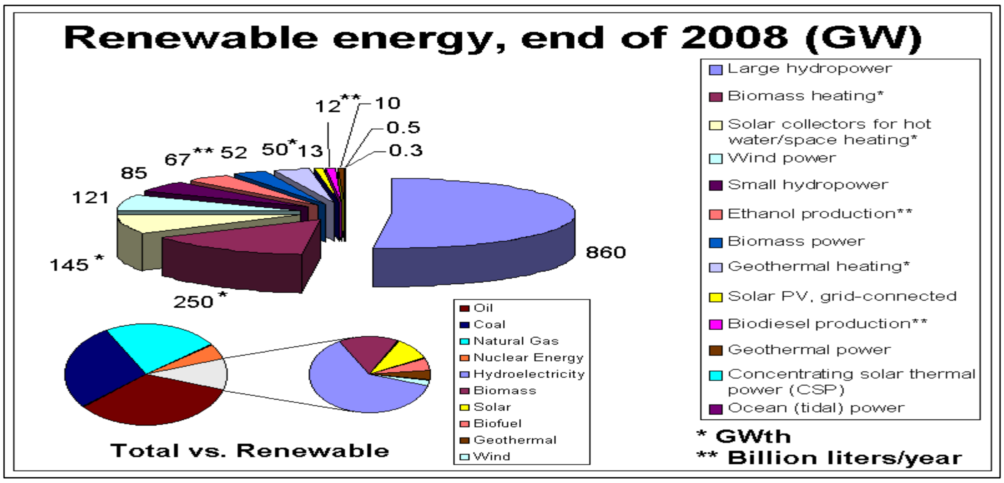


Figure 2.9 Renewable energy capacity (2008) (GW)

The available solar energy resources are 3.8 YJ/yr. The consumption of solar hot water and solar space heating was estimated at 88 GWt.

In 2007 grid-connected photovoltaic electricity was the fastest growing energy source, with installations of all photovoltaics increasing by 83% in 2009 to bring the total installed capacity to 15 GW.

According to the World Wind Energy Association, the installed capacity of wind power increased by 29 % from the end of 2007 to the end of 2008 to total capacity 121 GW [32].

Wind power changes in time and these changes are not controllable. For that reason the use of wind power with great capacity in the power systems causes serious problems of power balance control. The efficiency of wind power integration to power systems needs complementary research. Analogical problems will arise with the integration of solar power plants to power systems. Useful integration of wind and solar power to electric power systems needs creation of effective energy storing systems and research into their economical and technical suitability.

Until the end of the 19th century biomass was the predominant fuel, today it has only a small share of the overall energy supply. Electricity produced from biomass sources was estimated 44 GW in 2005. A further 220 GW was used for heating (in 2004), bringing the total energy consumed from biomass to around 264 GW.

Biomass (wood) is used in the electricity production for small unit capacities as illustrated in Figure 2.10. [14].

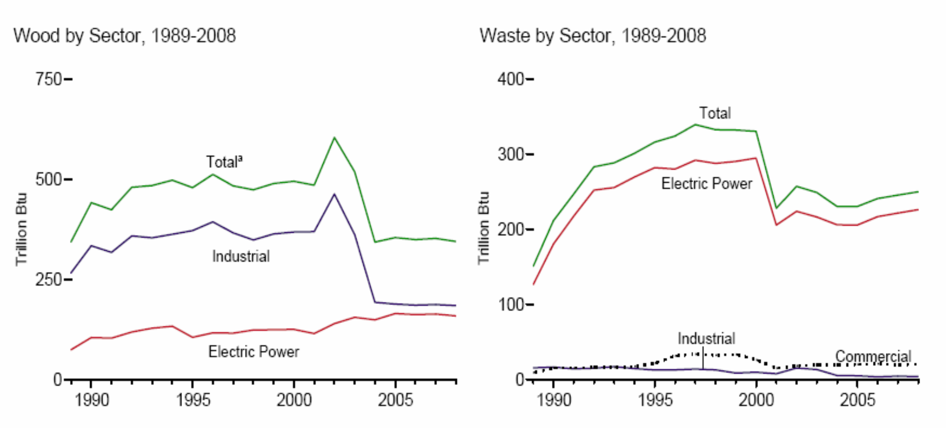


Figure 2.10 Electricity generation by wood and waste, 1989-2008

The use of wood in power generation is in the growing trend, being the decreasing trend in other sectors of economy. Waste incineration in particular is the question of environmental holding, the slow rate in electricity generation has been perceived recently.

Geothermal energy is used commercially in over 70 countries. In 2007, the world had a global capacity for 10 GW of electricity generation and an additional 28 GW of direct heating, including extraction by geothermal heat pumps. By year 2015 the electricity generation from renewables including hydro sources in OECD and non-OECD countries will be on the level 20%, and will reach 26% by year 2030 in OECD countries.

2.6. Energy consumption

In 2008, total worldwide energy consumption was 474 exajoules with 80 to 90% derived from the combustion of fossil fuels. More than 66% of electricity and 95% of transportation fuels are derived from fossil resources. Therefore the energy is gotten mainly from non-renewable energy resources. From renewable energy resources is remarkable only using of hydro power plants (about 17%).

World energy consumption forecasts have become modest, because of the fast development of technology of regeneration, optimal working regimes of fuel and energy sector, energy-saving information, expansion of uses and increasingly stringent environmental restriction of pollution.

Over the past 30 years, the growth of primary energy consumption in the non-OECD countries was quicker than in OECD countries. Different types of primary increments at an interval of 10 years are illustrated in Figure 2.11 [33].

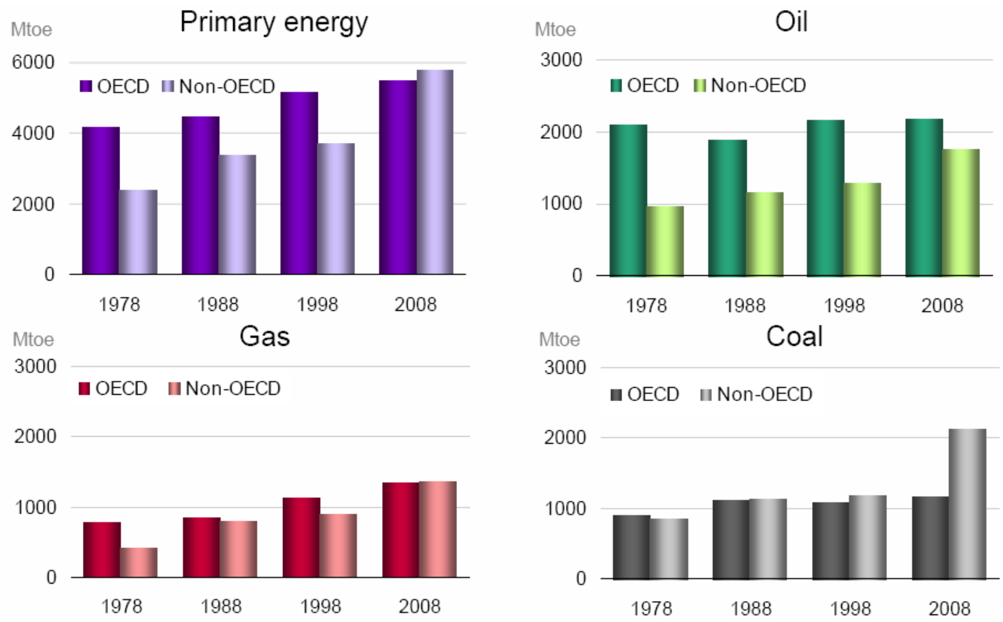


Figure 2.11 Energy consumption in years 1978-2008

Fossil fuels used for electricity generation and renewable energy resources and their intensity in the 2006 and projections to 2030 are presented in Table 2.17.

Table 2.17 The structure of primary energy consumption for the electricity generation in the world *(trillion kWh)*

Non Renewables						Renewables					Total
Year	Liquids	Nuclear	Natural Gas	Coal	TOTAL	Hydro-electricity	Wind	Geothermal	Other renew-ables	TOTAL	
2006	0,9	2,7	3,6	7,4	14,6	3,0	0,1	0,1	0,2	3,4	18,0
2010	0,9	2,8	4,2	8,7	16,6	3,4	0,3	0,1	0,3	4,0	20,6
2015	0,9	3,0	4,9	9,5	18,3	3,9	0,5	0,1	0,4	4,9	23,2
2020	0,9	3,4	5,7	10,4	20,4	4,4	0,7	0,1	0,5	5,6	26,0
2025	0,9	3,6	6,4	11,8	22,7	4,6	0,9	0,1	0,6	6,1	28,8
2030	0,9	3,8	6,8	13,6	25,1	4,8	1,2	0,1	0,6	6,7	31,8

Growth in energy consumption in OECD countries is explained by the increasing number of inhabitants as seen in Figure 2.12 [33].

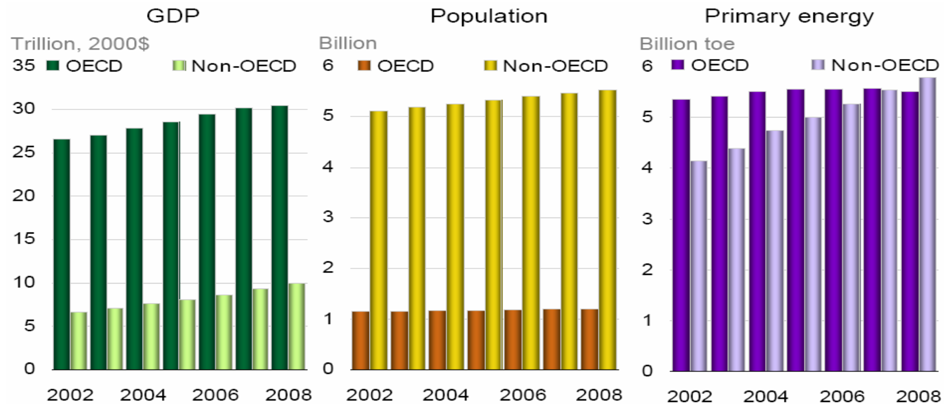


Figure 2.12 Growth in primary energy consumption, population and GDP in OECD and non-OECD countries (2002-2008)

Based on current statistics, World Energy Outlook 2009 [34] predicts World Energy demand until 2030 in accordance with the following Figure 2.13.

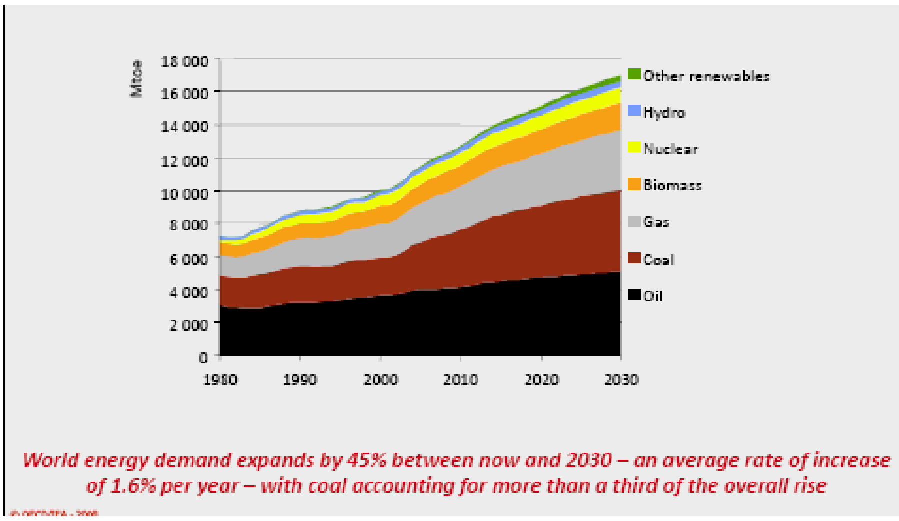


Figure 2.13 Word primary energy demand

Analyzing the average prognosis we can conclude that fossil fuels will remain the main primary energy species for the long-term period (up to 100 years).

Renewable energy sources can save the opportunity to develop their presence, together with the scientific and technological progress, expanding uses of nuclear energy and, of course, the introduction of new types of energy.

2.7. Main problems of energy supply

The quantities of energy consumption in the world are very large and will increase in the future. The consumption of energy will especially rapidly increase in China and India. At the same time the quality requirements are arising.

- The places of fuel are relatively far from the energy consumption centers. The average distance between these is about 2000 km.
- A great part of energy resources are located in unstable areas (62% oil and 41% of gas reserves in the Middle East).

The EU currently imports 65% of its oil and 57% of its gas, making itself the world's leading importer of these fuels.

2.7.1. Environmental impacts of growing energy consumption

Energy industry is always associated with environmental impact. The effect depends on the size of the country or the region of primary energy resources. One of the most important goals of energy-shaping is to minimize the environmental impact. Main objectives of optimization energy supply are to minimize the cost of fossil fuels and the environmental pollutions.

World Energy Outlook 2009 the Reference Scenario prognosis is based on the forecast of primary energy growth analysis from 2000-2007. Opportunities of the energy and consumer needs in the future are taken into account. The climate and resource availability are key factors in the environment pollution issue.

Kyoto process in the world and especially EU environment policy are directed to greenhouse gas limitation and trading. This will increase the fuel and energy prices, which in turn reduces the competitiveness of the economy.

The World Energy Outlook 2009 (WEO-2009) quantifies the challenge and shows what is required to overcome it.

The capital required to meet the projected energy demand through 2030 in the Reference Scenario is huge, amounting in cumulative terms to \$26, equal to \$1.1 trillion (or 1,4% of global gross domestic product per year on average [35]. The power sector requires 52% of total investment as seen in Figure 2.14.

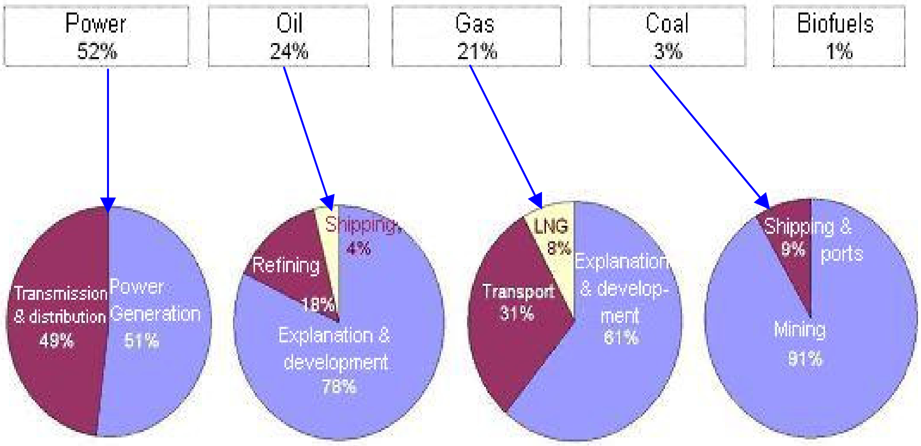


Figure 2.14 Cumulative energy- supply investment 2007-2030

Electricity generation, transmission and distribution development is a priority for all regions and countries. World Energy Outlook 2006 predicts electricity investments 11,357 billion USD 2030 [36]. Investments in power sector in 2010-2030 are given in Table 2.18.

Table 2.18 Investments in Power sector *(billion USD)*

Region, Country	N-America	S-America	Europe	Africa	M-East	Russia	Oceania	India	China
Generation	953	320	1014	203	166	285	668	408	1170
Transmission	314	126	159	89	73	67	258	176	579
Distribution	711	273	507	193	158	237	529	383	1258
Total	1977	719	1680	484	476	589	1455	967	3007

Chinese investments in the power sector will be over 25% of total world investment during the next 20 years [37].

The world is planning the development of energy sector using two possible scenarios. These scenarios are based on the principle that human activities have a result – the average temperature of the Earth has risen. There will be given allowed increase of temperature and on the basis of that the allowed quantity of CO_2 emissions.

Based on the not sufficiently studied original terms WEO-2008 has proposed two possible scenarios:

1. 450 Policy Scenario, which depicts a world in which collective policy action is taken to limit the long-term concentration of greenhouse gases in the atmosphere to 450 parts per million of CO_2-equivalent (ppm - CO_2eq), an objective that is gaining widespread support around the world. Although opinion is mixed on what might be considered a sustainable, long-term level of annual CO_2 emissions for the energy sector, a consensus on the need to limit the global temperature increase to 2°C is emerging.

2. 550 Policy Scenario- taken to limit the long-term concentration of greenhouse gases in the atmosphere to 550 ppm CO_2-eq, the global temperature increase to 3°C is emerging. Key results of the post-2012 climate policy analysis are shown in Table 2.19.

Table 2.19 Climate policy analysis

450 Policy Scenario	550 Policy Scenario
Corresponds to a c. 2º global temperature rice	Corresponds to a c. 3º global temperature rice
Energy demand grows, bat half as fast as in reference Scenario	Energy demand continues to expand, but fuel mix is markedly different
Rapid deployment of low- carbon technologies- particularly CCS	CO_2 price in OECD countries reaches $90/tonne in 2030
Big fall in non- OECD countries emissions	Additional investment equal to 0,25% of GDP
CO_2 price in 2030 reaches $180/tonne	
Additional investment equal to 0,6% of GDP	

However, such developments can not be long (50-100 years) and seriously considered because the assumption that human activity is warming the earth's climate needs serious scientific substantiation. There are totally opposite results of measurements and calculations of scientists that the earth's temperature will decline. The current logic is based on an acceptable temperature warming. The permissible temperature will be given and according to these scenarios, energy policy will be proposed. If there is sufficient research and scientifically proven reasons, only then we can design remedies.

As in the present work we analyze the formation of energy strategy in the time horizon of 50 and more years, I will not deal with the only possible option – taxation of greenhouse gas emission.

Approach like this creates a very different economic capacity of basic conditions for different countries. These, however, cannot be changed by the state, because the use of different fuels has different effects on the environment.

Shaping the structure of energy production and used fuels, the starting point is integrated goals. These are durable, long-term security of supply and the total energy production, the efficacy of transport and it use, including the environment friendliness.

2.7.2. Optimization of fuel industry

Whereas renewable energy sources and artifact fuels can not substitute the fossil fuels, than the strategy of fuel consumption must be the saving of fuel resources and minimizing of fuel consumption.

Optimal strategy for consumption and storing of energy resources

1. The mineral deposits have to use, shut and open on the base of the thorough economical analysis.
2. The mining, rework and transport of the fuels must be organized economically, minimizing losses of fuels and environmental pollutions in the long-term period.
3. The roles of scientific researchers and innovation must be raised.

The problems are very complicated. The fuel industry must be optimized according to multi-criterions at the same time. It is necessary to consider long-term time period of optimization and different forms of initial information (deterministic, probabilistic, uncertain and fuzzy information).

The optimization of fuel industry enables to save the fuel resources and to decrease the environmental pollutions approximately 20-40%.

2.7.3. EU energy policy

An important driver in energy policy is the European Council Decision of The European Union's Energy Action Plan 2007-2009, adopted in March 2007. According to the Energy Action Plan the European Union's energy-climate package (20+20+ 20 +10) as compared to the base year 2005:

- to reduce greenhouse gas emissions by 20% (compared to the year 1990 be reduced to 30%)
- to raise the share of renewables to 20%
- to increase the effectiveness of the final consumer of primary energy use by 20%
- to increase the share of biofuels in transport to 10%

Energy development scenarios for EU-27 in 2020 have four scenario analyses:

- baseline scenario (i.e. without the Energy Policy for Europe), with oil prices at 61$/bbl,
- baseline scenario with oil prices at $100/bbl,
- scenario with the Energy Policy for Europe and the moderate oil price,
- scenario with the Energy Policy for Europe and the higher oil price.

Our local fuel oil shale is rich in CO_2, then in the emission trade, the biggest loser is the Estonian economy. The task of politicians should be finding compromises, and the task of scientists should be using more effective technologies. Similarly, the consumer has very great potential to optimize the use of energy.

CO_2 per tone price was 20 Euro within the last two years, in addition the price of electricity as illustrated in Figure 2.15 [33].

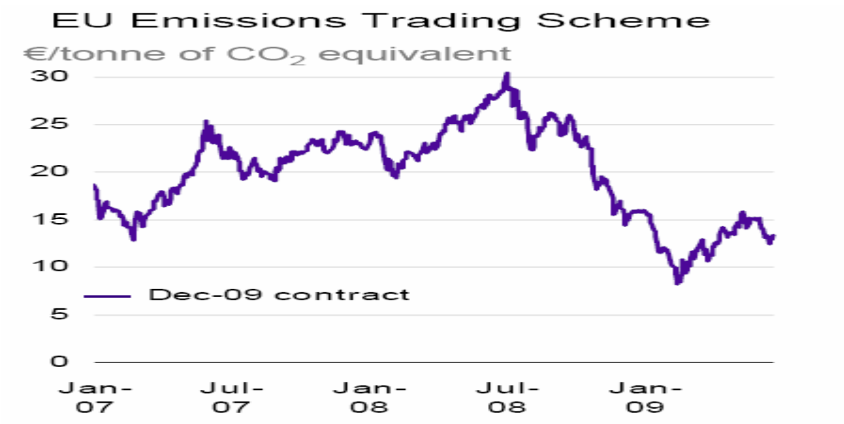


Figure 2.15 EU Emissions Trading

For Estonia, World Energy Outlook 2008 (WEO-2008) by the proposed energy development opportunities sees direct negative effects on the nation's economy, reducing the movement of goods, services, competition ability. WEO-2008 is based on plans proposed by the view that the earth's temperature has risen as a result of human activities, although it has not been scientifically proven.

It also assumes, without scientific justification, that the earth's temperature changes are only related to the quantity of greenhouse gases emitted into the atmosphere. The proposed measures are allowed under the earth's temperature increases.

2.8. Conclusions

1. Economic growth and an increasing population coupled in many countries with significant improvements in standards of living are pushing the world energy demand up. In the world energy outlook 2005, the IEA predicts that energy demand will rise by more than 50% from approximately 10,7 billion toe (2003) to approximately16,3 billion toe in 2030. Worldwide energy consumption is expected to rise by approximately 1,6% annually.
2. The main energy sources are nowadays fossil fuels (coal, gas and oil). About 85-90% of total energy and more than 66% of electrical energy used by humanity is produced from fossil fuels. About 16% of electrical energy is produced from hydro power by great hydro power plants with big water reservoirs and 16% by nuclear

power plants. The part of renewable energy sources (including hydropower plants petty water reservoirs) in energy supply is nowadays very small, only 4%.

3. The main challenges for energy policy have not changed for years:

- rapidly increasing demand for energy from the industrialization of developing countries,
- geopolitical constrains – by 2050, nearly 50% of continental oil is likely to come from the Gulf States and five producers of gas (Russia, Iran, Saudi Arabia, Qatar and the USA) will control 60% of world supply,
- different public opinions on the withdrawal from nuclear across Europe,
- the possibilities and limitations of market mechanisms,
- the relatively high cost of renewables,
- funding to safeguard security of supply.

4. The key objectives of the new energy policy should by:

- development of a security of supply strategy that clearly identifies objectives, criteria for security, mechanisms to secure and fund the necessary investments and crisis management,
- the present plethora of schemas for state-aid to favored technologies,
- support for energy technology research & development,
- support the adequate provision of infrastructure at all levels – in regulation for matters of reliability,
- promotion of the internal energy market.

5. After 50-100 years the main energy resources will be coal, oil shale and nuclear fuel, while a big part of oil and gas are produced from coal and oil shale. Coal has been used in production of liquid fuel and also in production of gas.

6. In order to use more renewable energy it is necessary previously to save it and make it controllable through saving.

7. Greenhouse gas emissions trading is a mechanism of punishment and leads the prices of energy out of competition (energy price increases) in those countries where there is no record able renewable energy resources (hydro), and it takes more energy for heating.

8. The key words for the security of energy supply are: economy, optimality and reliability.

9. Energy supply systems must be optimized perceptibly more perfectly than so far:

- The main objectives of optimization must be minimizing the consumption of non-renewable energy resources, environmental pollutions, waste and losses of energy
- The whole energy supply chain from mines to energy consumers must be optimized
- The vector optimization methods have to used.

10. All countries should begin to minimize energy consumption and pay more attention to energy efficiency.

11. Investments in the introduction of new forms of energy and in developing new technologies depend on fossil fuel price and availability of their receiving.
12. The studies of natural resources are activated and the introduction of new localities will increase.

3. ELECTRICITY CONSUMPTION AND GENERATION

3.1. Introduction

Electricity, unlike gas and water, cannot be stored. Therefore electricity supply of consumers needs the power systems (electric power systems), where power plants and consumers are electrically connected.

Power system is a technical system consisting of power plants located at a certain territory and of electrical networks connecting the power plants themselves and with consumers' appliances.For operational control the system has a system operator and the dispatching centres. A structure of power system is shown in Figure 3.1.

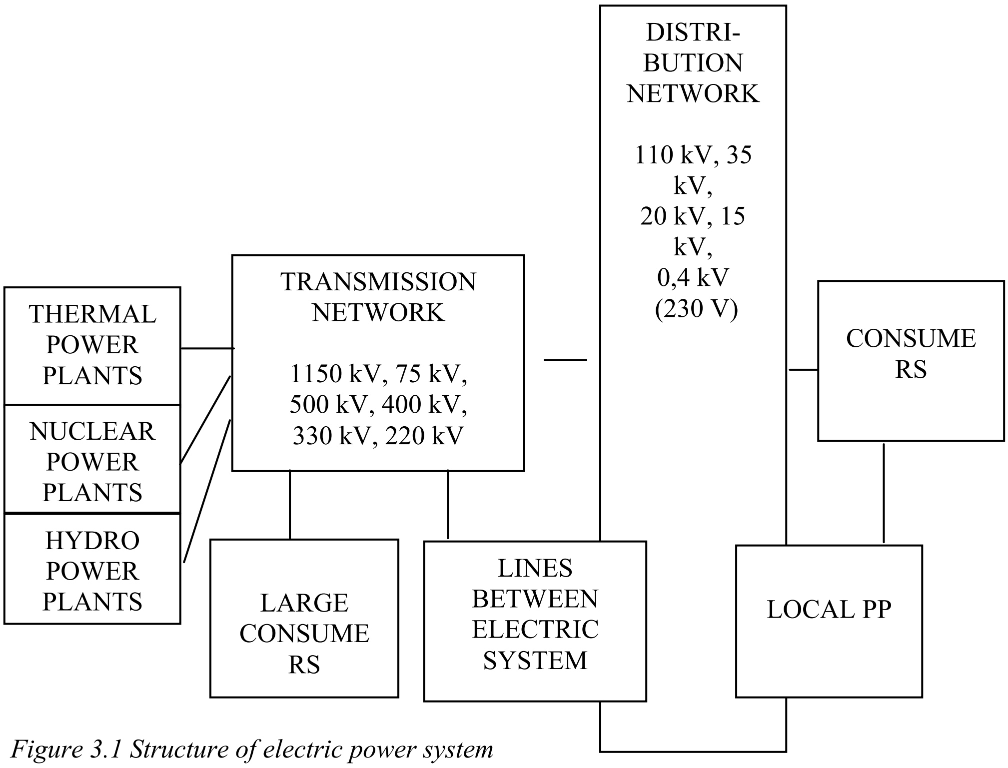


Figure 3.1 Structure of electric power system

In the power system electricity generation, transmission, distribution and consumption are taking place practically simultaneously. That is why power generation and power demand with power losses must be in equilibrium at any moment. As the load demand is continually changing it is necessary to regulate the active and reactive power generation in the power systems correspondingly.

The consumers are getting electricity from the local or national power system. The larger the power system, the greater reliability, security and efficiency it usually has. For that reason the power systems are often interconnected with neighboring power systems.

Interconnected power system consists of several power systems. The interconnected power systems may or may not have a system operator.

The basic problems of this chapter are as follows:

- Power system load and its future trends
- Main types of power plants and their suitability for power system
- Optimization of electric power generation, transmission, distribution and consumption.

3.2. Power system load

The active and reactive power loads of power system represent the random processes since they can't be forecasted exactly. For the long-term planning of energy supply it is necessary to forecast the total active power load or active power load demand curves.

The power system load is continuously changing and very complicated random process that contains different periodical components. By the speed and amplitude of changing the following three components are differentiated in power system load processes:

1. Extremely fast, irregular component with small amplitude (amplitude ±0,1-0,5% with the duration of few seconds)
2. Fast, irregular component with noticeable amplitude (amplitude ±0,5-1,5% with the duration of few minutes)
3. Slow power demand component described usually by tables and diagrams.

Power plants do not have to react to the first component, but power plants must react to the changes of slow power demand component. The second component is balanced by the automatic regulators of primary and secondary frequency and power control. For that frequency and power control reserve 5-10% is needed. The third component is changing relatively slowly, but its changes are the biggest. Within day and night the slow component is changing 40-60% of peak load value. Therefore the daily base load is 40-60% and the changing part of load is 60-40% correspondingly. [38]. Typical power system daily load curve (slow component) is presented in Figure 3.2.

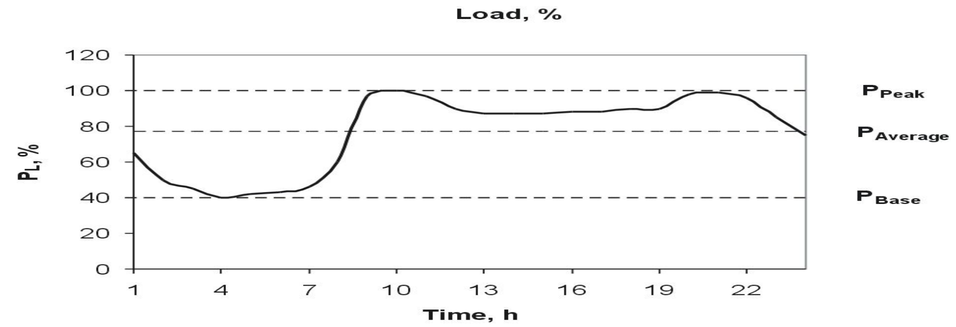


Figure 3.2 A typical daily power system load curve: P_{Base} *- daily basic load,* P_{Peak} *- peak load,* $P_{Average}$ *- average load.*

The substantial indicators of load curve are the base load (P_{base}), the peak load (P_{peak}), the average load (P_{aver}) and the following relations of indicators:

$$a = \frac{P_{Aver}}{P_{Peak}}, \quad (3.1)$$

$$b = \frac{P_{Base}}{P_{Peak}}, \quad (3.2)$$

$$c = \frac{P_{Aver} \cdot T}{P_{Peak}}, \quad (3.3)$$

Here T is the time period of the curve (h).

The daytime period is about 2-2.5 times longer than the nighttime period. The peak load hours are at 9-11 o'clock in the morning and at 20-22 o'clock in the evening.

Power system load varies through daily, week and annual cycles, creating difficult operating problems.

A weekly load curve of the power system is presented in Figure 3.3.

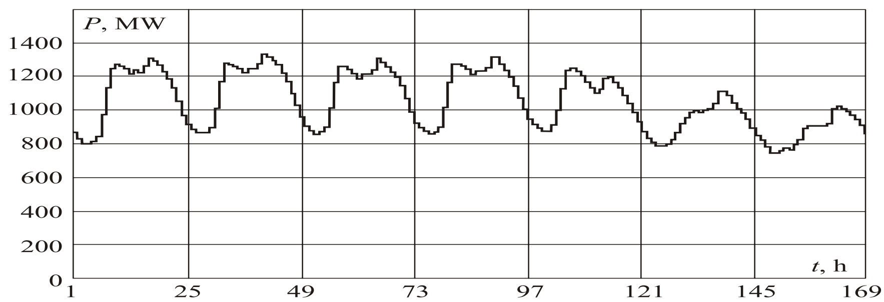


Figure 3.3 Example of a weekly power system load diagram

Annual load curve of the power system is in Figure 3.4.

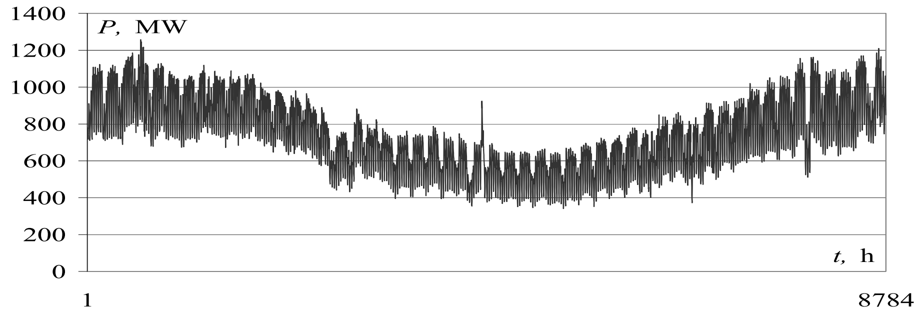


Figure 3.4 Example of a yearly power system load diagram

3.3. Long-term forecasting of load

Load curves have a random character and they can't be forecasted exactly. For approximated forecasting different methods have been developed [39]:

- Load forecast with load increase factors
- Load forecast based on economic characteristic data
- Load forecast with standardized load curves and others.

The main models of long-term forecasting are:

- Exponential model
- Linear model
- Their combinations.

In this work the exponent model [40] is used. Let suppose that the load increasing per year is proportional to the load value at present:

$$\frac{dP_L}{dt} = aP_{L0} \tag{3.4}$$

Here a is the constant of proportionality or in other words a is the per-unit load growth rate. The solution of equation (3.4) is an exponent:

$$P_{Lt} = P_{L0}e^{at} \tag{3.5}$$

Where P_{L0} is the load value at $t = 0$.

From equation (3.5) we have:

$$\frac{P_{Lt}}{P_{L0}} = e^{at} \tag{3.6}$$

From (3.6) the doubling time t_{doub} and the triple time of load growth may be calculated.

$$t_{doub} = \frac{\ln 2}{a} = \frac{0{,}693}{a}. \tag{3.7}$$

$$t_{tripl} = \frac{\ln 3}{a} = \frac{1{,}0986}{a} \qquad (3.8)$$

The doubling times t_{doub} and the tripling times t_{tripl} for different values of a are presented in Table 3.1.

Table 3.1 Doubling times t_{doub} and tripling times t_{tripl} of load P_L for different growth rates a

Growth rate a	Doubling time t_d	Tripling time t_t
0,01 (1%)	69 years	110 years
0,02 (2%)	35 years	55 years
0,03 (3%)	23 years	37 years

The world power demand is now increasing about 2-3% per year. Thus after 23-35 years the power demand will be 2 times higher and after 37-55 years 3 times higher than now.

The prognoses should be repeated after every 5 years to see if the constant of proportionality a has been changed.

By formulas (3.5)-(3.8) the electricity consumption and others indicators of power load may be approximately forecasted: curves – base load (P_{base}), peak loads (P_{peak}), average value of load (P_{aver}) and others values.

3.4. Electricity consumption

The demand for electricity grows in proportion to the national GDP growth in great countries. Energy and electricity use and GDP per capita ratios for 2025 are in Table 3.2 [41].

Table 3.2 GDP, TPES and Electricity Consumption / *Population by the country*

Country	Population (million)	GDP/Mill. US $/Pop.	TPES/ Population (toe/pop.)	TPES/ GDP (toe/ thousand 2000 US$)	Electricity consumption / population (kWh/ pop.)	CO_2/ GDP (kg CO_2/ 22000 US $)
Estonia	1,34	6,95	3,64	0,52	5890	1,63
Russian Federation	142,50	2,62	4,75	1,81	6122	4,25
Poland	38,13	5,55	2,56	0,46	3586	1,45
Finland	5,27	27,51	7,11	0,26	17178	0,46
Latvia	2,29	5,68	2,02	0,36	2876	0,62

Lithuania	3,40	5,24	2,52	0,48	3232	0,77
Hungary	10,07	6,11	2,76	0,45	3883	0,92
Ireland	4,25	31,41	3,63	0,12	6500	0,34
Denmark	5,44	32,57	3,85	0,12	6864	0,31
Germany	82,37	24,42	4,23	0,17	7175	

Primary energy consumption per unit of GDP production in Estonia is one of the largest due to our fuel balance sheet and a very small quantity of GDP, as well as the production of electricity consumption per GDP unit.

Gross Domestic Product per capita (GDP) and consumption of electricity per person is connected and the difference between the European Union Member States is the six-fold.

Developed industrialized countries are also large electricity consumers, but consumption growth is below 2%. Thus the electricity consumption in the developed countries will be doubled in 35 years and tripled in 55 years.

In developing countries the electricity consumption growth rate is 3,5% per year. It means that electricity consumption in the developing countries will be doubled in every 20 years and tripled in 31 years.

The global electricity consumption growth in the year is 2,3% (Table 3.2.), in which case the doubling time is 30 years and tripling time 48 years.

Table 3.3 World Net Electricity Consumption by Region, 2001-2025 [42]
(Billion Kilowatt-hours)

Region/Country	2001	Projections 2010	2015	2020	2025	Average Annual Percent Change, 2001-2025
Industrialized Countries						
North America	4 036	4 839	5 306	5 792	6 314	1,9
United States	3 386	4 055	4 429	4 811	5 207	1,8
Canada	500	578	630	680	728	1,6
Mexico	150	206	247	301	379	3,9
Western Europe	2 246	2 486	2 659	2 839	3 029	1,3
Industrialized Asia	1 014	1 132	1 208	1 279	1 354	1,2
Australia/N Zealand	226	262	288	314	342	1,8
Total Industrialized	7 296	8 456	9 173	9 910	10 697	1,6
EE/FSU						
Form. Soviet Union	1 397	1 666	1 862	2 044	2 202	1,9
Eastern Europe	418	515	585	662	739	2,4
Total EE/FSU	1 815	2 181	2 447	2 706	2 941	2,0
Developing Countries						
Developing Asia	2 650	3 723	4 508	5 342	6 274	3,7
China	1 237	1 856	2 322	2 825	3 410	4,3

India	554	751	896	1 053	1 216	3,3
Oth.Develop.Asia	628	797	919	1 045	1 181	2,7
Middle East	476	635	723	818	926	2,8
Africa	384	499	602	716	808	3,1
C. and S. America	668	864	1 000	1 196	1 425	3,2
Total Developing	4 179	5 721	6 833	8 072	9 434	3,5
Total World	13 290	16 358	18 453	20 688	23 072	2,3

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

The projected growth of installed electrical capacity is 3.1% with the electricity production growth of 2.3% per year.

Estimates GDP for long time and pace of development in different regions, we may plan growth of the world's electricity consumption up to 100-year run, 1.5-2% per annum. Installed capacity growth remains within the limits of 2-2,5%.

3.5. Electricity generation

Electricity can be generated from different forms of primary energy using different technologies. Most often electricity is generated at power stations by electromechanical generators, driven by heat engines, hydro turbines or wind turbines.

World electricity installed capacity by types of power plants was following (January 1, 2006):

- Conventional thermal power plants 2752,191 GW 68.59%
- Hydroelectric power plants 776,760 GW 19.36%
- Nuclear power plants 376,824 GW 9.39%
- Other generating capabilities 106,661 GW 2.66%

World total: 4012,435 GW 100 %

World production of electrical energy by types of power plants was following (2003):

- Fossil fuel power plants 66,1%
  of which:
    - Coal fuel power plants 39,8%
    - Gas fuel power plants 19,6%
    - Oil fuel power plants 6,7%
- Hydropower plants 16,1%
- Nuclear power plants 15,7%
- Other power sources 2,1%.

Over two-thirds of electrical energy is produced by fossil fuel power plants. Coal remains the dominant fuel for the world's thermal electric power plants. Coal has been the main thermal electric fuel due to its cheap price, worldwide availability, easy transport, and low-technology threshold. However, as stated above, coal's biggest drawback is the pollution emitted from its combustion. Modern gas-fired power plants are much cleaner and more efficient than their predecessors. They are also larger, cheaper to build, less polluting, and easier to switch on and off. In addition, the obtaining of permits to build gas-fired plants is usually much easier than an equivalent coal or nuclear plant for these reasons.

The fossil fuel power plants together nuclear power plants are producing over 80% of electrical energy.

The **capacity factor** (CF) of a power plant is the ratio of the actual energy output of a power plant over a period time and its maximum energy output if it had operated at installed power all time:

$$CF = \frac{W_A}{P^{Max} T} \tag{3.9}$$

Where W_A is the actual energy produced in the period T, P^{Max} - maximal capacity of the power plant.

Capacity factor varies greatly depending on the type of power plant and load curves of the power system. Capacity factor of base load power plants is relatively high (0,7-0,9) and for peak load power plants – relatively small (0,1-0,2). Average capacity factor of hydro power plants in the world was recently 0.44. Capacity factor of wind power plants is 0,15-0,35 [38].

As shown above, the daily load curve has the 3 zones: base load, intermediate load and peak load. Base load corresponds to the minimum load representing about 50% of total generation capacity required. The load of intermediate and peak loads zones are changing. Corresponding to load changes, the power plants must regulate their own power generation. Typical base load power plants are nuclear power plants. The hydro power plants with water reservoirs can cover only base load, only intermediate load, only peak load or the whole load curve. The condensing thermal power plants can cover base load or the whole load curve. Gas turbines power plants are used specially for covering the peak load. Peak load plants cover demand during the periods of highest consumption. These plants must be able to come online quickly, and because they are not used all the time, they have relatively low fixed costs but can afford high operating costs. Typically, peak load plants are gas-fired or diesel-powered generators [38].

Condensing power plants

Traditional condensing power plants are equipped with steam boilers, condensing steam turbines and generators. The main fuels used in condensing power plants are coal, oil shale, peat, gas, oil and wood. The efficiency of condensing power plant is changing depending on unit's load within the limits 30-36%.

The main combustion technologies for solid fuels:

- pulverized firing,
- fluidized bed combustion,
- under pressure Fluidized bed combustion.

The loads of generators are controllable without shut down of the units in the following intervals:

- if a solid fuel is burned – from 40-50 to 100%,
- if the gas or oil fuel is burned – from 25-30 to 100%.

The traditional condensing power plants may be operated as base load power plants or as power generation regulating power plants. The capacity factor of traditional condensing power plants is 70-90%. The condensing power plants are widely in use because their power generation is independently controllable at a certain interval. The main fuel for condensing power plants is coal.

Gas turbines are mostly used for covering the peak load of the power system and for emergency reserves. The fast start-up and shut-down of gas turbines is 2-10 min.

Cogeneration power plants

There are five types of cogeneration power plants:

- Traditional cogeneration power plants – thermal power plants equipped with steam boilers, cogeneration turbines and electric generators. Cogeneration turbines can be condensing steam turbines with automatic extractions or back-pressure turbines.
- Nuclear cogeneration power plants – nuclear power plants with cogeneration turbines
- Gas turbines power plants with heat accumulators
- Diesel power plants with heat accumulators
- Combined-cycle cogeneration power plants – cogeneration power plants where the energy conversion process based on the Brayton and Rankin cycles. These power plants have gas and steam turbines and may have also the heat accumulators. The efficiency of combined cycle is more than 50%

Cogeneration power plants are operating correspondingly to the heat load. Their changes of power generation must be regulated by the hydro power plants that have water reservoirs or by the condensing thermal power plants.

Nuclear power plants

Nuclear power plant is a thermal power plant, the main equipments of which are nuclear reactor, condensing steam turbine and generator. Nuclear power plants are the base load stations. They are not designed for continuing control of power generation. Every power unit (block) is placed in the special building and is called a nuclear power plant.

The construction of nuclear power plants requires large investments. Investment costs of nuclear power unit are approximately above 2 times higher than investment costs of an ordinary condensing power plant of equal capacity. Nuclear power plants are suitable to build to the power system, where are hydro power plants with water reservoirs or pump power plants [43].

In case of nuclear power plant the costs of future dismantling of a depreciated nuclear plant and also the risk of possible accidents has been considered. Electricity generation cost of the nuclear power plant depends essentially on the life period output of the unit.

There are five types nuclear reactors:

- Pressurized water reactor (PWR),
- Boiling water reactor (BWR),
- Pressurized heavy water reactor (PHWR),
- Light water cooled graphite reactor (LWGR), light water moderated reactor (LWR),
- Gas cooled reactor (GCR).

Nuclear power plants close to Estonia: Leningrad, Lovisa, Ignalina, Olkiluoto, Forsmark, Kalinin and Smolensk.

At the beginning of 2007, there were 435 nuclear power reactors in operation worldwide, totalling 367 GWe of generating capacity. In 2005 nuclear power supplied about 16% of the world's electricity.

Hydro power plants

Hydro energy is based on the potential energy of water, which is converted to mechanical energy by a hydro turbine. This mechanical energy in its turn is converted to electrical energy by a generator. Water is a renewable energy resource. Most hydroelectric power comes from the potential energy of dammed water driving a water turbine and generator.

Wind power plants

The wind power plants have random power inputs and outputs. Power generated by wind power plants depends on the wind speed that is a random process. For that reason the generation curves of wind power plants are random processes that are not correlated with power demand curves. If the weather is calm or the wind speed is smaller than 4-5 m/s or greater than 20m/s, the wind power plant generation is zero. Depending on weather the wind power plants may stand for several days or weeks. Because of that there must be 100% of reserves in the power system for wind power plants.

The wind power plants generation curves have to regulate as the load demand changes. In case of wind power plants it is possible to save the water resources in power systems with hydro power plants that are regulating the power generation curves of wind power plants. The research has shown that using wind power plants in the power system with only thermal power plants may give economical losses, as the thermal power plants have great controlling losses [44].

If the wind power plant generation is not regulated in the same power system, the majority of wind power plant's production goes to the other power system.

The United States is the world's largest producer of electricity, but there is rapid growth in China. The projected growth in electricity consumption until 2025 was 2,4% from energy final consumption (including China 4,3% and India 3.4%).

As indicated by Eurostat, the total power generated in EU increased by 17% during the period from 1996 to 2006. Power generation for the majority of EU countries came mostly from thermal power plants. In the years 1996–2006 power generation from thermal power stations grew by 19% in EU [41].

3.6. Prognosis of installed electricity capacity

Installed capacity of electrical layout of the world is uneven. In particular, it depends on the region's standard of living, amount of GDP and the volume of electricity consumption.

The installed capacity of electricity generation plants by type and by region is seen in Table 3.4.

Table 3.4 World Total Installed Generating Capacity by Region and Country, 2006-2030 /*Gigawats*

Year	2006	2010	2015	2020	2025	2030
Total OECD	2 250	2 433	2 566	2 682	2 834	2 956
Total non-OECD	1 176	2 160	2 453	2 808	3 151	3 496
Total World	4 004	4 593	5 019	5 490	5 985	6 452

After 2015 in non-OECD countries the installed power exceeds the installed power in OECD countries because of the differences in growth rates. The structure of electricity production is seeking to diversity as possible [45].

During the construction of new electrical capacity the diversification of fuel requirement is monitored. The Table 3.5 below shows the construction of 20 power stations in the perspective of various fuels.

Table 3.5 Electricity Generating Capacity installed different fuels in World (*Gigawats /%)*

Year	2010 GW	2010 %	2020 GW	2020 %	2030 GW	2030 %
Liquids-fired Inst. Capacity	433	9,4	404	7,4	380	5,9
Natural-Gas-Fired	1158	25,2	1356	24,7	1556	24,5
Coal-Fired city	1500	32,6	1670	30,4	2101	32,6
Nuclear	381	8,3	453	8,25	509	7,9
Hydroelectri	896	19,5	1178	21,5	1284	19,9
Wind-Power	159	3,4	319	5,8	490	7,6

Geothermal	11	0,2	14	0,3	15	0,2
Other renewable	56	1,2	96	1,8	119	1,8
Total in World (GW) 4 593	4 593	100	5 490	100	6 452	100

Worldwide installed capacity is planned to grow an average of 3.1% by 2030. The energy chain optimization, energy storage and deployment of new types of primary energy – these are the results to slow down the growth rate further.

In the structure of using fuels there are no significant changes provided in the nearest 25 years. A slight decrease trend can be seen in using of liquid fuels for power generation, and the increase of the share of nuclear energy does not aim in the near future in the long term perspective.

Coal remains in the same intensity level, and even with a slight increase. The development of perfect burning technologies is expected, which creates prerequisites for the widespread use of oil shale in electricity production in the world.

The installed generating capacity in non-OECD countries exceeds the installed generating capacity in OECD countries by 2020.

Using different fuels for power generation will increase the security of supply. Risk management is very important for the security of supply in EU. EU installed generating capacity from different fuels is shown in Table 3.6 [41].

Table 3.6 EU installed generating capacity from different fuels in 2007 *(%)*

Fuel	Coal	Natural Gas	Nuclear	Large Hydro	Fuel Oil	Wind	Biomass	Other
%	30	21	17	15	7	7	1	2

European Union Member States power structure is similar to the world's structure of electricity generation, but the difference is in the lesser use of natural gas and increased use of nuclear energy.

3.7. Generation of electrical energy by type of power plants

The world's largest producers of electricity are: the U.S., China, Japan, Russia and Germany, which produce more than half of the electricity in the world. In 2005, the distribution of electricity production of fuel types is following as presented in Table 3.7 [46]:

Table 3.7 World Net Electricity Generation by type, 2005 *(Billion KWh and per-cent)*

Country	Thermal		Hydroelectric		Nuclear		Geothermal, Solar, Wind Wood, Waste		TOTAL
	Billion kWh	%	Billion kWh	%	Billion kWh	%	Billion kWh	%	Billion kWh
United States	2 909,99	71,6	270,32	6,7	781,99	19,3	99,68	2,4	4 061,98
North America	3 242,60	66,2	657,69	13,4	879,69	18,0	119,60	2,4	4 899,58
Central and South America	254,74	28,1	611,94	67,5	16,27	1,8	24,09	2,6	907,04
Europe	1 840,80	52,5	541,33	15,4	959,82	27,4	160,44	4,6	3 502,39
Eurasia	846,38	63,6	244,73	18,4	235,83	17,7	3,12	0,2	1 330,06
Middle East	577,66	96,5	20,91	3,5	0		0,01	0,002	598,59
Africa	430,85	80,5	89,60	16,7	12,24	2,29	2,27	0,42	534,96
Asia Oceania	4 262,08	76,2	731,60	13,1	535,40	9,6	62,24	1,11	5 591,31
World Total	11 455,12	66,0	2 897,80	16,7	2 639,25	15,2	371,75	2,14	17 363,93

During the 60 year period, electricity consumption has risen about 6 times. World Energy Outlook 2006 expects worldwide production of electrical energy in 2030 33 750 TWh, roughly three-fold increase in 40 years.

As to the global electricity generation, there is an increasing demand for electricity, coupled with reduced tolerances for nuclear and hydro plants, tightening limits on air, water, and noise pollution emissions, as well as high cost for wind and solar energy. This leaves the gas-fired generation as one of the only remaining options for electrical utility companies. As the cost of fuel accounts for approximately 65% of the cost of electricity, the choice of fuel is an important decision for power plant developers [46].

Coal has been used most of all for the production of electricity and its growth continues. Use of natural gas in power generation is significantly increased (approximately 50%).

As indicated by Eurostat [41], the total power generated in the EU increased by 17% in the period from 1996 to 2006. Power generation for the majority of EU countries came mostly from thermal power plants in the years 1996– 2006, power generation from thermal power stations grew by 19% in EU, while power from hydro declined by 5%.

3.8. Future power systems and interconnected power systems

The specific character of electricity supply will be preserved also in the future. Active power generation in the future power systems must follow the power demand even more exactly. The load-frequency control has to guarantee the better quality of frequency and power flows including power changes with other power systems. Voltage and reactive power control will also improve. The new technologies and equipments will come. The power systems optimization and automation will continue in the 21st century. We will hope that after a decade the standpoint about the climate warming will be clear, that energy will not be so political area than presently and that problems of energy supply will be solved on the basis of scientific research.

The main objectives for optimal operation and development planning of electric power systems are:

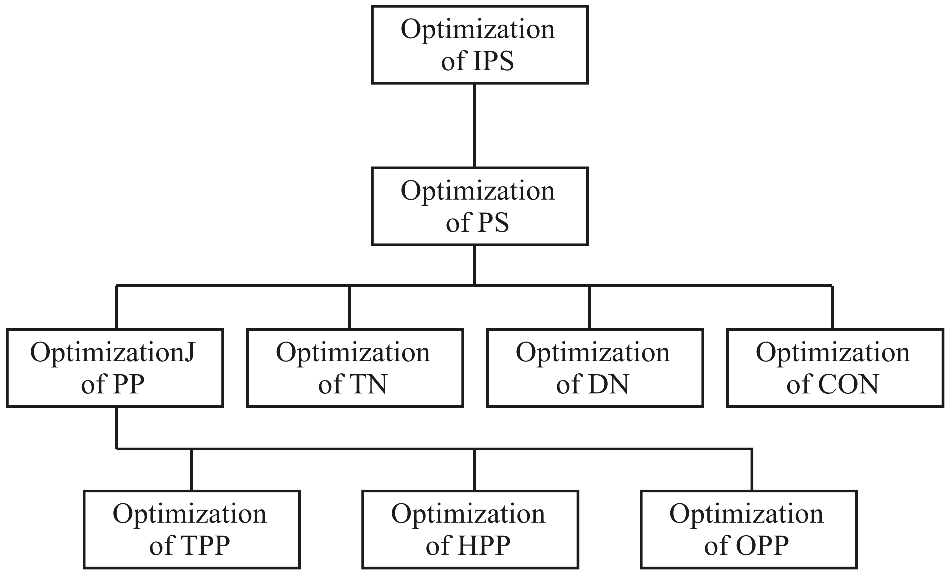
- Minimization of non-renewable primary energy cost
- Minimization of environmental pollutions and waste (CO2, SO2 and NOX emissions, fly ash and others)
- Minimization of the losses of energy
- Minimization of operation costs
- Minimization expected investments and operational costs
- Minimization of electricity consumption.

The constraints for optimization problems may be presented in the form of equations and inequalities. They must consider all others requirements that objective functions does not account. Depending of the problem of optimization the technical, reliability, safety, quality, political and other constraints have to be taken into account.

Thus the optimization of electricity supply in the large sense is a very complicated problem of the vector or multi-criterion optimization.

In order to achieve these objectives the technologies, equipment, operation of power systems and also energy consumption have to be optimized. It does not mean that all problems of electricity supply will be solved by mathematical models of optimization problems. It means that the general goal must be to try to solve the problems in a best way. But there are many problems that will be solved by mathematical models.

The hierarchy of optimization problems by objects of power system is presented in Figure 3.5.



IPS – interconnected power system, PS – power system, PP – power plants, TN – transmission network, DN – distribution network, CON – consumers, TPP – thermal power plants, HPP – hydroelectric power plants, OPP – other power plants

Figure 3.5 Hierarchy of the interconnected power system operation optimization

In addition there exists the hierarchy of optimization problems by different time horizons: seconds, minutes, hours, days, weeks, months, years [47]. Very important is the complex optimization of power systems operation [48] and taking into account the different forms of information [49].

The more perfect optimization of power systems enables to decrease the consumption of fossil and other fuels, to reduce pollution of environment and to improve other indices about 10-20%. But the effect may be also much greater. The exact estimation of available effect is impossible.

Consequently the optimizing of electricity supply from the major investments until the end-user is very important.

Economic communities have set a goal – to build a united infrastructure on their own territories, combination of electrical energy to create a single national system.

To meet this goal the European Union has a solution – the trans-European energy network programs.

The trans-European energy networks are integral to the European Union's overall energy policy objectives, including reinforcing security of supply, increasing competitiveness and protecting the environment.

The development of an integrated European internal energy market means that supplies of electricity should be better matched to demand across Europe, but a crucial element for this internal market to function efficiently is the availability of secure, reliable networks to transport energy supplies to the load centres. The trans-

European energy networks will play a significant role in increasing efficiency of energy systems, in developing additional supply routes from third countries and in increasing the proportion of energy from renewable sources within the EU as part of the strategy to respond to the challenge of climate change

3.9. Conclusions

1. The main power plants of electricity supply are the fuel burning condensing thermal power plants and hydro power plants with water reservoirs because they are able to regulate power generation corresponding to the daily load curves of power systems. The main fuels are coal, natural gas and oil. Over 66% of world electricity is generated by traditional thermal power plants and 16.1% of electrical energy is produced by hydropower plants.

2. Nuclear power plants are base load plants. The nuclear power plants are suitable to be built in the power systems with hydro power plants or pump storage power plants. If the nuclear power plant are built to the power system with only thermal power plants, the generation control problems in the system will arise.

3. Gas turbine power plants are used for covering peak loads and for emergency reserve.

4. Use of wind and solar power for generation of electricity is bounded by the fact that the changes of input power must balance the traditional power plants. For that reason the wind power plants are suitable only for the power system with hydro power plants.

5. Coal remains the dominant fuel for the electricity generation. The use of oil shale will soon increase. The future fuel will be oil shale.

6. The main strategy for developing electricity supply in every country would be:

- vector minimization of fossil fuels consumption and environmental pollutions;
- to brake the electricity consumption increasing by saving and optimisation;
- a more perfect optimisation of the power systems and its development considering long time horizon (50-70 years);
- less politics and more scientific research in the electricity supply area.

4. INNOVATION IN ENERGY SUPPLY

4.1. Introduction

The innovation is essentially the choice of a new and better road, which is reflected in the changes of thinking, economics, business, technology, engineering, organization, social sphere, society, etc ... and which will result in positive changes [50].

Activities taking place at various levels and positive changes in the society will increase capacity and ensure sustainable development. Innovation actors are individuals, organizations and countries, that is – all of us together.

Innovation is based on knowledge and skills.

Innovation as an interdisciplinary science is most closely connected with economics, technical and social sciences. Future-oriented innovation requires the function of national strategy, coordinated long-term strategic cooperation in various fields.

In R&D, the guidelines of the Frascati Manual have become de facto standard for both for collecting and analysing the research and development activities across the globe.

The latest edition Frascati Manual proposes the following basic definitions.

"Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications".

"Technological innovation activities are all of the scientific, technological, organisational, financial and commercial steps, including investments in new knowledge, which actually, or are intended to, lead to the implementation of technologically new or improved products and processes. R&D is only one of these activities and may be carried out at different phases of the innovation process."[47].
Innovation is a national economic competitiveness as the main pillars of sustainability and also in energetics. Energy technology development program (ETP) is an Estonian R & D and innovation strategy for 2007-2013 in accordance with the roadmap to energy program.

Innovation in energy is: innovating the structure of organization, prioritizing the regulatory role of the state, rooting the new technology and processes, and optimization of the whole value chain [50].

It is important to optimize generating capacities, co-operation of different types of power plants, optimize cooperation of the power systems.

Elements of the innovation must be included in the long-term energy planning, using the existing scientific potential, developing and exchanging the new knowledge. Innovation is the new knowledge in energy.

In particular the value of innovation is a positive impact on improving the quality of Estonian people's life and general well-being of society and the country's sustainable development.

Innovation is a prerequisite for the improvement of society's and the individual's quality of life [51], this is illustrated in Figure 4.1.

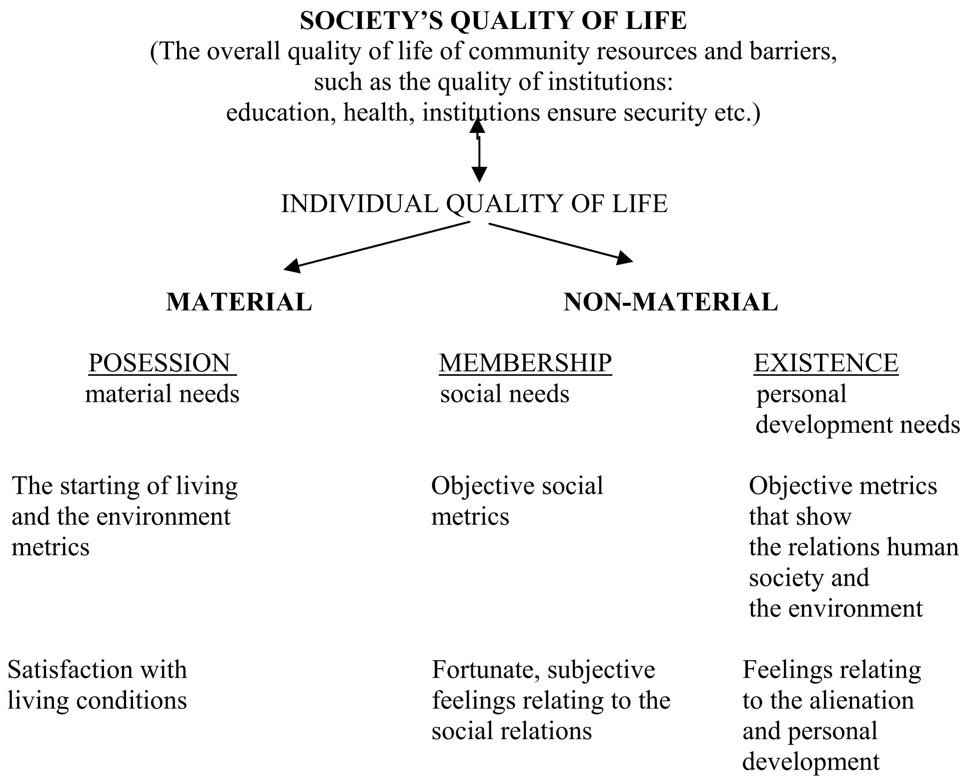


Figure 4.1 Society's quality of life

4.2. The levels of innovation

On a positive note in the development of R & D there is a relatively large share of the basic research (56%), applied research (31%) and test and development works (14%).

A high level of technological development and its complexity has increased the requirements for the quality of research. Assessment of international expertise and research quality has become very important. Globalization of the economy, global technological development and stiffer international competition, has increased the business sectors interest in the R & D.

As a whole, by assessing the costs of research, it is important to bear in mind that R & D is today a major factor in the growth of Estonia, competitiveness of Estonia's technological development in the European Union and around the world [52].

Innovation has the following expected results:

1. Individual person will have a wider view on the world, more knowledge, skills and abilities.

Indicators:

- the work contribution and work efficiency of the person are higher;
- the value of the labour force is higher;
- the functioning life-long learning system.

2. Business association will have a more competitive product or service in the market.

Indicators:

- product development and technology development has the first priority;
- the product or service conforms to the needs of the market;
- the additional value created in the company increases.

3. The state will have an increase of the economic and social welfare and a sustainable development.

Indicators:

- more active investments from abroad;
- valuing the role of research; the full linkage of research, development and business (R&D&B) is functioning;

The support structures for research, development and business are functioning. The functioning of the innovation system of the state ensures a sustainable country; the following factors are important for this:

- the members of the society must be informed and there must be a participatory democracy in action;
- the education and vocational qualification system must conform to the needs of the labour market;
- innovation must function on all levels;
- united national strategy must exist and function.

Differences between the various formations in society are important and changes are directed towards the knowledge-based society as presented in Table 4.1.

Table 4.1 The structure of the post-industrial society

Axis of society	Theoretical knowledge
The dominant technology	Information technology
Primary institutions	Universities, research institutes
Economic basis	Research-intensive industry, and information
Economic structure	Private and public sector
Primary resource	Human capital
Basic problem of politics	Research and education policy
Basis of social stratification	Education, professionalism

The possession of information which enables the transfer of technology is crucial. Various types of technology transfer are:

- material transfer – technological equipment, machines and similar imports. It must be accompanied by staff training and equipment maintenance, and most importantly – improvement, renewal;
- know-how transfer – requires a commitment to training that means cooperation between R&D institutions and enterprises.

Cooperation is ongoing, so the new know-how is available and acquired in a continuous process.

4.3. Estonian economy and innovation

Estonia's business structure is not research-intensive and in order to change this, it is essential to ensure sustainability. Investments can not be made at low volumes in the long future – this is our weakness in the private sector. The importance of scientists and engineers in business is modest [53].

Our export capacity is an indicator of the competitiveness in EU economic space. In 2008 70% of the export was in the Member States of the European Union (EUR 8.452 billion), while EU countries accounted for 80% of imports (10.870 billion EUR) [54]. The main competitive advantage for research-intensive foreign investment in the country are not receiving benefits, or a package of marketing measures, but existence with competitive price for suitable people with knowledge and skills [52]..

Foreign investment in 2008:

- Financial intermediation 34%
- Property 27%
- Manufacturing 15%
- Wholesale and retail trade 12%
- Transportation, warehousing 5%
- Construction 2%
- Electricity, gas and water supply by 2%
- The remaining 3%

Our options are:

- limited know-how and financial conditions to mobilize the transfer of technology and foreign know-how;
- participation in regional international joint projects and to involve foreign experts in our development projects;
- participation in the research and development projects at the European Union level and taking the role of leadership in priority developmental projects that are interesting for Estonia.

On the basis of Innovation Survey (European Innovation Scoreboard 2006) the countries are divided into four categories: innovation leaders, catching-up, trailing, and followers as seen in Figure 4.2 [54].

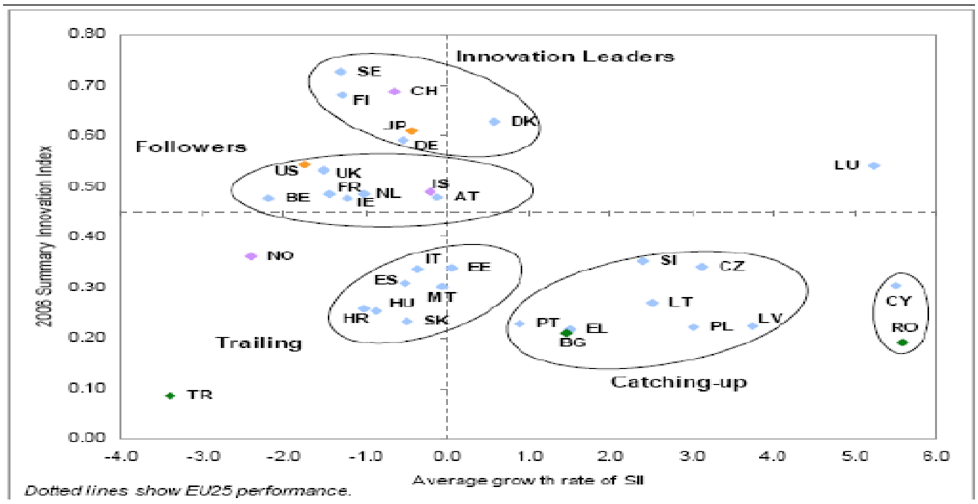


Figure 4.2 Distribution of states in the field of innovation

Each successfully functioning system, including National Innovation systems (NIS), must be self-regulating, developing and evolving.

The image of the Estonian innovation is characterized by six parameters, NIS success criteria which are pointed out in Figure 4.3 [54].

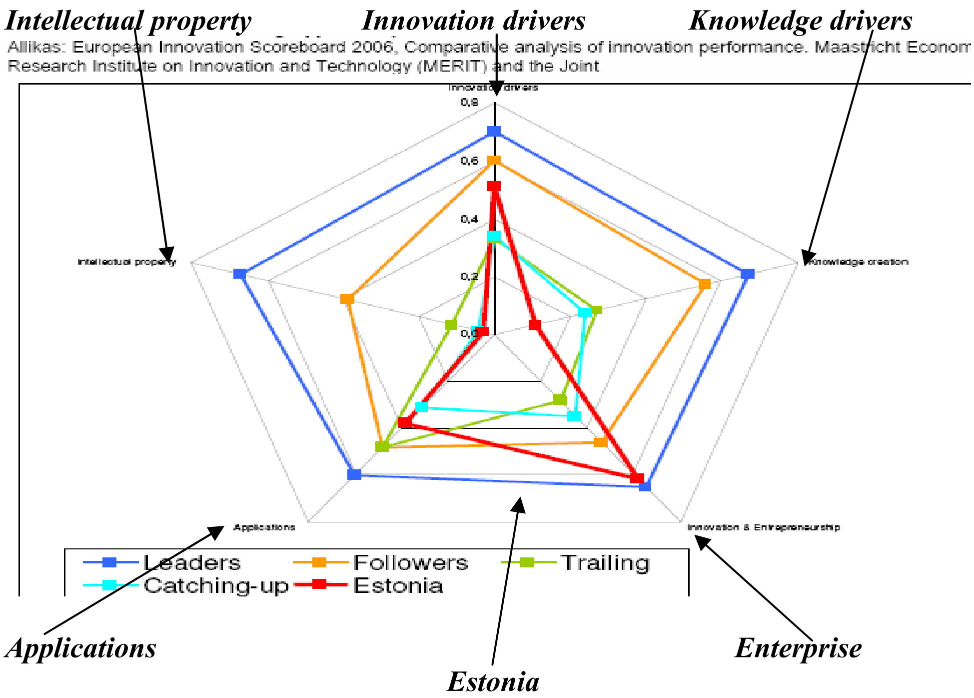


Figure 4.3 The image of the Estonian innovation

National innovation success assessment is based on Global Summary Innovation Index (GSII).

Within 50 analyzed countries in the world, this index is 0.11 (Romania) to 0.76 (Finland), Estonia has the 31st place, 0.34. EU is located in the 20th place and the average index of 25 countries is 0.50 [55].

4.4. Energy research and development opportunities

Energy science background

Estonian energy sector researchers have considerable experience in the oil shale processing and management of large infrastructure systems in the world.

Contemporary developments in energy science in Estonia began in the 1950s, when the Tallinn Polytechnic Institute developed a thermal energy (I. Öpik, A. Ots, I. Mikk) and electrical (O. Terno, L. Krumm, M. Valdma) research directions. Thermal energy focused on oil shale energy use problems and electro energetic specialists on the systems of optimal energy management issues.

The Department of Thermal Engineering Institute (formerly TPI thermal engineering department with the industrial thermal energy problems laboratory (1969-1992), Department of Electrical Power Engineering Institute (formerly TPI electrical department with the Energy Systems Cybernetics research laboratories

(1988-1992) and the Estonian Energy Research Institute (formerly the Thermal Physics and Electro physics Institute) became the main research centres.

Research in the field of thermal engineering:

- shale and other ash-rich fuels dust - burning , fluidized bed combustion (FBC) and under overpressure
- boiler steels corrosion, erosion, serviceable life
- introduction of local fuels and heat supply systems optimization.

Research in the field of power engineering:

- stochastic optimization of power plants and energy systems
- loss analysis of power networks, voltage regulation, load models
- optimal planning of energy development and use of alternative energy sources.

As the result of the Estonian scientists' work the boilers of oil shale burning in Baltic Power Station and even further, they have created a whole school of oil shale. The research in the field of electroenergetics has been invaluable: optimization techniques of power stations and energy systems under conditions of incomplete information.

Research and Competence Council (RCC) provides the following steps for helping Estonia's energy studies:

- buying in the new leaders to the investigation teams which are in the most critical stage (preferably in an international competition);
- extension of the composition of research groups in the fields related professionals in Estonia (application- mathematicians application, system-theory professionals, etc.);
- finding talented young people and sending them abroad for a doctorate;
- analysis of their views and activities , values, correction of values;
- mainstreaming the role of energy institutions and engineers, prioritizing the role of their cooperation in society;
- starting with the discussion of the principles of the social compromise (agreement).

4.5. Innovation in energetics

According to Industry Classification Benchmark in European Union information and communications technology (ICTs), bio-pharmaceutical and automotive industries, account for 2/3 of global private R&D investment. Private R&D investment by major industries is illustrated in Figure 4.4 [54].

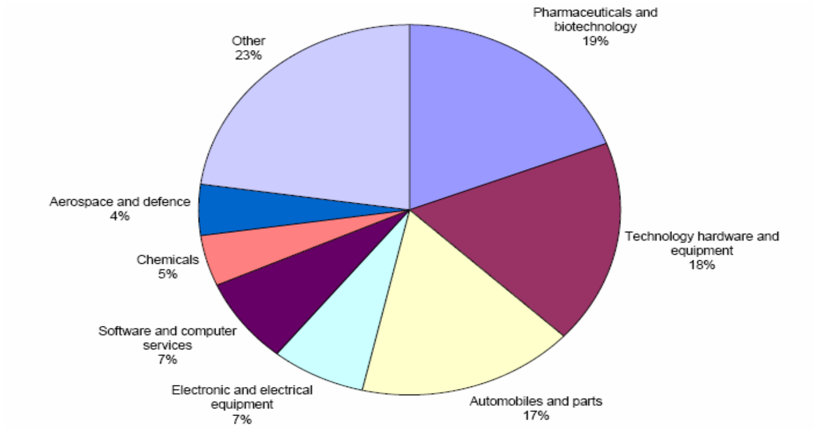


Figure 4.4 Private R&D investment by major industries in EU

The structure of intramural business R&D expenditure varies obviously from country to country depending on the presence and comparative strengths of individual industries. Nonetheless, Estonian BERD figures fit largely the above global pattern [52].

In 2007 computer related activities, manufacturing of electrical and optical equipment; and transport, storage and communication accounted for one half Estonian business sector intramural R&D investment. Financial intermediation as intrinsically ICT intensive services sector; and manufacturing of chemical products contributed also significantly. Intramural R&D expenditure in Estonian business sector is presented in Figure 4.5 [53].

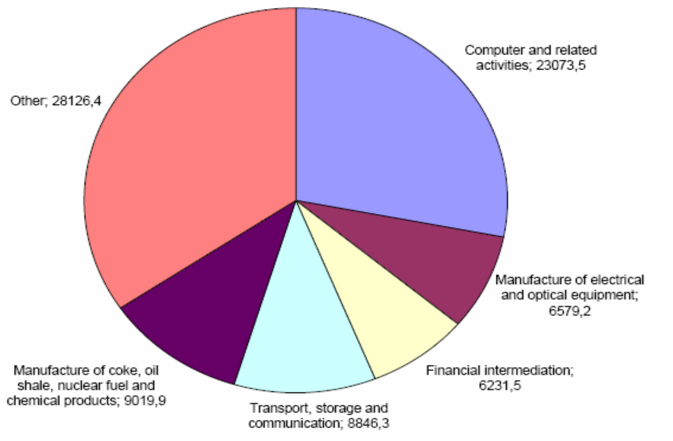


Figure 4.5 Intramural R&D expenditure in Estonian business sector, 2007, in EUR.

Thus, ensuring availability of qualified R&D personnel – especially in information and communication technologies and biotechnologies – has a crucial role to play in making the Estonia‘s aspirations reality and allowing for significant increase of business sector R&D investment.

Europe has set out to be a leader in eco-innovation and energy-efficient product. A product made in Europe has to be, terms in energy the most efficient, in terms of resources the most sustainable, in terms of technology the most advanced and in terms of safety. The emerging economies have a tremendous need for environmentally friendly, energy-efficient new products in technologies.

The innovation process planned in energy is a long-term and resource intensive and the results are affecting the economic situation of whole country.

The planning of the comprehensive innovation process in energy:

- analysis of the state,
- defining the problem,
- setting the aim,
- planning resources,
- carrying out innovation
- feedback

R & D compared to the level of investment in different types of activity we can make the conclusion of the priority directions.

Different sectors have specific outcomes and opportunities for innovation, and so there are differences in investments also as seen in Table 4.2.

Table 4.2 Financing R & D expenditure

Field of application	2000	2002	2004	2006
Expenditures Total/ thosend crowns	303 717	417 220	588 490	959 609
Agriculture, forestry, fisheries	28 595	48 345	101 085	84 050
Industry	31 529	27 019	45 889	47 765
Energy production and rational use	12 464	22 961	14 085	49 373
Development of Infrastructure	6 757	22 961	14 085	60 298
Environmental protection	19 364	27 740	31 698	60 790
Health-support	3 784	5 385	28 860	103 314
Social Affairs and Services	5495	12 076	41 435	107 587
The use of Earth and atmosphere	1 271	2 242	6 716	22 040
World room for the use of civilian	-	1 327	-	136
National defense	1 130	660	5 132	10 923
Application unspecified	193 328	249 095	281 982	413 333
Publicly funded %	80	74	71	80

Energy research and development of state funding is increased by 6 years from 46% to 64%.

4.5.1. Main directions of innovation in the field of energy

An energy strategy significantly influencing the sustainability of the country must be based on research, experience and international co-operation. All this requires stability, setting long-term goals and having a consensus in the society.

The main directions of innovation in energy are:

1. Technology and technical innovation

Development of combustion technologies, development of steam turbines with parameters over critical levels, use of shale oil and shale gas in energy production. The issues of establishing fast-start energy resources for top loads of the power supply system and as an emergency reserve need to be solved.

2. Cybernetic innovation

Cybernetic innovation in controlling technical systems in the field of energy and in planning their development; optimizing the co-operation between the energy production resources and managing energy flows in large energy systems. Preparing prognosis of energy supply according to the market demand, using mathematical models; control and management of the work parameters of connected energy systems.

3. Energy management innovation

Support structures of the State in the management and development of the field of energy – research, analysis and control institutions. Levels of freedom of the business associations in the field of energy; relations between the market economy regulation and governmental regulation.

The success of all these three directions is based on the following:

- availability of educated people and professional competence;
- long-term energy strategy based on a societal consensus.

In addition to the economic functions, the complex of fuel and energy industry also has social, regional and ethical functions [56].

Energy production and sustainable use of research and development work over the years funding levels have risen. Energy saving is becoming a living standard.

In order to plan the development strategy of energy industry, one needs a unified, complex scientific view on society. Algorithm for preparing the future prognosis.

4.5.2. Development in the future

In order to forecast the future it is most important to determinate their status, setting a goal and clarification of opportunities. This work is based on the analysis of synergy and partners, as illustrated in Figure 4.6 [57].

Discussions of the related parties and notifying the wider public about the results

Not foretelling an inevitable future, but studying how the future can go along different paths depending on the actions of the important parties and the decisions made today

Discussions about future

MONITORING THE FUTURE
Open
Involving

Shaping future

Action-oriented

Not only analyzing or weighing different future developments, but supporting the relevant parties in actively shaping the future

Figure 4.6 Prognosis of future

In planning the innovation process, it is of primary importance to have the research potential available and to involve this in the planning process. The first factor regarding research and development work in the field of energy is the needs; after that all the available resources are gathered [58].

Societal demand (incl. laws): client needs, resources (finances), conclusions and feedback. Process management in the field of energy is given in Figure 4.7.

PEOPLE, EXPERT NETWORKS, CO-OPERATION PARTNERS

MONITORING DEVELOPMENT

DEVELOPING DECIDERS

INVESTING

STUDIES AND EXPERIMENTS;

GATHERING DECIDERS;
STATING QUESTIONS;
CONDUCTING DISCUSSIONS;

DEVELOPING RISK CAPITAL MARKET;
INVESTING INTO GROWING ENTERPRISES;
PROVIDING MANAGEMENT SUPPORT;

SUPPORT PROCESS

Results and effects: results and effects, more knowledge, better decisions, more active risk capital market, more growing enterprises, richer state, richer state, better life

Figure 4.7 Process management in the field of energy

Oil shale energy will continue to be the most prospective fuel for electricity generation and oil shale chemical inputs, while the competitiveness of oil shale energy is threatened:

- the gradual increase in environmental taxes,
- deterioration in the terms of oil shale mining, nature conservation areas and restrictions on the quality of the rock-fall "sweet tracks" exhaustion,
- the proposed emissions trading system for execution.

4.6. Energy technology

Energy technology sector is one of the largest business sectors in Estonia, which ties all sectors of the economy. It includes the developers of different devices, a variety of services and products closely linked to energy providers and industrial enterprises. This area of the economy, the financial turnover of several tens of billion per year, and the labour force accounts for more than 10% of local employment [59].

Based on the competencies and the actual market demand, the focus is primarily putting on the strategic energy planning:

- optimal cooperation of generating capacity;
- oil shale technologies;
- integration of renewable energy;
- fuel cells, hydrogen energy, and micro energy.

We have reached a major technological innovation in the mining of oil shale (new techniques) if the ignition – the first circulating boiling layer-based assembly of the boiler. These measures allow to improve the production efficiency to some extent and almost avoid SO_2 emissions into the atmosphere. The efficacy of the system still remains low – given the high level of electrical fittings and losses in its networks to reach consumers where a good 25% of energy from the combustible fuel, taking into account the losses in mining. Reasons to be addressed are the following:

- due to the very high level of oil shale in the primary energy balance for the whole energy chain the efficiency is only 53%;
- consumption of electric generating capacity and the distance between the consumers is large (200 km);
- consumption is a big savings potential, especially in thermal insulation of buildings.

Energy technology development program (ETP) is an Estonian R & D and innovation strategy for 2007-2013 in accordance with the roadmap to energy program.

The wider aims in Energy Technology R & D work::

- Estonia's R & D growth of innovative capacity,

- transfer to other key economic sectors especially in industry and vital issues.

Overall goals of the Energy Technology Program (ETP):

- optimum use of the resources directed into this field;
- improving the co-operation within a sector, between the state and the private sectors;
- developing human resources and research potential;
- supporting R&D and innovation in the field; supporting technology transfer.

Relations of the Energy Technology Program to the R&D and the National Innovation System form a coherent whole. Each link is to be fixed and depends on the cooperation as seen in Figure 4.8 [59].

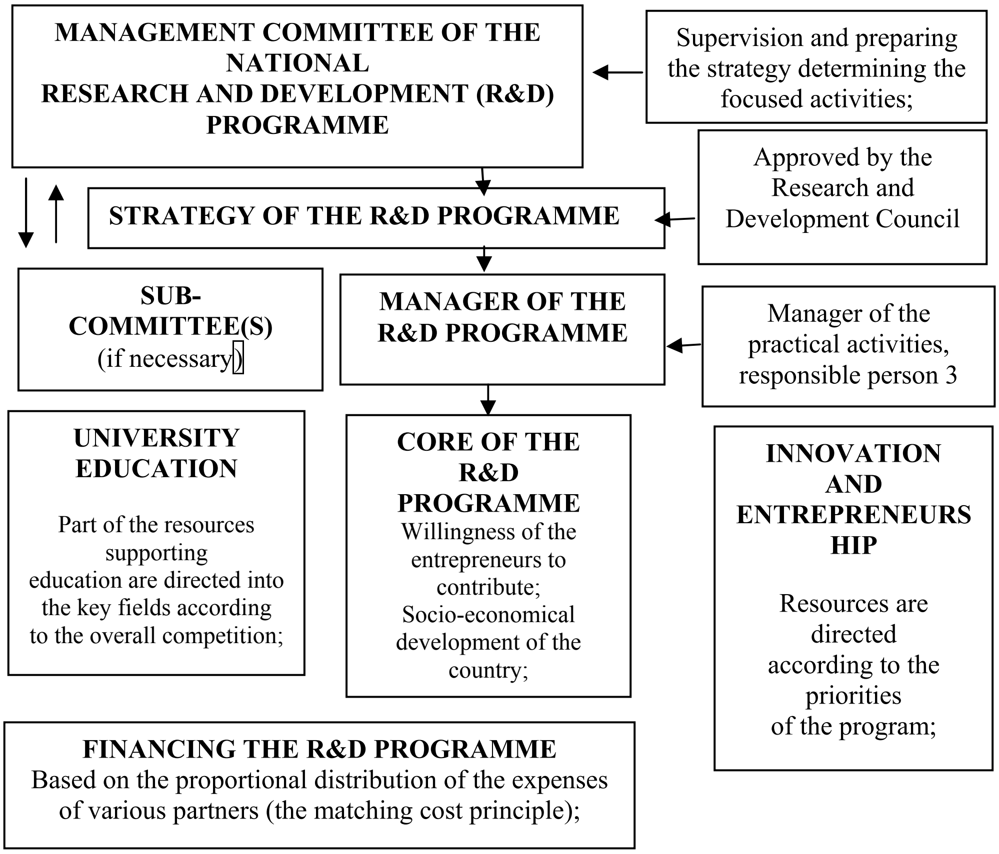


Figure 4.8 Relations of the Energy Technology Program to the R&D and the National Innovation System

Reorganizing economy to be knowledge-based is an activity that has to be supported by the energy industry. Historically there have been different reasons for establishing ways of thinking, and also different consequences [60].

Transfer tactic of knowledge and innovation has also changed together with stages of economic development.

Transition from skills-based economy to knowledge-based economy takes place in several development steps, as given in Table 4.3.

Table 4.3 Transition from skills-based economy to knowledge-based economy

1970-1980 Skills-based economy “OLD ECONOMY” Preserving existing industries	1980-1990 Competence-based economy “TRANSITION-TIME ECONOMY” Adjusting to industrial changes	1990-2000+ Knowledge-based economy “NEW ECONOMY” Establishing knowledge-based industries
FOCUS “Ability to do” Less attention towards “understanding” and personal competencies (attitudes)	FOCUS Wide-scale comprehensive competencies Increasingly more attention towards integrating technological, social and personal competencies and attitudes	FOCUS Integrating formal and informal (practice-based) knowledge and know-how Including dimensions related to business activities, technologies, social / organizational aspects and self-management
SKILLS, KNOWLEDGE, ATTITUDE SKILLED WORKER	SKILLS, KNOWLEDGE, ATTITUDE COMPETENT WORKER	SKILLS, KNOWLEDGE, ATTITUDE KNOWLEDGEABLE WORKER

Energy is a component of economic development. In the beginning of 21st century, we have big choices in energetics. Innovation is a priority, to ensure optimal operation of energy infrastructure. Innovation in energy works in level: organization, technology, infrastructure and the optimization.

4.7. Conclusions

1. The goal of innovation is a positive change, to make someone or something better. Innovation leading to increased productivity is the fundamental source of increasing wealth in an economy.

2. Innovation is an important topic in the area of R&D:
   - R&D undertaken by one firm may spill over to other firms and bring benefits to those,
   - R&D is a risky business – the return to R&D investments is inherently very uncertain and this may make it difficult for firms to obtain external financing,
   - private investment in R&D may be below the optimal level as seen from society’s viewpoint,

- the socially optimal level of R&D investment is extremely challenging to estimate,
- the government intervention in order to stimulate private R&D may be welfare enhancing. The main methods for financing R&D are direct subsidies and tax subsidies.

3. Our key is an educated man, scientist, engineer and workers and their qualification. The knowledge acquired at school, the practical skills acquired in the workplace, and the experience are a precondition for success. Civil society also calls for citizens active approach, and then must provide an opportunity for citizens to get involved in community life.
4. Innovation factors in the field of energy:

1. Prerequisites:

- gathering of the existing knowledge and material resources into a unified research and development institution of the energy industry;
- ensuring the continuity in energy-related education; transferring the experience of researchers;
- co-operation between entrepreneurs, researchers and developers.

2. Hindrances:

- a lack of capital;
- the deficit of business competence and management experience;
- the difference between the cultures of business and research worlds;
- a lack of competition.

3. Possibilities:

- helping to establish an economic output for export-capable products and services;
- gathering researchers, developers and entrepreneurs of the field;
- helping to establish a better quality of life, especially regarding the infrastructure of energy industry.

4. Innovation results:

- new formulations of problems;
- mapping of resources;
- connecting new solutions to the attitudes of the society and to the overall trend;
- establishing relations with other national and regional development strategies;
- connecting the programs of education and qualification systems;
- finding of common interests between researchers, developers and entrepreneurs;
- mapping the stakeholder organizations and signing co-operation agreements with them;

- establishing the sustainable energy industry conforming to the expectations of the society.

All this requires a smooth co-operation between the public sector, entrepreneurs and the third sector.

Renewal process is carried out with motivated people together – scientist & engineer & operator.

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5. ENERGY SUPPLY IN ESTONIA: REALITY AND PERSPECTIVES

5.1. Introduction

Estonia is a small state, member of the European Union. The territory covers 45,237 km², population – 1.34 million. Estonia regained its independence on August 20, 1991. Estonia is nearly independent supplying over 90% of its electricity needs with locally mined oil shale. Alternative energy sources such as wood, peat, biomass and others make up approximately 9% of primary energy production. Estonia is the biggest producer of electricity from oil shale. The country has large oil shale and limestone deposits.

Energy development in Estonia after 1980s is described and analyzed in this chapter. Also an introduction has been made into the general development strategy of Estonian.

5.2. Energy policy

We will analyze the process of energy policy, strategy and development in the re-independence period. The process of energy development may be divided into several stages.

An independent state energy policy started with the national awakening period in 1986-87. National structures were integrated into a single energy complex of the USSR, but the researchers, specialists began to develop sustainable energy principles of the Republic of Estonia.

I The first stage could be called as the national awakening period (1986-February 1990*). Description of this period:*

- rise of emotional activity,
- sense of the mission in the research community.

Positive results:

- On the basis of acquired knowledge the energy development plan "kW" was completed.

Summary:

1. The initiative of the Tallinn University of Technology power engineering researchers drew up the energy development plan "kW", which is also very relevant today [61].

The main conclusions of the development plan:

- energy companies must be in the Estonian SSR power field since 1990;
- create economically effectively operating businesses from the departments of energy companies;
- we need to build a national energy development program;
- develop a combined heat and power production;
- to build gas turbine stations to cover peak loads;

- support small energy, which helps to dispel the production of electricity;
- not to accept the Baltic Power Station innovative project, which is based on old technology;
- not to allow the construction of Viru Power Plant and Mine of Kuremäe;
- existing electrical capacity (power) since 2005 – 2010 is sufficient;
- in addition to internal restructuring reforms were also recommended in other Soviet republics and cooperation of electrical power engineering engineers with other Nordic countries (Balti Ring).

2. Rapid political developments enabled the creation of energy management structures in Estonia.
3. In 1939 the Baltic Countries energy congress in Riga was cancelled. In 1989 the Latvian energy specialists and their work was known in Europe before the war based on materials of the cancelled congress in 1939.
4. Division of tasks in the field of energy in Baltic States: (the prime ministers joint decision was: the coordinator of power engineering – Estonia; in gas economy – Latvia; in the field of liquid fuels – Lithuania);
5. The first air cable lines were built in Estonia under the guidance of NOKIA specialists and with their resources in 1987.

II Pre-independence period (March 1990 – Sept. 1991).

Description of this period:

- rising fuel and energy prices;
- Active External Communications (Agreements with Finland, Sweden, Russian, Latvia, Lithuania) and WB loan of heavy fuel oil;
- creation of energy national structures, planning the future.

Positive results:

- subordination of corporate change (from USSR command under the command of Estonian Republic);
- high degree of communication in business and society;
- participation of scientists in the energy management;
- cooperation with neighbours, continuation the parallel work of the electrical systems.

Summary:

1. National Energy Management was acting and a distant future plans were designed.

2. "General principles for the development of the Estonian Energy 2030", temporary research team, the general coordination of the Estonian Academy of Sciences, the National Planning Committee of ESSR, Tallinn, March 1990 [62].

Three main trends:

- create legislative base, to develop economic relations;
- functioning price and tax policy, starting energy savings;
- functioning regional energy complex, integration.

3. Estonian SSR Supreme Council of the restriction of oil shale production.
4. The National Energy Authority (16.09.1991 No 188) was established.

III Statehood reconstruction period (Oct. 1991–1992)

Description of this period:

- consumption decreased exponentially;
- oil products supply channels shut down;
- own currency was put into circulation in Estonia.

Positive results:

- money circulation was starting up, the prices of goods and services were shaping;
- the minimum fuel requirement of consumers was satisfied;
- energy savings became actual;
- Energy Council decisions were taken as the basis of energy management for Ministry Industry and Energy.

Summary:

1. The problems in the supply of oil products were giving a warning signal to the possibility of using imported fuels in general.
2. The Government of the Republic confirmed the Energy Savings Program.
3. Short-term energy development plans were drawn up.
4. Operating instructions for a shorter time horizon – "Estonian Energy Development Plan 1995" Industry and Energy Ministry (TEM) 1991; "Estonian Energy Development Plan 2005" (TEM, 1992) were drawn up based on long-term trends.

Generalized results:

- energy management restructuring, new management structure;
- separation of the production of energy from transmission;
- SC Estonian Energy transformation into national transmission network;
- setting the price mechanism for products and services of monopoly enterprises;
- technical education reform project;
- working out the basic principles of the National Energy Policy;
- substantiate the need for environmental monitoring system;
- fixing the fundamental principles of cooperation in the Baltic States;
- restructuring and privatization of energy enterprises;

- need for standards and norms.

The Baltic countries had a joint operation output:

1. "Estonia, Latvia, Lithuania, the energy policy guidelines", curated by the energy ministries of the Baltic States, Riga, 1991.
2. Founded joint power control centre Rigas “Baltija" foundation was signed in 1991 October, in Pärnu.
3. Cooperation of Finnish Ministry of Trade and Industry and the Ministry of Industry and Energy in 1991.
4. A joint Energy Group R&D was formed between Estonian Academy of Sciences and Finnish Academy of Technology.

Our common goal is:

- to switch to the trans-European energy network Nordic Gas Grid and Baltic Ring;
- to launch the first instance: Baltic electricity market and after that – the accession to the Nordic electricity market;
- participation in the Nordic research and development programs.

IV Priority of local fuels (1993 – April 1995).

Description of this period:

- privatization, return,
- state guaranteed loans for local fuel use,
- preparing a loan project structures.

Positive results:

- mitigate the shortage of money, good relationships with banks,
- the use of foreign money for training our people.

Summary:

1. 2 billion EEK of the loan money to develop the use of local fuel fired .
2. There was established a price commission consisting of representatives of producers and consumers, regulated prices for electricity and oil shale.
3. National control bodies (Electrical Control Centre and Technical Supervision Authority) were established.
4. Baltic Energy Conference, Gdansk, in 1994.

Result: the Estonian-Finnish submarine cable is part of the Baltic Sea interconnected electrical system.

5. Energy Council of scientists, energy specialists was founded.

V Preparations for a market economy, period (April 1995 – August 1998).

Description of this period:

- the completion and enforcement of legislation,
- thermal energy companies were given under the command of local municipalities,

- restructuring of oil shale energy companies, participation in co-operation structures.

Positive results:

- internationally accepted business,
- local government decision-making.

Summary:

1. The Agreement of Association (1995) between the Republic of Estonia and the European Union was signed. *Basic requirements:*
   - equipment, processes, compliance with technical requirements;
   - necessary activities needed to open the fuel and energy market;
   - the natural monopoly market supervision and technical control system
2. The Parliament approved Energy Act (1997) [63].

Energy act established the direction and implementation of energy policy;

3. The Parliament approved the fuel and energy sector long-term National Development Plan (1998). [64] *Purpose:*
   - Fuel and energy market development prognosis, including the planning of primary energy balance until 2005–2010;
   - Action planning to optimize power system operation and development, minimization of environmental pollution.
4. The Parliament ratified the European Energy Charter. [65]
5. "Energy and the International Development Research Program until 2000" ("Energy 2000") was prepared; TEM, 1995 [66].

"Energy 2000" was the joint work of energy researchers. Unity of purposes is expressed by the membership of working teams from different development agencies and the representatives of various traditional research directions.

The program was aimed at:

- creating a complex system of development projects;
- development of policies for financing the system;
- creating the preconditions for co-operation with research and development programs of other countries.

Unfortunately, the program has not achieved the objectives set in “Energy 2000” as:

- research and development activities are caught in the squeeze of commercial activity,
- impartial, reasoned recommendations are not needed (Estonian Energy Research Institute of the Ministry of Economy declines the consultation of Energy Council),
- we are not able to create concentrated destination resources,
- Energy Development Fund will remain creating,

- Energy savings Trust Fund has become non-existent.

Reasons for the insufficient state budget are convincing, but here I see a clear rear view. A wider circle of experts, interest groups are needed for the development of energetics. In order to map the potential of Baltic countries, we conducted a research in the Baltic Energy Committee. Three Baltic countries have a considerable scientific potential on the European scale, it is necessary to use it.

In conclusion, I suggest the following:

- consensus of scientists, politicians and businessmen is essential, the suitable form for this would be a National Energy Board;
- create preconditions for participation in international development projects;
- management system and further development of oil shale burning knowledge;
- the implementation of long-term energy development plan (according to the Energy Act, requires a review in the Parliament) requires drawing up action plans and finances covered by national programs;
- system of technical education requires analysis and organization;
- popularization of engineering science;
- scientific and technological development need the support of national development centres, research topics.

6. Restructuring and partial privatization of SC Estonian Energy and SE Estonian Oil Shale.
7. Organizational changes:
7.1. State Energy Board and the position of Minister of Energy were abolished.
7.2. Energy Market Inspection was established.
8. Thermal energy companies were given under the command of local municipalities (Tallinna Soojus 1996).
9. Negotiations started with NRG Energy.
10. Estonian membership was restored in the World Energy Congress (WEC).
11. Cooperation agreements with Baltic Sea region countries, the Baltic countries energy ministers of the European Commission and the joint statement called screening process of the European Union Energy Directorate.

VI Oil Shale Energy development, period (October 1998– March 2003)
Description of this period:

- double-action decision of Parliament and the difference of Government activity;
- electricity market management was changed according to the NRG energy requirements;
- decisions on oil shale energy-status [67].

Positive results:

- creating the opportunity for using oil shale as fuel

Summary:

1. The Baltic Sea Region Council of Minister Power Engineering started the systematic work in 1998 in four sub-groups:

- climate change (Kyoto Protocol),
- energy efficiency (energy saving, environmental pollution – sustainable development),
- natural gas supply (supply, the gas network),
- power supply (including the Baltic Ring, the electricity market).

Electrical Equipment Group headed by Ministry of Economic Affairs (1999-2000), together with Norwegian Oil and Water Resources Ministry.

Main tasks of the working group:

- "Baltic Ring" project realization, possibilities of the process,
- preconditions to start the creation of a common electricity market,
- necessary coordination of legislation and harmonization in the direction of EU,
- planning the bridges of power transmission, optimization of regional power system,
- diversification of energy carriers' financial planning schemes,
- development of the mechanisms that stimulate the use of renewable energy sources,
- mutual training and consultation.

2. Working project for creating the Baltic electricity market, 1999 April, Pärnu

Baltic energy strategy was discussed extensively in the WEC plenary session in 1997 and at the General Assembly in the Polish Academy of Sciences.

The objective for creating a Baltic electricity market:

- to increase the number of competing power producers;
- allowing consumers freedom of choice of electricity suppliers;
- harmonization of the basic documents, the creation of uniform rules of the game in the Baltic States;
- fixing the working relationship with the Russian power system;
- adapting to the electricity trade, to join the Nordic and Baltic States free electricity market.

3. At the request of NRG Energy the legislation of the Republic of Estonia was changed.

4. Negotiations with NRG Energy were ended.

5. Electricity Market Law was adopted (March 2003) [68].

6. The concept of "Electricity generation and development of the National Electricity system" was prepared.

VII Stable development, period (April 2003 – March 2007)

Description of this period:

- protection of oil shale energy production. Large scale investment projects, stable economic growth.
- Adaptation of the legal regulation with the existing situation.

Positive results:

- an updated technology in shale stations. International interest in the use of oil shale;
- the State increases its interest in company's activities.

Summary:

1. CO_2 successful sales period created the illusion of prosperity.
2. Innovation in oil shale burning technology created new opportunities to produce oil shale electricity.
3. Estonia's power system found an output in Nortpool market area.

VIII Goals plurality, period (April 2007 until presently)

Description of this period:

- financial and economic crisis. Fuel and energy prices rising fast
- adoption of the EU Climate and Energy package

Positive results:

- search for using new energy sources,
- priority in free market and environmental issues

Summary:

1. Party programs are quite similar but the output is different and unsystematic.
2. The supplier has not "seen", the fuel and energy is at the heart of debates.
3. The aim is to produce, but not reduce the intensity of energy component in the prices of goods and services.
4. Shaping energy policy using the scientific justifications was replaced with discussions and emotions.

General conclusions:

1. Strategic decisions are not based on the continuity requirements.
2. Policy agenda of political parties has led to inconsistent energy policy.
3. Scientific expertise has not preceded the adoption of the decisions.
4. Society's opinion, including the opinion of the scientific community has been systematically ignored.

5. Social consensus and fixing the starting positions are needed for shaping long-term energy policy.

5.2.1 The results of energy policy 1990-2010

During the period of independence in Estonia 3 national energy strategy and several development plans have been drawn up as shown in Table 5.1.

Table 5.1 Energy development stages in the newly independent

Positive result	Negative result
State regulation of oil shale and electricity price (Price Commission was set up in 22.04.1994 – organised by the Minister of Economic Affairs)	Fast rise of the prices of fuels and energy
The use of national scientific potential in drawing up development plans of energy	Revealed the difference between science and business ethics
Starting the regional co-operation (the Nordic and the Baltic States)	In competence of politicians and their ambitions caused energy strategy consistent operation
Involvement in the energy projects of international financial institutions (WB, EBRD, NIB)	Foreign consulting firms have too many rights to make decisions – the limited use of debt finance area. The mainstreaming of local fuels
Participation of energy scientists in solving national tasks (the International Energy Development and Research Program "Energy 2000", the energy working group of the Estonian Academy of Sciences and the Finnish Academy of Engineering , justification of the harm of the privatization of the power plants)	Liquidation of research institutions (Energy Institute) and national research organization of the reforms did not allow for energy research and development projects to be implemented. There was a gap between the right hand "place clean" policy and a knowledge-based mode of thinking
The development and adoption of the primary regulation of the Energy Act (RTI 1997,53,833)	The gap between the fuel and energy long-term national development plan confirmed in the Parliament and the laws and decisions of energy policy of the Government of the Republic
Adopting the declarations of sovereignty Significant rise of responsibility for all levels of management	Adoption of declarations took place in the Baltic countries at different times. Active pressure of national forces provoked a reaction – InterFront
Development experience of its own national energy policy acquired	Public decisions are based on the day-to-day policy but often ignore the opinion of the society and scientific rationale.

Energy policy will ensure the sustainability of the country:

- energy policy has been drawn up by consensus and passed the scientific expertise;
- in the energy and fuel market all the market participants have equal requirements for participation;
- implications of decisions of the energy policy are long-term;
- R & D and educational policy fosters innovation in energetic.

5.3. The current status of Estonian energy

Due to the rapid economical development in 2000–2007 the final energy consumption increased by 28%, real GDP grew by nearly 71%.

In Gross Domestic Production (GDP) the energy intensity (primary energy supply ratio to GDP) Estonia is in constant decline trend, but nevertheless it is still 2,1 times higher than the EU average. Estonia is holding 76th place in the world and 24th place in the European Union. Estonian local fuel accounts for 73,3% of primary energy and 95,5% of electricity received from the combustion of oil shale (Tab. 5.1). The other side of the coin is the over-dependence on oil shale and "ecological imprint" of oil shale industry [69]. Energy efficiency indicators are seen in Table 5.2.

Table 5.2 Energy efficiency indicators by Years

	1999	2001	2003	2005	2007	2008
Electricity generated by renewable energy sources, %	0	0.1	0.6	1.3	1.5	2.1
Share of renewable energy in primary energy production, %	17.1	17.0	16.5	17.2	16.4	17.2
Share of renewable energy in gross inland consumption, %	10.8	11.2	12.6	12.9	12.8	13.5
Production of primary energy per capita, GJ	90.6	96.8	120.0	119.3	134.8	130.8
Supply of primary energy per capita, GJ	143.4	147.1	157.5	159.4	173.1	167.1
Production electricity per capita, MWh	6.0	6.2	7.4	7.4	8.9	7.7
Import per capita, GJ	56.4	58.1	57.5	59.0	70.9	62.9
Share of CHP in total electricity production, %			10.6	10.2	7.1	8.6
Energy intensity of the economy, GJ per million EEK	2251.	1936.	1772.	1520.	1395.	1396.
Energy dependency, %	35.7	33.6	27.8	27.6	26.9	26.7

The use of low efficiency primary energy is due to low characteristics of oil shale (the ratio of final energy consumption to used primary energy is only 53%).

5.3.1 Short description of Estonian Energy

The most essential domestic energy resources are oil shale, peat and wood. The domestic fuels are dominant to meet the need for energy. The main imported fuels are fuel oils, motor fuels and gas. Estonian enterprises export shale oil, peat briquettes, wood pellets and electricity. Share of solid fuels is decreasing, as well as the use of heat as presented in Table 5.3.

Table 5.3 Final energy consumption* by year, indicator and type of energy

Year	Energy total	Solid Fuels **		Liquid Fuels***		Gaseous Fuels****		Electricity		Heat	
1960	60796	23299	38	22524	37	1193	2	4353	7	9427	16
1965	101852	28571	28	34847	34	9382	9	7288	7	21764	22
1970	133763	28826	21	44287	33	10212	8	10648	8	39790	30
1975	157930	25693	16	54153	34	10188	7	15146	10	52750	37
1980	187711	26002	14	62287	33	10532	6	19805	10	69085	37
1985	207047	25791	12	68139	33	10049	5	23778	12	79290	38
1990	213436	21689	10	66071	31	9504	5	26277	12	89895	42
1992	136873	14982	11	34266	25	5789	4	21298	16	60538	44
1994	114931	13373	12	36073	31	4910	4	18594	16	41981	37
1996	114162	24185	21	29012	25	3988	4	17382	15	39595	35
1998	105386	19830	19	29493	28	4171	4	18299	17	33593	32
2000	90998	18018	20	20730	23	5040	5	17897	20	29313	32
2001	102370	18742	18	28393	28	5576	5	18490	18	31169	31
2002	104286	16732	16	32656	31	4419	5	18979	18	31500	30
2003	109066	17783	16	34503	32	5998	5	20061	19	30771	28
2004	113580	18094	16	35813	31	6540	6	21212	19	31921	28
2005	114870	16814	15	37217	32	6942	6	21680	19	32217	28
2006	117015	16478	14	38188	33	7255	6	23302	20	31792	27
2007	129063	24318	19	41122	32	8101	6	24395	19	31127	24
2008	122284	22878	19	37887	31	8377	7	24859	20	28283	23

* *Excluding consumption of fuels for non-energy use, losses in transport, preservation and distribution.*

Type of energy
*Solid fuels***
***Coal, coke, oil shale, peat, firewood, wood chips, wood waste.*

Type of energy
*Liquid fuels****
****Heavy fuel oil, light fuel oil, motor fuels*

Type of energy
*Gaseous fuels******

Supply of primary energy by energy carriers is the numerical data seen in Table 5.4.

Table 5.4 Supply of primary energy (2008)/ *Terajoules*

	Coal	Oil shale	Peat	Wood	Natural Gas	Fuel oil	Motor fuels	Others	Total fuels
Tj	4477	139324	3564	25020	32668	11856	35296	82	252287
%	1,77	55,3	1,4	9,9	12,9	4,7	14	0,03	100

Domestic resources of fossil fuel are sufficiently large for covering the domestic energy needs in the next decades. In recent years more attention is paid to the utilization of alternative incl. renewable energy resources.

There are unique and long term experiences in oil shale processing and utilization for energy purposes in Estonia. The two largest oil-shale fired power plants produce the major part of electricity in Estonia.

District heating systems are dominant for heating the buildings. District heating is organized by municipalities. Electrical power produced in 2008, 10 581 GWh.

Electricity generation from different fuels is presented in Table 5.5.

Table 5.5 Electricity generation from different fuels/ *Terajoules*

	Oil shale	Peat	Wood	Natural gas	Fuel oil	Motor fuels	Others	Total fuels
Tj	94583	64	52	1813	362	5	2231	99110
%	95,45	0,064	0,052	1,81	0,37	0,004	2,25	100

Heat production from different fuels is presented in Table 5.6.

Table 5.6 Heat production from different fuels/ *Terajoules*

	Coal	Oil shale	Peat	Wood	Natural gas	Fuel oil	Motor fuels	Others	Total fuels
Tj	144	5154	1687	8216	17513	3801	1	2710	39229
%	0,37	13,1	4,3	20,9	47,72	9,76		6,91	100

Estonia, together with other Baltic power systems are only EU countries that belong to synchronous zone of IPS/UPS of Russia. Estonia is interconnected with Russia and Latvia via five 330 kv links. Since the end 2006, Estonia has made interconnection available with Finland via HVDC submarine cable Estlink 1, which made it possible for energy market participants to enter the Nordic energy market. It is decided that there will be a second interconnection with Finland via Estlink 2 and it should operate by year 2013.

Estonian electricity system is highly integrated with other electricity systems as seen in Table 5.7. It is necessary to build interconnections even more intensively in the future.

Table 5.7 Electricity balance sheet by Indicator and Year

	1960	1970	1980	1990	2000	2002	2004	2006	2008
Gross produc-tion	1950	11575	18898	17181	8513	8527	10304	9731	10581
Net produc-tion	1771	10383	17163	15448	7591	7634	9232	8728	9498
Own									

use by power plant	179	1192	1735	1733	922	892	1072	1003	1083
Losses	140	477	960	1147	1240	1258	1112	1077	1130
Export	560	7559	11073	8477	1303	1102	2141	1001	2310
…to Russia			5715	4959	374	396	713		
…to Latvia			5358	3518	929	706	1428	797	572
…to Lithuania								204	0
…to Finland								0	1738
Imports	123	608	370	1475	374	412	347	251	1369
…from Russia			198	1352	138	76			
…from Latvia			172	123	116	200	297	152	83
…from Lithuania					120	136	50	99	1207
…from Finland									79
Consumption	1194	2955	5500	7299	5422	5686	6326	6901	7427

Loads of Estonian power plants are different based on the cost of production. Estonia's power plant's load is significantly higher than in the Baltic power station. Distribution of the production in Estonian power plants is seen in Table 5.8.

Table 5.8 Distribution of the production

Power station	Power (MW)	Distribution of the production (%)	Other production
Estonia	1615	76	135 thousand/t oil shale
Baltic	765	20	40 mill/ nm^3 Generatorgas

The structure of electricity production in the Baltic region is relatively good as presented in Table 5.9.

Table 5.9 The structure of electricity production in the Baltic region

State	Production TWh	Consumption	Main fuel	% of the main fuel	as %	Others %
Finland	82	87	mix			
Lithuania	14	12	nuclear	70	23	hydro 7
Estonia	10	9	oil shale	94	3	3
Latvia	5	7	hydro	66	33	1

Structure of the electricity production and the proposed changes in Baltic States is given in Table 5.10. Oil shale is a low level of use, and the emphasis is – teamwork between the countries.

Table 5.10 Structure of the electricity production in year 2009 and 2016 in the Baltic region

	Core %	Oil shale %	Gas %	Hydro %
Today (2009)	34	33	19	14
Year 2016	54- gas,	13	19	14

Because of closing the Ignalina Nuclear power plant and stringent limits on air pollution, and because Estonia can not generate sufficient capacity in hours, the Baltic electricity market will become short of supply since 2016. Extension of the generating capacities needs optimization of investments. Strengths, weaknesses, opportunities and threats of the Estonian electricity are described in Table 5.11.

Table 5.11 Analysis of the Estonian electricity sector

Strengths	1. Strong electrical connections with Latvia and Russia, and Finland 2. A strong and well-developed transmission system 3. The current level of capacity will ensure supply of electricity at any given time 4. Effective cooperation between transmission system operators in the Baltic States and Finland 5. Transparent and orderly market regulation
Weaknesses	1. A small electricity market with few suppliers. 2. Age of electricity plants is very high 3. Concentration of electricity production in one region 4. Oil shale stations have a major environmental impact, the importance of oil shale is very large in electricity production 5. Low technical quality of the distribution networks 6. Level of aid of renewable and cogeneration electricity insufficient justification 7. Weak and non-transparent price signals for investment in new generation capacity 8. Inadequate electrical connections in the Baltic region and the rest

	of the EU Member States
Opportunities	The market participants interest to develop electricity market and invest in it Create a varied and balanced power system in a relatively short period of time Reasonably, increase the use of renewable energy Increase output of cogeneration electricity 5. Establish stations to cover peak load for domestic fuel
Threats	1. Production capacity can be inadequate from the year 2016 2. From Russia, the electricity with *dumping* elements can be a dominant position in electricity 3. Negative impact of emission trade on the energy balance 4. Possible increase of electricity prices with the opening of the electricity market The possibility of large-scale network failures, and/or flow interruption 6. Overload in Russia's electricity transmission system may affect the functioning of electricity market.

5.4 Optimal energy strategy

5.4.1. Optimal strategy of power system development

Oil shale is only local energy resoyrce of what it is possible to produce electricity and oil in the great quantities. This is a strategic mineral wealth of Estonia, that consumption must be economical for the long-term future.

Optimal strategy of oil shale consumption

Optimal strategy of oil shale industry enact the state. The goal of the strategy is:

- To regulate the oil shale mining and consumption for electricity, oil, gas and others matters
- To develop the mining and reworks technologies, minimizing losses and environmental influences and optimizing the shutings of old mines and the openings of the new mines.

Optimal strategy of power system development

Installed capacities of electricity generation were in 2009 the followings []:

- Narva PP - 2000MW
- Cogeneration PP - 302MW
- Wind PP - 115MW
- Hydro PP - 4MW.

Production of electricity in 2008:

- From oil shale >91%
- From gas 4%
- From hydro and wind power 1,5%

Consumption of electricity will increase 2-3% per year (Doubling time 23-35 years).

Estonian power system consists really only of thermal power plants. Optimal way for developing the electricity generation is:

- To bild correspondingly to case of need the new oil shale power units with clear combustion technology. The power unit's capacity must be increased from 200 MW to 300-400MW.
- To bild the gas turbine power plants for covering peak loads and emergency reserves.
- To bild the cogeneration power plants that are profitables. .

The important optimization problems for Estonia are:

- Optimization of thermal power plants operation []
- Optimization of load distribution between power plants of Estonian power systttemmm
- Optimization of load distribution between neighbour power systems in the interconnected power system
- Optimal unit commitment
- Optimization reserves.

The main objectives of optimization must be minimization the fossil fuels consumption and pollutions of carbon dioxide at the same time.

The mathematical model of optimization has the following form:

$$\min\left(B(P), S_{CO2}(P)\right) \tag{5.1}$$

Subject to the constraints

$$G(P, X) = 0 \tag{5.2}$$

$$H(P, X) \leq 0, \tag{5-3}$$

Where

B – total input of power unit

P – output vector of power units

S – emissions of power unit

G – vector-function of equations

H – vector-function of enequalities

X – vector of non-controllable variables.

The main methods used in vector optimization are the optimal principle of Pareto and the criterion of Hurwitzs.

Analogically the methods of vector optimization must be used in optimal planning of power system development.

Energy strategy planning is based on

- long-term, sustainable, optimal need of performance;
- balanced interplay of all components;
- planning activities carried out under the hypothesis of incomplete information;
- dynamism of investment in a changing environment.

The primary requirements for energy are:

- sustainable operation,
- ongoing supply with optimal prices.

The roads of the supply for ensuring security are:

- diversity of primary energy balance, the use of different fuels;
- optimization of fuels logistics, long-term contracts and the use of different suppliers,
- creating fuel reserves;
- outsourcing of the energy production and fuel terminals;
- independence of fuel and energy supply, preference of domestic fuels and energy;
- it is necessary to optimize the security of political stability, the plurality of suppliers, manufacturers and the delivery channels and producers;
- the optimal functioning of the whole system, using the best technologies;
- improving the state regulations, promotion of the market economy.

5.4.2. Short term development

The structure of electricity generation until 2025 is planned as follows [70]: Cleaning equipment will be installed on old oil shale boilers in 2011-2013 and oil shale boilers without renovation will be closed in 2016.

Intensity of wind farms is growing rapidly since 2012. In 2013 an emergency power plant and big low power plants are planned to be built.

Power adjusters will become very important in the existence of electrical system, especially in compensating the wind energy.

In 2022 nuclear plant is scheduled to become operational. Net power development in Estonian electricity in 2010-2025 is illustrated in Figure 5.1.

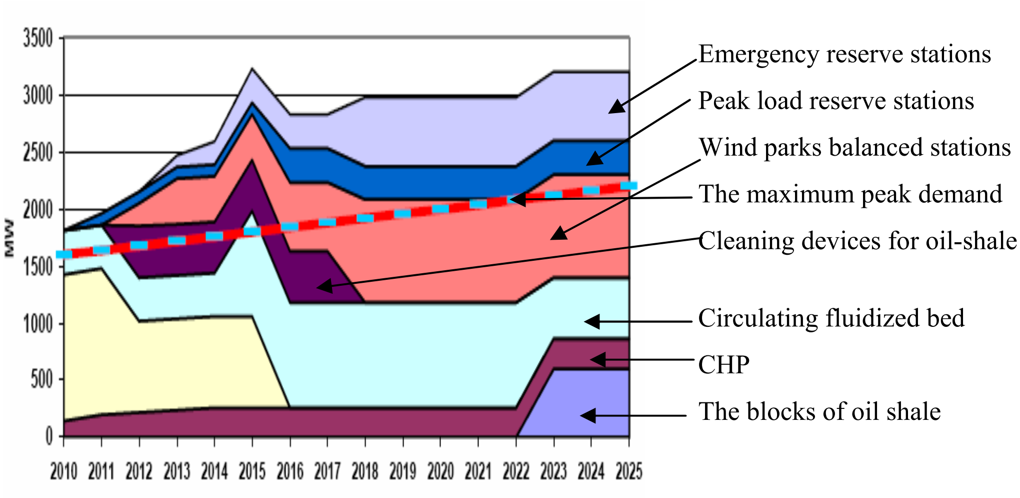

Figure 5.1. Net power development in Estonian electricity in 2010-2025

5.5. Energy restructuring

The European Union's fundamental principles of energy, the three basic conditions:

1. Separate from the vertically integrated company undertaking a natural monopoly status of the networking of all the other competition under the authority of the business.

Unbundling the utility system into generation, transmission and distribution components (Functional unbundling or ownership unbundling).

The network of state regulation, transparency and accessibility of public-service uniform is available to all network users.

2. Electricity and gas transmission must act on the basis of EU uniform rules under the direction of independent system operator (TSO – Transmission System Operator, or ISO Independent System Operator) and market operator (MO) under the control of market operator.

3. Organizing the competitive market for producers, buyers, dealers.
Exchange, the seller is an indicator of consumer initiative.

An indicator is the exchange of the seller of the competitive market. [71]:

In the organization of work the main attention has been directed to a transmission system operator (TSO)

1. Administrative functions of the energy market (Bilateral and multilateral contracts):

1.1. Market monitoring and ensuring equal terms to participants;

1.2. Creating the best conditions for the development of market;

2. Functions of networking service;

3. Investments in transmission facilities;

Electricity market regulation from Electricity Market Operator (MO) and Transmission System Operator (TSO) is illustrated in Figure 5.2 [72]:

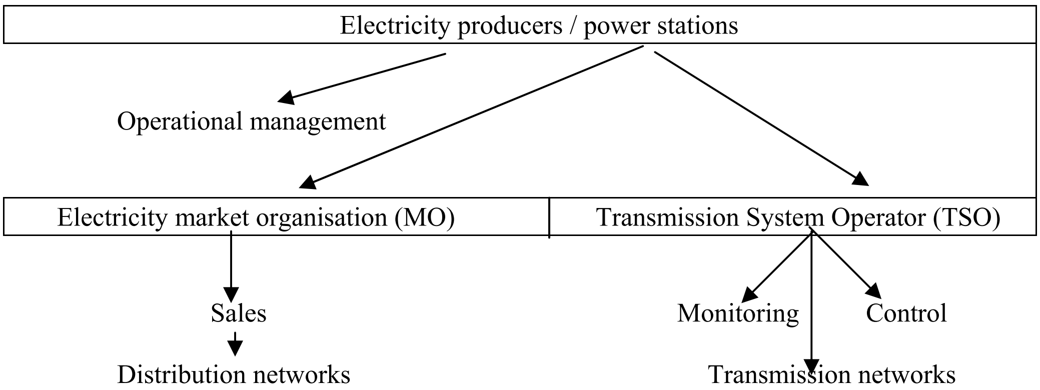

Figure 5.2 Regulation from MO and TSO

5.6. Electricity market

A small state has an advantage of being flexible, ready for fast changes. The government of every state, especially a small state, must create conditions for the growth of the GDP, an environment beneficial for business activities, good living conditions. The infrastructure, especially the fuel and energy sector are the basis for the development of production and business activities as a whole. During its long history Estonia has made good use of this advantage and developed its potential.

The implementation mechanism of the role of the state works through legislation.

The opening of the electricity market has been slower in Estonia compared to the rest of EU, where all electricity consumers are already able to choose their electricity provider as of 1 July 2007. Since 1999 the Estonian electricity market has been open for eligible customers whose annual consumption exceeds 40 GWh. In 2008 the consumption by eligible customers presently forms ca 10% of the total electricity consumption. During the accession negotiations, Estonia and the EU reached a compromise solution for further opening of the electricity market. From April 2010 35% of the Estonian market was opened. Full opening of the electricity market is planned to be completed by the year 2013.

In the situation of the open energy market the need for regulation is greater, the market regulator has the central position and it is more complicated for the state to perform its role.

Functions and activities of the Estonian Competition Authority (CA) are stipulated by the Government of the Republic.

Act, by special laws that regulate communications, postal service, railway and energy sector, as well as by the Statutes of the Authority. It can be concluded that the requirement for independence of regulatory authorities stipulated by the EU Electricity and Gas Directive is fulfilled in Estonia. The Authority is independent in decision making and in management of the organization. The level of financing can also be considered sufficient. The differences in the regulation of natural monopolies in Europe and in United States of America are shown in Table 5.12 [73].

Table 5.12 The regulation of natural monopolies

Parameter	Europe	USA
Regulating duration	Regulation began in 1980-90, approximately 20 years of experience	The end of 19th century, the start of 20th century. Experience more than one hundred years
Involvement of regulators with the country	National regulators, government	Government outside regulators, committees in the states and in the federal states

Depending on the multiplicity of manufacturers, suppliers (providers) in different countries there are different levels of regulation [74].

There are also differences in the regulation of electricity markets in Finland and Estonia as seen in Table 5.13.

Table 5.13 The regulation of the electricity markets in Finland and Estonia

Estonia (closed market) is regulated	Finland (open market) does not regulate
Production, the price of the final consumer Competition is possible, but not yet effective: Oil shale price limit Narva PP – the electricity price limit Sales – to the final consumer price limit Network of natural monopoly: The transmission network – coordinated rate Distribution network – coordinated rate Principle: prices coordinate with a three-year period and an annual adjustment according by the CPI and costs saving tasks	Production, the price of the final consumer Competition works Fuel and energy prices are not regulated Network of natural monopoly: The transmission network – coordinated rate Distribution network – coordinated rate

Supervision over the energy market is exercised by the Estonian Competition Authority. Supervision over the liquid fuel market is also exercised by the Customs Board. The Technical Inspectorate supervises the technical fitness of equipment in use. The interests of customers in relations with the energy companies are the responsibility of the Consumer Protection Board.

5.7. Oil shale industry

Oil shale mining in Estonia started in 1916. Oil shale oil industry was developed strongly in the 1930s, according the interests of Germany, who was preparing for war, according to the interests of the Soviet Union after World War II in the Baltic Sea for naval and for the production of domestic gas (first of all to the City of Leningrad). During the 1960s the large-scale consumption of oil shale started in power plants, which were built in the Soviet Union to supply electricity to the North-Western regions of the Soviet Union.

Electrical power engineering has been historically in the subject of the policy of the Soviet Union's imperial interest. Similarly, at the time of regaining independence in Estonia, energy is used as a tool for political struggle.

The components of oil shale industry:

- mining,
- oil industry,
- power generation,
- oil industry,
- the production of heat and
- cement.

Oil shale is and will be the main fuel in the future for electricity generation in the regime of based and half based consumption. For big load and electricity consumption and for the emergency reserve of the electricity system we need fast starting oil and gas generating capacities. Another specific of the Estonian electricity market is an extreme concentration and reliance on a single fuel. Namely, 96% of electricity is produced with oil shale, the share of other fuels is very modest. Thus, the share of natural gas is only 2,6%, while the share of renewable sources and peat is only 0,4% and for other fuels 3,2%. Estonian oil shale electricity system can read a well functioning system, the description of which is seen in Table 5.14.

Table 5.14 Characterization of oil shale in Estonia

Positive	Negative	Trend
1. Mainly local fuel is 73.2%. 2. The capacity of Estonian power stations exceeds domestic consumption. 3. The share of oil shale is 96% of electrical power production. 4. Increase in world fuel prices has no immediate impact on the price of electricity production. 5. Energy infrastructure is developed, transnational exchange capacities are sufficient. 6. Transit logistics of fuel and energy is working.	1. The low efficiency of the use of whole energy (the ratio of final energy consumption of primary energy, 54%). 2. The environmental impacts of oil shale make it difficult for the sustainable development. 3. Due to concentration of power generation there are excessive security risks. 4. Oil shale resource is sufficient, but the mining value is less than 78% of the extraction medium and 37% of the resources are located in protected areas.	1. Implementation of the EU directives will increase the costs of complex operations. Operating costs. 2. CO_2 trade substantially impairs the competitiveness of oil shale. 3. Opening of the electricity market will lead to electricity price increases. 4. Public pressure to increase production of renewable electricity. 5. Decrease in energy is a reality.

5.8. Power system planning

The biggest challenge for planning is combining ancillary services for the power generation mix in an optimal manner by securing the reliability in the system. This requires also that rules for the power play will by established in such a manner that both electricity generation markets and ancillary service markets can be optimized at the same time [75; 76].

The rapid changes in price of fuels and electricity have confused the planners. It is better not to believe in rapid changes, while in electricity business there should be long-term planning where the power plants should be planned for whole life time of 50 years.

Systematic planning of the future power system will require visionary thinking. The planner should see the problems that might emerge in the future, a vision of the power system should be for 50 years from today.

The future power system will be planned using three different scenarios:

- business as usual – the oil shale fired condensing power plants will generate more than 50% of all electricity needs;
- nuclear expansion – the nuclear plants will generate about 50% of the Estonian electricity in 2050;
- optimal power system – the oil shale fired condensing power plants, CHP plants and gas turbines.

The world electricity consumption will be 39 000 TWh in year 2050, 117% more than in 2005.

The fuel and energy economy long-term national development plan in Estonia up to 2015 is:

1. The overall consumption of primary energy in 2010, does not exceed the level of the year 2003.
2. Moderate growth in electricity consumption 2-3,75% per annum.
3. Electricity must be covered by the local generating capacity.
4. The share of renewable electricity will be 5.1% by 2010.
5. Take into maximum use the heat and electricity co-generation in Estonia by 2020, which allows to cover 20% of the national electricity gross consumption.

Estonia's electricity development plan which has been approved by the Government provides for four different scenarios for the development of generating capacity. Possible scenarios for power generation are in Table 5.15.

Table 5.15. Possible scenarios for power generation

Variants	1	2	3	3a	
Fuel capacity (MW)					
Oil shale	400	400	800	-	1200
Nuclear	1200		400	400	
Wind energy	250	1200**	400	400	400
Gas (gas turbine)	-	1300	500	500	500
Coal	-	-	-	400-800	-
Results (indicators)					
The investment (in million EUR)	4,3	3,4	3,5	3,5	3,0
CO^2 emission (t/MWh)	0,17	0,36	0,41	0,39	0,67
Electricity price (cent /kWh) *	100/110	140/155	125/140	130/148	120/148

* *depending on the price per ton of CO^2 - 25/50€*

** *The balance responsibility of wind generators ensuring with gas turbines*

5.9. Opportunities of state regulation

National legislation has two directions:

- price regulation of natural monopolies and market control;
- planning of strategic developments.

In long-term planning of power systems and the whole energy policy the state has to play a determining role, forecasting the economic development and environmental changes as a whole. Considering the needs and possibilities of the society it is necessary to deal with development planning with an outcome of long-term (50-70 years) power development plans [78,79].

The state has an immediate responsibility to ensure:

- reliability and security of supply – the customer must have security;
- safety – the functioning of the power system and its servicing must be safe;
- regulation – control over the enterprise that has a dominant position. For this purpose the state has regulatory and control mechanisms;
- innovation – support mechanisms for new ideas, research and development, transmission of scientific achievements;
- energy efficiency – sustainable development in the whole cycle of fuel production, utilization in energy production, transmission and consumption.

The implementation mechanism of the role of the state works through legislation.

In the situation of the open energy market the need for regulation is greater, the market regulator has the central position and it is more complicated for the state to perform its role.

The article describes various possibilities for the state to implement its role in the energy policy:

1. Control and guidance through ownership relations – the state owns the most important infrastructures.

2. Analysis of long-term development trends and planning – national development plans.

3. State surveillance, market inspection in the open market situation.

5.9.1. Strategic goals and state constraints

Strategic goals

The state determines strategic objectives for the optimal development of the fuel and energy sector.

The energy sector must be as efficient as possible and comply with safety and environmental requirements.

The state must set the following goals when determining the strategies of the energy sector [80];

- stable and permanent functioning of the energy sector. This requires long-term national development plan
- availability of the infrastructure for all agents in the market. This requires fuel and energy prices corresponding to the customers' purchasing power;
- energy companies not resorting to their monopolistic market position [2];
- creating the availability of the naturally monopolistic energy network for all the market agents;
- control over the dependency of the state on the fuel and energy resources. This requires multiple supply channels and kinds of fuel in the primary energy balance;
- international cooperation. This requires international contracts and agreements between states.

Tactical goals:

- By building new power plants, optimal utilization of the existing heat networks, preference of heat and power co-generation.
- Developing small-scale energy for heat and power production on the basis of bio-fuels and natural gas.
- Promoting the building of power plants suitable for covering the peak load near the consumption centres.
- In developing the national fuel policy, proceeding from the need to increase the share of local and preferably renewable fuels in the energy balance, at the same time bearing in mind the economic efficiency and security of supply.
- Expanding the utilization of the renewable energy sources, employing national support programs.
- Elaboration of the new taxation system for complex regulation of the environment and energy as well as legislative acts required for the implementation of emissions trade and other mechanisms stated in the Kyoto protocol [6].
- Improving cooperation with the Baltic and Nordic states for elaborating common positions concerning the development of the EU energy policy.

Constraints:

- Limited production due to small market capacities.
- Low consumption density per kilometre of power network.
- More strict environmental requirements due to the EU regulations in the environmental strategies.
- Concentration of the electricity production in the north-eastern area of Estonia while the biggest consumption is concentrated in Tallinn and Tartu. This is not

expedient from the point of view of national security, dispersion of power system and reliability.

• Electricity production is 93% fossil fuel based which has an immense environmental impact.

Recommendations:

• Cooperation of the state, educational institutions and energy companies in increasing the possibilities of continuing education of experts and specialists for the energy sector. In order to do that the certification system of continuing education and corresponding programs should be worked out.

• Further development of the strategic program on energy conservation with an aim of improving energy utilization in the heat, electricity and heating sectors by composing and implementing detailed plans in each sector.

• Developing preconditions for building connections with the power systems of Nordic countries and Central Europe.

5.9.2. Fuel and energy security risks

Threat and risk environment have by their nature become highly complex and mutually dependent long ago, objects of infrastructure are in use of different owners.

Distinguish the following sub-type of risk:

- equipment security risks – transmission and distribution system reliability;
- supply risks – the EU's dependence on natural gas and liquid fuels by 2030 80%.

North America's dependence on natural gas by 2020 is increasing to 45%. Political risks of fuel reserves are located in unstable regions.

To ensure the operation of vital area, infrastructure protection, it is necessary to assess the risks in advance, and then to minimize the likelihood of occurrence and potential negative consequences.

In the strategic level of risk treatment and minimizing the security risks there is an important national role:

a) state as regulator –

the risk of treatment is the government / government agencies firm policy, where risk assessment is based on the laws and regulations, so called – the philosophical part of act creating;

b) state as investor –

the price of the risk approaches – how much tax payers' money, and which (strategies, preventive measures, education, health, safety, protection, etc.), it is appropriate to spend in order to avoid the risks of realization – the creation of an emergency;

c) state as supervisor (examiner) –

risk analysis, risk assessments to optimize the use of regulations, evaluation of the adequacy of regulations, the definition of targets of national coercion, surveillance, the systemic of control procedures etc for the establishment;

d) state as the service provider –

public service (government service, mandatory response services) – police, rescue, ambulance, customs, border guards, etc.) – administrative and physical protection of the life and health of population;

The treatments of risks are different as seen in Table 5.16

Table 5.16 Risk treatment and minimizing the security risks

The treatment method and the theoretical basis	Assessment methods	Use area
Technical: management of technological processes, probability theory	The statistical methods, probability calculations	Regulations, safety, technological and management processes, Creating a natural resource (investment)
Psychological: the individual's subjective attitude towards the feasibility of	Statistical methods, psycho-metrical techniques	Regulations, labour market
Sociological: the risk of social theory	Interviews, panel analysis, statistical methods	Regulations, labour market, ial and economic policy
Cultural: cultural theories	Grouping, cluster analysis, network analysis	Regulations, product market, labour market, foreign economic
Economic: economic theory, utility theory	Statistical and econometric methods, expert estimates	Regulations, economic policies, economic processes

The main task of all ministries have their own area of policy formulation and elaboration of regulations, investing in a crisis management mechanism, including training and regulatory compliance controls.

5.10. Conclusions

Energy is an important infrastructure for the existing of the state, real-time technical system functioning in the real-time.

Output is characterized by: reliability, energy price and quality. Operation of the system is characterized by safety, environmental impacts, integrated circuit efficacy and costs of operation.

Energy policy planning is based on:

- long-term, sustainable, the optimal need of performance;
- balanced interplay of all components;
- planning activities carried out under the hypothesis of incomplete information;
- dynamic of investments in a changing environment;
- more diversity and group of short driving restrictions in the interests of emerging civil society;
- ethics of society:
- lack of social agreement;
- special interests of political parties and politicians;
- a reasonable amount of implementation of alternative energy options.

In various stages are not followed up:

1. Policy agenda of political parties disturbes the formation of intergrated energy policy
2. The adoption of decisions is not preceded by scientific expertise.
3. Society, including the opinion of the scientific community has been systematically ignored.
4. In shaping the long-term energy policy there is necessary societal consensus and fixation of place of origins.
5. Decisions on energy policy have not often been necessary to justify, but they are based on the day policy.

The state has the following instruments at its disposal for the implementation of strategic goals and principles of the fuel and energy sector:

1. Regulative or legislative measures (including the pricing mechanism)
2. Taxation system
3. Investment support

6. CONCLUSIONS

The goal of the thesis was to analysis the strategic problems of energy supply and perspectives of energy development in a long-term time period (50-70 years forward). In this work is not proceeded from the nowadays environmental policy that at present occurs a global climate warming, but from the possibilities of continue consumers supplying with energy and from real possibilities to degrease the environmental pollutions in the long-term future. Here are not considered with new technologies as nuclear fusion power, hydrogen fuel and others.

The following problems have been studied in my work:

1. Energy and environment
2. Consumption and reserves of primary energy
3. Electricity generation and power systems
4. Innovation role in energy engineering
5. Energy development long-term perspectives in Estonia.

The conclusions that may be made on the base of this research work are the follows.

1. Energy supply of consumers is extremely important service that must continue for ever.

2. The present environmental policy is very active, but its bases are not proved by scientific methods. Because the applying of the compulsion measures (quotas, taxis of CO_2 emissions and others) are not justified. The quotas and taxis of CO_2 emissions are the particulary harmful for the countries having only fossil energy resources as, for example, Estonia.

3. About 80-90% of the world's energy consumption bases on the fossil fuels (coal, natural gas, oil, oil shale). Renewable energy sources cannot after 50-70 years to substitute the fossil fuels. Because the consumption of fossil fuels will growing. The resources of natural oil, natural gas and nuclear fuels probably will finish already in the XXI century. The coal and oil shale resources will continue wet also in the XXII century. A future fuel will be oil shale.

4. There are three general minimizing criterions that must be taken into consideration in the controlling and planning of energy supply processes and systems:

1) Minimize the total consumption of energy resources and environmental pollutions at the same time

2) Minimize the expected investment and operational costs.

3) Minimize the losses of energy and energy consumption.

At that the optimal decisions must be realizable and profitable as by energetic so by economic point of view.

5. The optimization of fuel industry is very important, this enables to save the fuel resources and decrease the environmental pollutions approximately 20-40%.

6. To the optimal operation, control and planning of power systems must be turned perceptibly more attention. The methods of vector optimization, complex optimization and the method of optimization under incomplete information have to

develop in the near future. The optimization of power systems operation and development enables to degrease the total fuel costs and environmental pollutions about 10-20%.

7. Very important is minimizing of electricity and thermal energy consumption.

8. Estonia is the biggest producer of electricity from oil shale in the world. The great resources of oil shale enable to produce electricity also in XXII century. But for that the Government of Estonia must fight against taxis of CO_2 emissions. Extremely important is optimization of oil shale power plants operation and optimal development planning of Estonian power system and optimal cooperation with neighbor power systems.

9. For optimal decision making in energy engineering and for avoiding the wrong decisions it is necessary to increase perceptibly the part of researches in solving the complicated problems of energy supply. Also the innovation deserves the support and stimulation.

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ABSTRACT

ANALYSIS OF ENERGY DEVELOPMENT PERSPECTIVES

In the paper there is analyzed the current situation of energy development in the world and in Estonia, and the proposals are made in order to ensure to consumers energy supply after 50 – 70 years. The main content of the work is energy strategy and – policy.

The chapters of the work:

- Introduction
- Energy resources and their use
- Electricity Generation and Energy Systems
- Innovation in energy
- Energy supply in Estonia: reality and perspectives
- Conclusions

Key results of the world energy:

1. About 80-90% of the energy consumption is derived from the combustion of fossil fuels.
More than 66% of electricity and 95% of transportation fuels are derived from fossil resources.
Serious threat to future energy supply is the decrease or finishing of oil, gas and nuclear fuels in XXI century. On current prognoses coal and oil shale will continue much longer than 100 years.

2. Oil and natural gas reserves are located very unevenly in the world, so the logistics is very important. 90.7% of the world natural gas reserves are located in 20 countries, the leader is the Russian Federation with 26.9%. 2/5 of natural gas reserves are located in the Middle East and only 2.8% in Europe.

3. The European Union's biggest challenge is to ensure supply of consumers, as Europe's own production declines and in 2030 there must be import 75-80% of useful natural gas and oil-based products.

4. Estonia is the world's largest producer of electricity and oil shale. Optimized power and energy system with a revolving technology allows much more efficiently and with lower emissions to produce electricity compared to current.

5. Today’s short term energy strategies are based on the criterion of global warming and, as a result of this - the allowable number of air emissions. This greatly restricts the use of fossil fuels and inhibits the development of countries in different climatic conditions.

6. The main goal in developing the world's energetics there should be optimize energetics according to several criteria:

- minimize the cost of fossil fuels and environmental issues (vector optimization)
- minimize the expected investment and operating costs
- minimize energy losses and consumption

7. Fuel economy optimization (deposits, mining, processing, transport) allows fuel savings and environmental impacts approximately 20-40%.

8. Electricity generation and function of energy system optimization, as well as developing the technology will help to reduce fuel consumption and environmental pollution about 10-30% in the energy system.

9. Scientific experience in the use of oil shale in the world allows us to participate in the use of oil shale technology developments

10. Since resolving energy problems are very complicated on the scientific basis, it requires constant scientific study. To this end, we must make every effort to ensure continuity of energy research.

11. Innovation in energy is an interdisciplinary, where science is closely related to economic, technical and social sphere. Future-oriented innovation is a long-term balanced development strategy of different areas thus ensuring the sustainability of the state.

12. Long-term strategy planning all market participants have their own role, the state must perform the role of regulator, investor, supervisor and social services provider’s role.

Bibliography of 81 title

KOKKUVÕTE

ENERGEETIKA ARENGUPERSPEKTIIVIDE ANALÜÜS

Töös on analüüsitud energeetika arengut ja praegust olukorda maailmas ja Eestis ning tehtud ettepanekuid selleks, et tarbijate varustamine energiaga oleks tagatud ka 50-70 aasta pärast. Sisu poolest kuulub töö energiastrateegia ja -poliitika valdkonda.

Töö osad:
1. Sissejuhatus
2. Energiaressursid ja nende kasutamine
3. Elektrienergia genereerimine ja energiasüsteemid
4. Innovatsioon energeetikas
5. Energeetika arenguperspektiivid Eestis
6. Järeldused

Põhitulemused maailma energeetika kohta:

1. Ligikaudu 80-90% kogu maailmas toodetavast energiast saadakse fossiilsete kütuste põletamise teel. Elektri tootmises kasutatakse fosiilseid kütuseid 66% ulatuses, transpordis 95% Tõsiseks ohuks tuleviku energiavarustusele on nafta, gaasi ja tuuma kütuste varude oluline vähenemine või lõppemine XXI sajanil. Praeguste prognooside kohaselt jätkub ainult kivisütt ja põlevkivi tunduvalt kauemaks kui 100 aastat.

2. Nafta ja maagaasi varud paiknevad maailmas on väga ebaühtlaselt, seepärast on väga oluline logistika. Üle 90% maagaasi varudest asub 20 maailma riigis ja esikohal on Venemaa 26.9%. 2/5 maagaasi ressursist paikneb Lähis-Idas, suure tarbimisega Euroopas aga vaid 2,8%.

3. Euroopa Liidu suurim väljakutse on tarbijate varustuskindluse tagamine, sest Euroopa enda toodang väheneb ja aastal 2030 tuleb importida 75-80% kasutatavast maagaasist ja naftasaadustest.

4. Eesti on maailma kõige suurem elektri ja õli tootja põlevkivist. Optimeeritud elektrijaamad ja energiasüsteem koos uueneva tehnoloogiaga võimaldab praegusega võrreldes tunduvalt efektiivsemalt ja väiksemate emissioonidega elektrienergiat toota

5. Tänased lühiaegsed energiastrateegiad lähtuvad vaid kliima soojenemise kriteeriumist ja sellest tulenevalt lubatavast õhuheitmete hulgast. See piirab oluliselt fossiilkütuste kasutamist ja pärsib erinevates klimaatilistes tingimustes asuvate riikide arengut.

6. Põhieesmärgiks maailma energeetika arendamisel peaks olema energeetika optimeerimine korraga mitme kriteeriumi järgi:

- minimeerida fossiilsete kütuste kulu ja keskkonna emissioonid (vektoroptimeerimine);
- minimeerida oodatavad investeeringud ja tegevuskulud;
- minimeerida energiakadusid ja tarbimist.

7. Kütusemajanduse optimeerimine (maardlad, kaevandamine, töötlemine, transport) võimaldab säästa kütuseid ja keskkonna mõjusid ligikaudu 20-40%.

8. Elektritootmise ja energiasüsteemide talitluse ning arengu optimeerimine, aga samuti tehnoloogia arendamine võimaldab vähendada kütusekulu ja keskkonna saastamist energia-süsteemi osas 10-30%.

9. Põlevkivi kasutamise teaduslik kogemus võimaldab meil osaleda maailma põlevkivi kasutamise tehnoloogiate arengutes

10. Kuna teaduslikul alusel energeetikaprobleemide lahendamine on keerukas, vajab see pidevaid teaduslikke uuringuid. Selleks peame tegema jõupingutusi energeetikateaduse järjepidevuse tagamiseks.

11. Innovatsioon energeetikas on interdistsiplinaarne, kus teadus on tihedalt seotud majanduse, tehnika ja sotsiaalsfääriga. Tulevikku suunatud innovatsioon on eri valdkondade pikaajaline tasakaalustatud arengustrateegia, seega riigi jätkusuutlikkuse tagamine.

12. Pikaajalise strateegia planeerimises on kõigil turuosalistel oma roll, riik on reguleerija, kontrollija, sotsiaalteenuse osutaja, koordineerja ja vajadusel ka investor

Kirjanduse loetelus on 81 nimetust

ELULOOKIRJELDUS

1. Isikuandmed
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3. Hariduskäik

Õppeasutus (nimetus lõpetamise ajal)	Lõpetamise aeg	Haridus (eriala/kraad)
Tallinna Tehnikaülikool	2000	Tehnikateaduste magister
Tallinna Tehnikaülikool (endine Tallinna Polütehniline Instituut)	1974	Elektriinsener
Tallinna Polütehnikum	1968	Tehnik-elektrik

4. Keelteoskus (alg-, kesk- või kõrgtase)

Keel	Tase
Eesti keel	Kõrgtase
Inglise keel	Kesktase
Vene keel	Kõrgtase

5. Täiendusõpe

Õppimise aeg	Täiendusõppe läbiviija nimetus
1988-1999 Ettevõtte strateegia.	Majandusministeerium. Baltic Computer Systems
1999 EL energiaalane seadusandlus.	EL Komisjon Leideni Justiitsülikool
1998 Elektrituru- ja gaasituru regulatsioon, Regulatsiooni funktsioonid	EL Komisjon, Suurbritannia Kaubandusassotsiasioon, Brüssel.
1996-1998 Juhtimisstrateegia	Majandusministeerium
1997 Energeetika juhtimisstruktuurid ja-meetodid	EL Komisjon, Oxfordi Ülikool
1995 Riigistruktuuride rollist	Saksa Majandusministeerium, Bonn
2000 Liberaliseeritud energiaturg	EL Komisjon, Ülikool Commillar

2003 Gaasisüsteemi juhtimine	E-ON Ruhrgas
2003-2005 Euroopa Liidu regulatsioon	EL
2006 Elektrituru korraldus	E-ON Nordic
2006 EU Legislation as it Affects Mining	Tallinna Tehnikaülikool
2006 E-ON strateegia * Juhtimisstrateegia * Turundus * Tehnikapoliitika	E-ON Nordic

6. Teenistuskäik

Töötamise aeg	Tööandja nimetus	Ametikoht
2001-	AS Eesti Gaas	nõunik
2000	EV Majandusministeerium	nõunik
1999-2000	EV Majandusministeerium	asekantsler
1997-1999	EV Majandusministeerium	ministri nõunik
1992-1997	EV Majandusministeerium	asekantsler
1990-1992	EV Tööstus- ja Energeetikaministeerium	ministri asetäitja
1988-1990	Eesti Energia	peadirektori asetäitja
1986-1987	Eesti Energiajärelvalve	peainsener
1982-1986	Põhja Kõrgepingevõrgud	direktori asetäitja
1975-1981	Põhja Kõrgepingevõrgud	Rapla Elektrivõrgu juhataja
1967-1969	Põhja Kõrgepingevõrgud	Rapla elektivõrgu insener

7. Teadustegevus

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8. Kaitstud lõputööd

- Magistritöö aastal 2000
- Diplomitöö, TTÜ 5 aastane inseneriõpe aastal 1974

9. Teadustöö põhisuunad

- energeetika juhtimine
- energiamajandus

CURRICULUM VITAE

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3. Education

Educational institution	Graduation year	Education (field of study/degree)
Tallinn University of Technology	2000	Master of technical sciences
Tallinn University of Technology	1974	Electrical power engineering
Tallinn polytechnic school	1968	Electrical power – subprofessional

4. Language competence/skills (fluent; average; basic skills)

Language	Level
Estonian	fluent
English	average
Russian	fluent

5. Special Courses

Period	Educational or other organization
1988-1999 Corporate Strategy	Ministry of Economy. Baltic Computer Systems
1999 EU energy legislation.	EU Commission Justice University of Leiden
1998 Power and Gas market regulation, regulation functions	The EU Commission, UK Trade association, Brussels.
1996-1998 Management Strategy	Ministry of Economy
1997 Energy management structures and methods	The EU Commission, Oxford University

1995 The role of State structures	German Ministry of Economics, Bonn
2000 Liberalized energy market	The EU Commission, the University of Commillar
2006 Liberalized energy and natural gas market	The EU Commission, the University of Commillar
2006 EU legislation as it Affects Mining	Tallinn University of Technology

6. Professional Employment

Period	Organization	Position
2001-	AS Eesti Gaas	Adviser
2000	EV Majandusministeerium	Adviser
1999-2000	EV Majandusministeerium	Vice Chancellor
1997-1999	EV Majandusministeerium	Minister Counsellor
1992-1997	EV Majandusministeerium	Vice Chancellor
1990-1992	EV Tööstus- ja Energeetikaministeerium	Vice minister
1988-1990	Eesti Energia	Deputy director general
1986-1987	Eesti Energiajärelvalve	Technical director
1982-1986	Põhja Kõrgepingevõrgud	Deputy Director
1975-1981	Põhja Kõrgepingevõrgud	Division manager
1968-1969	Põhja Kõrgepingevõrgud	Division engineer

7. Scientific work:

7.1. Hamburg, A., Elektroenergeetika areng Eestis, Otto Reinvaldi konverents Eesti energeetika minevik ja tulevik, 13 – 14. nov. 1990, Tallinna Tehnikaülikool, Eesti Energia, Eesti Majandusjuhtide Instituut, Tallinn, 1990, lk. 48-53.
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8. Defended theses
Master Thesis: TUT, Master of technical sciences , 2000, Prof. Mati Valdma
TUT, 5 year study, 1974

9. Main areas of scientific work/Current research topics
energy management
energy provisional management

APPENDIX A

I. **Hamburg, A.** Energy situation and its development in independent Estonia, Baltic- Finnish conference: Energetic: From research to innovation, Estonian Academy of Sciences and Finnish Academies of Technology, Proceedings, 2001, pp. 53-57.

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I. **Hamburg, A.** Energy situation and its development in independent Estonia, Baltic- Finnish conference: Energetic: From research to innovation, Estonian Academy of Sciences and Finnish Academies of Technology, Proceedings, 2001, pp. 53-57.

ENERGY SITUATION AND ITS DEVELOPMENT IN INDEPENDENT ESTONIA

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National Gas Company Eesti Gaas, Estonia

Re-establishment of the Estonian independence called for gradual formation of the fuel and energy economy system in such way that it would be in correspondence with the needs of the statehood.
Even in the Soviet period, the fuel and energy complex in Estonia was a well-developed structure. Electric power of 330 kV produced from oil shale was distributed to St. Peterburg
and Piskov regions and to the Latvian SSR.
The Vinezi-Tallinn gas grid ensured the natural gas supply through three pipelines. The railway network for liquid and solid fuel transport made headway.
As soon as the independence of Estonia took clear outlines and consolidated, there was started the restructuring of the power-engineering sector. The fuel transport network was forcefully expanded through build-up and use of sea carriage potential.
The essential events and timetables related to development of Estonian energy are presented below.

1. THE WAY TO INDENPENDECE OF ESTONIA (1988-1989)

- On 16 November 1988, the Supreme Soviet of the ESSR (Estonian Soviet Socialist Republic) proclaimed the Declaration of the Sovereignty;
- Creation of the Problem Council in order to work out the home rule economy management programme for Estonia (the so-called IME Programme);
- Formation of the Popular Front – a nationalist political union;
- Rise of the so-called □ □ Internationalist Front to oppose the nationalist movement;
- Development Plan for Estonian Energy, for the period until 2005, elaborated by the Temporary Creative Association in 1989 (grass-roots initiative);
- Tentative research into building of the Estonian-Finnish undersea cable;
- Baltic Electric Power Engineering Conference, Riga 1989 (held based on proceedings of a similar conference held in 1939)

2. ELABORATION OF STATEHOOD STRUCTURES (1990-1991)

- Establishment of the executive power structures of the State (February-March 1990);
- Bilateral Moscow-Tallinn subordination for industry and energy;
- Definition of the main principles for energy development until 2030 (1990)
    - State Planning Committee of the ESSR
    - Academy of Sciences of the ESSR

In this period the overall development trends were defined and tentative ways for their realisation were formulated. The Baltic joint aspirations in the energy sector were established.
Considered as the cornerstone of the Estonian energy can be the elaboration of the Development Plan for the Estonian Energy Sector, for the period up until 2005.

Main conclusions of the Plan were as follows:

- The energy enterprises must carry on, under the administration of the Estonian SSR;
- The national energy programme must be worked out;
- The co-generation of electric and heat power must be developed;
- The gas turbine plant to cover peak-load must be built;
- The small scope electric energy production must be supported, and the power generation diversified;
- The outdated technology-based renovation project in the Baltic Power Plant must be rejected;
- The building of the new Viru Power Plant and Kuremäe mine must be hindered;
- Existing electric power capacity would be sufficient for the years 2005 to 2010.

In addition to domestic reform, there were supported the rearrangements in other Union republics and the co-operation of the Nordic States in the field of energy (Baltic Ring).

- The Supreme Soviet of the ESSR approved the decision on restrictions in application of the oil shale power engineering;
- International agreements on parallel work of the electric power system with Russian Federation, with the Swedish National Electricity System Vattenfall and with the Imatran Voima in Finland were signed;
- The Energy Committee under the Finnish and Estonian Academies of Science began its work;
- Estonia joined the European Energy Charter process.

At the time, the basic document was the Main Principles of the Estonian Energy Sector Development until 2030. There were envisaged three evaluation phases:

- Creation of the legislative basis, formation of economic relations;
- Creation of the operational price and tax system, start-up of the energy conservation activities;
- Ensuring of the work of regional energy complex and its integration.

3. INTERNATIONAL RECOGNITION OF THE REPUBLIC OF ESTONIA (SEPT. 1991-1992)

- Establishment of diplomatic relations;

- Common projects between WB, EBRD and Estonia;
- Development plan for the Estonian energy sector to the year 1995 (1991);
- Co-operation agreement between Finnish Ministry of Trade and Industry and Estonian Ministry of Energy;
- Elaboration of the Baltic electric power system (October 1991).

4. PERIOD OF BUILDING THE STATEHOOD (1993-FIRST HALF OF 1998)

The national enterprises of Estonia were formed, boards were appointed and directors general were replaced.

Estonian national currency was launched (20 June 1992).

There was generated a tangle-bundle of circular dependence between consumers and producers.

SUBSTANTIAL EVENTS AND DOCUMENTS WERE AS FOLLOWS:

- Monetary reform (1992);
- Energy-sector analysis and development trends – Finnish-Swedish-Estonian co-operation study (1993);
- International Development and Scientific Research Programme for the Power Engineering – (Energy 2000) – (1995);
  - Energy as a discipline;
  - Ratification of the European Energy Charter Treaty (1997);
  - Long Term Development Plan for the Estonian Fuel and Energy Sector (March 1998);
  - Government regulation on restructuring and privatisation of Eesti Energia AS (National electric power production, distribution and transmission company) and the company Eesti Põlevkivi (oil-shale production company) (December 1997);
  - Common energy related projects with the Baltic Sea States in the framework of Nordic Council of Ministers (March 1998);
  - Joining the work of WEC (January 1998);
  - Formation of an energy working group for the accession negotiations to the EU 1998).

5. MOST IMPORTANT DEVELOPMENT PROGRAMMES AND STEPS, REGULATIVE ACTS

The *Development Plan for the Estonian Energy Sector until 2005* specified the following:

- Elaboration of the new energy economy management structure;
- Establishment of the state supervision function, working out the mechanism to regulate the natural monopolies, creation of the price setting mechanism;
- Transformation of the state enterprise into a transmission network (transmission system operator);
- Working out the main energy policy principles;
- Drafting the technical education reform;
- Regulations to the environment monitoring;

- Elaboration of the co-operation forms of the Baltic States;
- Identification of the needs for introduction of technical norms and standards.

The *National Energy Conservation Programme* contemplated the following tasks:
- To enhance the share of local fuels;
- To raise the thermal resistance of buildings;
- To support the energy saving through tax policy measures.

Independent Fuel and Energy Price Setting Commission was formed in 1993.

Minister of Economic Affairs approved the concrete action plan for reformation of Eesti Energia – the State enterprise for energy production, distribution and transmission.

Common Intentions Protocol (March, 1996) and Agreement on Understanding for Development and Co-operation (December, 1996) between the Government of Republic of Estonia, NRG Energy Inc. and Eesti Energia were concluded.

Energy Act approved (1997).

Joint Decision of the European Commission and the ministers of the Baltic States (04.06.1998).

ENERGY 2000 SPECIFIED THE FOLLOWING:
- Setting up the complex development work system;
- Working out the principles of the financing system;
- Creation of the preconditions for participation in the international programmes.

MAIN OBJECTIVES OF THE ENERGY ACT:
- Conformity requirement of laws and processes to technical standards;
- Generation of the open energy market;
- Creation of the market surveillance and technical control system to regulate the natural monopoly.

Content of the *Long Term Development Plan for the Estonian Fuel and Energy Sector* was as allows:
- Implementation of the principles and trends defined in the Energy Act;
- Prognosis for the fuel and energy market and the primary energy balance up until the year 2010;
- Measures to be taken to optimise the functioning of the electric power complex, reduction of the environmental impact.

8. POLITICAL HORSE TRADING AND LOBBY OF THE INTEREST GROUPS (1998-2001)

- Main positions of the Government of the Republic of Estonia concerning the attraction of the strategic investor into the oil-shale based power engineering (October 1998);
- Government regulations on restructuring the companies Eesti Energia AS and Eesti Põlevkivi AS (December 1998);
- Letter from the EU Commission, 10 December 1999;
- The Government of the Republic approved the conditions of sale of 49% stock in AS Narva Elektijaamad to the American company NRG-Energy Inc. (June 2000);
- Draft Energy Market Act (2001);
- Development of the Baltic energy market has stopped.

Regarding the overall liberal market economy background in Estonia the energy policy formation within the last two years has been conservative and even regressive. Initial steps, designed to accord to the oil shale the so-called special status, were taken with the Protocol Decision of the Republic of Estonia (October 27, 1998).Moreover, in December 1998 the Decision of the Government established the monopolistic structure of the oil shale-based power engineering.

CURRENT SITUATION

NRG Energy Inc. gained, by using a coercive tactic, a particularly favourite privatisation conditions for its company and is planning now a completely risk-free business.
Therefore, it is the outside time to suspend the purchase of the stock in AS Narva Elektrijaamad, in present conditions of private offering.
The fitness of monopolistic structures has to be well analysed, on its entirety. The production, transmission and distribution functions should be tendered separately. Moreover, the rationale of privatisation should be weighed carefully. If the decision is made in favour of privatisation, new privatisation conditions must be determined which would be in conformity with principles of market economy. An investor will then be found who will meet those reasons and principles.

Life is making its corrections. Lets help it, by use of our common sense!

II. **Hamburg, A.** The role of the state in forming the energy policy. – Scientific Proceedings of Riga Technical University. Power and Electrical Engineering. Vol. 14. Riga, 2005, pp. 61-66.

THE ROLE OF THE STATE IN FORMING THE ENERGY POLICY

A.Hamburg

Keywords: Energy policy, state regulation, national power system.

Introduction

The first central station for electric power was applied in New York City in 1882. That was a direct current station. But soon the three-phase alternative current was introduced. Power systems were created. The first public power stations were launched in Estonia 1893. In Estonia the plan and principles of the national power system were compiled in 1939. Nowadays national power systems have spread all over the world and also interconnected power systems with neighboring countries are created. In many countries the state is the main owner of energy companies. At the same time energy markets are being opened. In connection with this the problem of the role of the state in forming and implementing the energy policy has been raised.

This paper is considering some aspects of the role of the state in forming the energy policy.

A small state has an advantage of being flexible, ready for fast changes. The government of each state, especially a small state, must create conditions for the growth of the GNP, an environment beneficial for business activities, good living conditions. The infrastructure, especially the fuel and energy sector are the basis for the development of production and business activities as a whole. During its long history Estonia has made good use of this advantage and developed its potential.

Power systems are specific because of their long-term functioning in real time. The operation of the input, output and of the whole system has to be optimized concurrently. The system itself is fairly inert and requires a lot of capital, at the same time being sensitive to changes in the environment.

The role of the state

In long-term planning of power systems and the whole energy policy the state has to play a determining role, forecasting the economic development and environmental changes as a whole. Considering the needs and possibilities of the society it is necessary to deal with development planning with an outcome of long-term (10-15 years) power development plans.

The state has an immediate responsibility to ensure:

- Reliability and security of supply – the customer must have security
- Safety – The functioning of the power system and its servicing must be safe

- Regulation – control over the enterprise that has a dominant position. For this purpose the state has regulatory and control mechanisms
- Innovation – support mechanisms for new ideas, research and development, transmission of scientific achievements
- Energy efficiency – sustainable development in the whole cycle of fuel production, utilization in energy production, transmission and consumption

The implementation mechanism of the role of the state works through legislation.
In the situation of the open energy market the need for regulation is greater, the market regulator has the central position and it is more complicated for the state to perform its role.

The article describes various possibilities for the state to implement its role in the energy policy
1.control and guidance through ownership relations – the state owns the most important infrastructures
2.analysis of long-term development trends and planning – national development plans
3.state surveillance, market inspection in the open market situation.

Strategic goals and state constraints

Strategic goals
The state determines strategic objectives for the optimal development of the fuel and energy sector.
The energy sector must be as efficient as possible and comply with safety and environmental requirements.

The state must set the following goals when determining the strategies of the energy sector:
- stable and permanent functioning of the energy sector. This requires
  a long-term national development plan;
- availability of the infrastructure for all agents in the market. This requires
  fuel and energy prices corresponding to the customers' purchasing power;
  energy companies not resorting to their monopolistic market position;
  creating the availability of the naturally monopolistic energy network for all the market agents
- control over the dependency of the state on the fuel and energy resources. This requires
  multiple supply channels and kinds of fuel in the primary energy balance
- international cooperation. This requires
  international contracts and agreements between states.

Tactical goals

- By building new power plants, optimal utilizations of the existing heat networks, preference of heat and power co-generation.
- Developing small-scale energy for heat and power production on the basis of bio-fuels and natural gas.
- Promoting the building of power plants suitable for covering the peak load near the consumption centers.
- In developing the national fuel policy, proceeding from the need to increase the share of local and preferably renewable fuels in the energy balance, at the same time bearing in mind the economic efficiency and security of supply.
- Expanding the utilization of the renewable energy sources, employing national support programmers.
- Elaboration of the new taxation system for complex regulation of the environment and energy as well as legislative acts required for the implementation of emissions trade and other mechanisms stated in the Kyoto protocol
- Improving cooperation with the Baltic and Nordic states for elaborating common positions concerning the development of the EU energy policy.

Constraints:

- Limited production due to small market capacities
- Low consumption density per kilometer of power network
- More strict environmental requirements due to the EU regulations in the environmental strategies
- Concentration of the electricity production in the north-eastern area of Estonia while the biggest consumption is concentrated in Tallinn and Tartu. This is not expedient from the point of view of national security, dispersion of power system and reliability
- Electricity production is 90% fossil fuel based which has an immense environmental impact.

Recommendations:

- Cooperation of the state, educational institutions and energy companies in increasing the possibilities of continuing education of experts and specialists for the energy sector. Thus the certification system of continuing education and corresponding programmers should be worked out.
- Further development of the strategic programmer on energy conservation with an aim of improving energy utilization in the heat, electricity and heating sectors by composing and implementing detailed plans in each sector.
- Developing preconditions for building connections with the power systems of Nordic countries and Central Europe.

State structures

The role of the newly independent small state in developing its infrastructure, including the energy sector

In 1990 we were integrated in the USSR energy and logistics system. In 1988 the Fuel Committee was founded and in 1990 the Industry and Energy Ministry of the Republic of Estonia was set up. Under the administration of this ministry the National Energy Department started to operate in April 1992. At public initiative the energy development plan "KW" was compiled in 1988, and it was followed by the national development plan of Fuel and Energy Sector commissioned by the Estonian SSR Planning Committee and worked out by the Estonian Academy of Sciences

Today The Ministry of Economic Affairs and Communication is responsible for the regulation and establishing of technical requirements. The regulations essentially influencing the energy sector are established by the Ministry of the Environment (utilization of natural resources, pollution taxes, environmental requirements etc.) and by the Ministry of Finance (excise taxes, principles of the turnover tax, using the budgetary funds etc.). The fuel and energy sector is within the area of government of the Ministry of Economic Affairs and Communication.

There are a number of voluntary associations, commissions and advisory establishments, e.g. the Energy Council of the Estonian Academy of Sciences.

The biggest energy company is the 100% state owned Limited Company Eesti Energia (Eesti Energia Ltd) (producing, distributing and selling electricity and heat) together with its associated companies Eesti Põlevkivi (Oil Sale) Ltd (extracts oil shale) and Narva Electric Power Plants Ltd (produces electricity and heat from oil shale).

Natural gas in Estonia is supplied by Eesti Gaas Ltd. The biggest producer of oil shale and chemicals from oil shale is Viru Keemia Grupp Ltd.

State regulation and open markets

Supervision over the energy market is exercised by the Energy Market Inspectorate. Supervision over the liquid fuel market is also exercised by the Customs Board. The Technical Inspectorate supervises the technical fitness of equipment in use. The interests of customers in relations with the energy companies are the responsibility of the Consumer Protection Board.

The major Acts regulating the fuel and Energy sector in Estonia at present are:

1. The Power Market Act
2. The Natural Gas Act
3. The District Heating Act
4. The Natural Resources Act
5. The Waste Act

A number of legal restrictions concerning the fuel and energy sector are in force in the environment protection area, the most significant being:

1. The Estonian Environmental Strategy (RT I 1997, 26, 390)
2. The Estonian Environmental Actions Plan for 2001-2003
3. The Sustainable Development Act (RT I 1995 31, 384; 1997 48, 772; 19909 29, 398; 2000 54, 348)

Electricity market

The activities of the electricity sector are divided into activities open for competition (production and selling of electrical energy) and monopoly activities (transmission and distribution of electrical energy). From July 1, 1999 the Estonian electricity market is open for large customers with annual consumption over 40 GWh. Their share in the total consumption in Estonia is about 10%. Negotiations with the European Union resulted in a compromise solution for gradual opening of the Estonian electricity market. At least 35% of the electricity market must be open not later than December 31, 2008 and for all non-household customers by December 31, 2012 at the latest. The share of the total consumption of the latter is about 77%.

Conclusions

For the implementation of strategic goals and principles of the fuel and energy sector the state has in its use the following instruments.

4. Regulative or legislative measures (including the pricing mechanism)
5. Taxation system
6. Investment support
7. National programmers

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ESTONIAN NATIONAL ENERGY STRATEGY

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Estonian national energy strategy since 1991 is analyzed in this paper. Estonia separated from the Soviet Union in 1991 and joined the EU in 2004. The first national energy strategy was worked out in 1938. Creation of contemporary energy strategy for re-independent Estonia started in 1988. Over 90% of electricity in Estonia is generated by oil shale thermal power plants. Estonian state is the owner of strategic power plants, electrical networks and mining enterprise. In this paper a short overview of national energy development programs and state's role in forming the energy strategy is presented.

Introduction

Energy plays an important role in lives of all of us. Therefore there are very high requirements established for energy supply. Execution of these requirements requires the development of the energy sector in time and to a needed extent. The development of energy sector is a very long-term and expensive process. For that reason the choice of optimal development strategy is very important.

The first energy strategy plan for Estonia was compiled in 1938. The basic ideas at that time were the following:

1) To form the interconnected electrical network in Estonia. Small local power plants have to be built only to the islands or areas, where the construction of high voltage network is not profitable.
2) To optimize the load distribution between power plants.
3) The great power plants must be interconnected by transmission lines.
4) The distribution network must interconnect all towns and all industrial and main agricultural centres.
5) The price of electricity in power system must be lower than in isolated power plants.

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For the realization of that plan in 1939 the "Electricity Centre" was created, but the actual life took a different turn. After the Second World War Estonia remained the member of the USSR until 1991. During that period the Estonian energy sector was developed as a part of the power system of the USSR. Four oil shale power plants (Kohtla-Järve, Ahtme, Balti and Eesti PP) and one oil-fired power plant (Iru PP) were built. Estonian Energy System was connected with power systems of St. Petersburg, Pskov and Latvia. Estonian oil shale power plants were exploited very intensively. Since 2006 the Estonian power system is also interconnected with the

Finnish power system. The main energy enterprise in Estonia is "*Eesti Energia*".

National energy strategy programs

The planning of national energy strategy for re-independent Estonia started in 1988. From 1988 to 2007 several energy development programs have been compiled for Estonia.

1. **Estonian Energy Development Plan (until 2005). Working group "kW". 1990.**

The first energy strategy plan for re-independent Estonia was compiled by a voluntary working group. The plan proceeded from the prognosis of energy demand and forecast of the technical progress in the entire energy sector. This report prioritized energy strategy goals and role of the state in achieving them. The main long-term targets for energy development were the following: 1) decreasing and cleaning of emissions of oil shale power plants, 2) energy saving, 3) decreasing of electricity export, 4) optimization of power system operation, 5) interconnecting of the power systems of Finland and Estonia.

2. **Energy Development Plan for Estonia (until 2030),** Estonian Academy of Sciences and Estonian National Planning Committee, 1992.

It was the first state energy development plan. The plan also treated the problems of new technology of combustion, restructuring of energy sector and research and development objectives.

3. **Energy saving Program, Ministry of Building, 1992.**

The main goals of the program were: 1) decreasing the import of fuels up to 50% compared to 1991, 2) to start using market base prices in the fuel and energy sector, 3) to promote energy saving.

4. **Research and Development Program ("Energy 2000"), Estonian Energy Institute, 1995.**

The main topics of scientific and innovative research work that have to be financed in Estonia were formulated. A Foundation of Energy Research to finance this program was recommended to be created.

5. **National Fuel and Energy Sector Development Plan. The Parliament of Estonia, 1998.**

The priority goals were: 1) quality and stability of energy supply, 2) independence of energy sector, security reserves, 3) energy saving, 4) execution of environmental requirements.

6. **National Fuel and Energy Sector Development Plan until 2015 (2030). The Parliament of Estonia, 2004.**

The main decisions: 1) the state will create conditions for continuous development of fuel and energy sector, 2) the presence of local electricity production capacities for covering annual load curve will be guaranteed permanently, 3) liberalization of the energy market and development of the free market will continue, 4) the new taxation system of environment and energy will be introduced, 5) the renovation of Narva Power Plants will continue, 6) the share of peat, wood and wind in the primary energy balance sheet will increase, etc.

7. **Electricity Industry program, Government of Estonia, 2005**

The program specifies the plan of electric generation capacity until 2015. The main attention is paid to the renovation of condensing power plants, to the use of gas turbines and alternative energy resources.

The first Energy Act was passed in 1997. In 2003 this act was transformed into the Electricity Market Act. Estonia decided to join the European Union in 1995 and joined the EU in 2004.

Fuel Committee was founded in 1988 and the State Energy Office in 1990. The office started to operate in 1991.

In 1998, the Estonian Energy Market Inspectorate and the Estonian Technical Inspectorate were founded.

Goals of state energy strategy

The main goals of state energy strategy are as follows:

1. To guarantee continuous energy supply with suitable prices
2. To guarantee the development of energy technology
3. To guarantee the reliability and security of energy systems [1]
4. To guarantee the quality of energy [2]
5. To guarantee the increasing of energy consumption efficiency and to promote energy saving
6. To develop free competition and energy markets [3]
7. To foster the use of alternatives energy resources
8. To discharge the environmental requirements
9. To develop cooperation between power systems interconnected with the national power system [4]
10. To develop education and research in the field of energy.

For achieving these goals the state uses legislation, long-term development plans, energy policy and owner's rights. The role of the state is very important in a small state such as Estonia.

A small state has an advantage of being flexible, ready for fast changes. The government of each state, especially of a small one, must create conditions for the growth of the GNP, a beneficial environment for business activities and good living conditions. The infrastructure, especially the fuel and energy sector, is the basis for the development of production and business activities as a whole. During its long history Estonia has made good use of this advantage and developed its potential. In long-term planning of power systems and the whole energy policy the state has to play a determining role, forecasting the economic development and environmental changes as a whole. Considering the needs and possibilities of the society it is necessary to deal with long-term development planning (30-40 years) of the fuel and energy sector. The long-term (30-40 years) energy development plans must also include the following items [1]:

1. Regulation – control over the enterprises that have a dominant position. For this purpose the state has regulatory and control mechanisms. The market regulator has the central position and it is more complicated for the state to perform its role [2]
2. Innovation – support mechanisms for new ideas, research and development, technology transfer [3]
3. Energy efficiency – sustainable development and utilization in energy production, transmission and consumption

The implementation mechanism of the state for these parts works through legislation.

Main directions of development of fuel and energy sector in Estonia:

1. To continue the development of oil shale power plants on the fluidized bed combustion (FBC) technology
2. To develop mining technology
3. To take into use the gas turbines for covering peak loads and emergency reserves
4. To foster the building of news cogeneration power plants and the use of alternative energy resources
5. To develop energy networks
6. To develop education and scientific research in the area of fuel and energy sector
7. To improve the cooperation between Baltic and Nordic states in the area of fuels and energy [5]
8. To work out a national security plan for the entire fuel and energy industry
9. To re-establish the State Energy Office.

Conclusions

1. National energy strategy and executing this into practice are very important problems requiring complementary research work.
2. Development of energy sector depends on the above-mentioned strategy and a large number of other factors such as:

- Economical development
- Reforms in energy sector
- Development of new technologies
- Development of the regional and international energy markets
- Environmental requirements etc.

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INNOVATION IN ENERGY SUPPLY

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The paper introduces the specialities of innovation in energy supply. The innovation is distributed into three parts: 1) technology innovation, 2) power system cybernetic innovation, 3) business innovation. The principles of acceleration and prognostication of innovation are considered in the paper too.

Introduction

The term **innovation** means using new ideas in certain activities to obtain certain goals.

The notion of innovation is very general. The peoples use the innovative or creative approach everywhere though not always. The innovative actions may have many concrete objectives but a general goal is progress. Innovation is the main engine of the progress [1]. The directions and the speed of progress depend of innovation. About great importance of innovation speaks the fact that year 2009 is deemed to be a year of creativity and innovation in EU.

Innovation in energy supply means using new ideas in energy supply. This contains the treating and producing of energy resources, the generation, transmission, distribution and consumption of electrical and thermal energy. Power engineering is a very important, complicated and expensive area, where the acceleration of innovation may give a great effect.

The paper introduces the specialities of innovation in energy supply and possibilities to accelerate innovation in power engineering.

Main directions of innovation in power engineering

The main directions of innovation in the power engineering are:

1. Technological innovation

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2. Cybernetic innovation
3. Business innovation

Technological innovation

The technological innovation means the developing and using of new technologies, materials and equipments in the mines, power plants, energy networks and energy appliances. It bases on the physical and technical researches as in the fundamental sciences, so in the applied sciences areas. The technology is developed for increasing safety, reliability, security, quality, efficiency, for decreasing costs and for improving many other indicators. At the same time it is tried to change the power engineering more environmental friendly.

The main directions of technological innovation in the energy supply area are [2]:

- Creation of controllable nuclear fusion reactors
- Development of nuclear fission reactors
- Development of new combustion technologies and boilers
- Development of combined cycles power plants
- Improvement the controllability of power plants and electrical networks
- Creation of energy storage units
- Application of renewable energy sources etc.

The main technological problems for Estonian energy supply are:

- Complex development of oil shale energetics
- Development of new combustion technologies and boilers for oil shale power plants
- Use of overcritical steam parameters in oil shale power plants
- High-voltage insulation problems and others.

Cybernetic innovation

The cybernetic innovation includes the theories, models and methods of optimal control, operation, development planning and analysis of power plants, networks and systems. This area is always very important in increasing the efficiency, reliability, security and quality of energy supply and also in diminishing the environmental losses. The optimization of power systems may decrease fuel costs and environmental losses up to 10%.

Busyness innovation

The busyness innovation consists of the management problems of energy companies and of energy markets problems. The busyness area is based on the energy policy, energy laws and state's energy strategy. It is always very important.

Supporting and accelerating of innovation

Among the energy supporting actions, the most important ones are:

1. Promotion and popularization of power engineering education;
2. Financing and signification of scientific researches in the field of energy engineering;
3. Information the publicity about new directions in energy development where Societies of engineers have a key role.

Fundamentally, innovation means selecting a new way, expressed as changes in the way of thinking, in ideas, economy, business, technology, organisation, social sphere, society, etc. and resulting in positive changes [3]. Positive changes at various levels and in various activities improve the capabilities of the society and ensure a sustainable development.

Innovation has the following expected results:

1. An individual person will have a wider view on the world, more knowledge, skills and abilities

Indicators:

 The work contribution and work efficiency of the person are higher;
 The value of the labour force is higher;
 The life-long learning system functions.
2. Business association will have a more competitive product or service in the market [4].
Indicators:
 Product development and technology development have the first priority;
 The product or service conforms to the needs of the market;
 The additional value created in the company increases.
3. The state will have an increase in the economic and social welfare and a sustainable development [4].
Indicators:
 More active investments from abroad;
 Valuing the role of research; the full linkage of research, development and business (R&D&B) is functioning;
 The support structures for research, development and business are functioning.

In a crisis it is more important than ever to make economy more researchbased and to change the perceived values of the society. The functioning of the innovation system of the state ensures a sustainable country [4].
The following factors are important:
1. The members of the society must be informed and there must be a participatory democracy in action;
2. The education and vocational qualification system must conform to the needs of the labour market;
3. Innovation must function at all levels;
4. A united national strategy must exist and function.

Developing the capacity for innovation is not so much a technological or financial matter, but an issue of culture [5].

An energy strategy significantly influencing the sustainability of the country must be based on research, societal consensus, international cooperation and analysis. All this requires stability, setting long-term goals and having a consensus in the society.

In addition to the economic functions, the complex of fuel and energy industry has also social, regional and ethical functions.

In order to develop different directions of this complex, one needs the availability of people with world-class knowledge. Both human resources and material resources should be gathered into research centres in the field of energy. The developments produced by these research institutions are necessary for determining a scientifically justified energy strategy.

Taking into account the actual competence and the market demand in

Estonia today, it can be said that the main question of the energy field is the issue of shale [7].

The following is important in order to have a varied structure of energy production and to ensure energy sparing:

1. Ensuring energy sparing in the entire energy circuit;
2. Establishing gas turbines in order to optimize reliability of the electricity system;
3. Developing technologies of combined heat and electricity production;
4. Developing renewable energy technologies and integrating them into the overall energy system;
5. Further developing shale industry.

We have achieved significant technological innovations regarding both shale mining and shale combustion in the fluidized-bed layer. The new combustion technology increased the efficiency of electricity production and reduced the atmosphere pollution.

In order to plan the development strategy of energy industry, one needs a unified, complex scientific view on society [2].

Algorithm for preparing the prognosis for the future is shown in Fig. 1.

Discussions of the related parties and
notifying wider public about the results
Not foretelling an inevitable future, but studying
how the future can go along different paths
depending on the actions of the important
parties and the decisions made today
Discussions **MONITORING THE FUTURE**
about the future Open Shaping the future
Involving
Action-oriented
Not only analysing or weighing different future developments, but supporting the relevant
parties in actively shaping the future
Source: European Commission

Fig. 1. Algorithm of prognosis.

Planning of innovation

In planning the innovation process, it is of primary importance to have the research potential available and to involve it in the planning process.

The goals of R&D work are as follows:

1. Increasing the innovation capacity of Estonia in the field of research and development;
2. Transferring key technologies into other areas of the economy, primarily industries and vital areas.

After the system has been established, specific development projects for energy production technologies can be planned.

Energy production industry is a servicing sector; its development trends can be planned ahead, taking into account certain existing patterns. The developments of the energy technologies across different levels of the field are planned on the basis of the development directions of the society (Fig. 2*)*.

Information
about external
environment
Current state
– statistics;
–universities,
research centres;
– companies;
– main activities;
Future trends and
objectives
– trends;
– technology roadmaps;
– technology pyramids;
– life cycles;
–competition, customers;
Future development
areas
– reduction of energy
consumption;
– new energy sources
and technologies;
Process of
preliminary
studies
1. Scope of survey (definition and fine-tuning the scope of the development
strategy project roles and resources)
2. Analysis and evaluation of the current state based on Estonian basic
data
3. University and research centre face-to-face interviews (20–30 persons)
4. Company face-to-face interviews (separately to energy producers, distributors
and users, 20–30 persons)
5. International benchmarking and objective current state analysis
(Boston)
7. Commitment and fine-tuning workshop(s): presentation of the
development strategy project results; commitment; strategic decisions;
future development states and main actions;
8. Mutually agreed conclusions, main findings and answers to key questions
9. Detailed action plans (key state holders)
10. Implementation
11. Follow up
Information
about internal
environment
Current state
– statistics;
–universities,
research centres;
– companies;
– main activities;
Future trends and
objectives
– resources and competences;
– technologies;

– networking and partnerships;
Future development
areas
– to be determined in
the project
Source: * Ministry of Economy and Communications, 2007
Fig. 2. Field levels of energy production technologies.

Overall goals of the Energy Technology Programme (*ETP)*:
1. Optimum use of the resources directed into this field;
2. Improving the co-operation within a sector, between the state and the sectors, and between different sectors;
3. Developing human resources and research potential;
4. Supporting R&D and innovation in the field; supporting technology transfer.

Relations of the Energy Technology Programme (ETP) to the R&D complex of the entire country and the National Innovation System (RIS) are presented in Fig. 3.

Source: Ministry of Economy and Communications, 2007
Fig. 3. Relations of the Energy Technology Programme to the R&D and the National Innovation System.

Reorganising economy to be knowledge-based is an activity that has to be supported by energy industry. Historically there have been different reasons for establishing ways of thinking, and also different consequences. Transition from skill-based economy to knowledge-based economy takes place in several development steps (Fig. 4).

1970–1980
Skills-based economy
“OLD ECONOMY”
Preserving existing
industries
1980–1990
Competence-based economy
“TRANSITION-TIME
ECONOMY”
Adjusting to industrial changes
1990–2000+
Knowledge-based economy
“NEW ECONOMY”
Establishing knowledge-based
industries
FOCUS
“Ability to do”
Less attention towards
“understanding” and
personal competencies
(attitudes)
FOCUS
Wide-scale comprehensive

competencies
Increasingly more attention
towards integrating technological,
social and personal
competencies and attitudes
FOCUS
Integrating formal and
informal (practice-based)
knowledge and know-how
Including dimensions related
to business activities, technologies,
social / organisational
aspects and self-management
SKILLS,
KNOWLEDGE,
ATTITUDE
SKILLED WORKER
SKILLS, KNOWLEDGE,
ATTITUDE
COMPETENT WORKER
SKILLS, KNOWLEDGE,
ATTITUDE
KNOWLEDGEABLE
WORKER
1970 1980 1990 Year
Source: Nyhan 2002

Fig. 4. Transition from skill-based economy to knowledge-based economy.

Conclusions

Innovation factors in the field of energy

Prerequisites:

1. Gathering the existing knowledge and material resources into a unified research and development institution of energy industry;
2. Ensuring continuity in energy-related education; transferring the experience of researchers;
3. Co-operation between entrepreneurs, researchers and developers.

Innovation results:

1. Mapping the resources**;**
2. Connecting the possible solutions to the attitudes of the society and to the overall trend**;**
3. Establishing a sustainable energy industry conforming to the expectations of the society

All this requires a smooth co-operation between the public sector, entrepreneurs and the third sector.

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