WORLD ENERGY COUNCIL
CONSEIL MONDIAL DE L'ÉNERGIE
For sustainable energy.

Polish Member Committee of the World Energy Council

ENERGY SECTOR OF THE WORLD AND POLAND

BEGINNINGS, DEVELOPMENT, PRESENT STATE

Second edition, updated

Warsaw, December 2014

Contents

Foreword

I pass into your hands the second edition of the report entitled *Energy Sector of the World and Poland – Beginnings, Development, Present State*. This report constitutes an update of the first edition which was elaborated for the Polish Member Committee of the World Energy Council in the year 2012 by Dr Jan Soliński.

A development of mankind and of the global economy is closely connected with the use of energy. In the ancient times and through the period of antiquity a man used the simplest forms of energy which exist in the nature. The substantial growth of energy use took place in Middle Ages and subsequently in the modern times with the development of the marine transport and the handicraft, and particularly with the development of industry in 18th and 19th centuries. No credible information concerning the quantities of energy consumed during that time by the mankind is however available.

First statistics of energy production and consumption were introduced in economically developed countries after the First World War, though the estimates of global production and consumption of energy were still not existing. Only after the Second World War, and particularly after the oil crisis of 1970s, the activities were initiated aimed to create the systems of energy statistics which would enable to publish data on the global production and consumption of energy as well as the comparable energy data of the individual countries.

Polish Committee of the World Energy Council has decided to collect the appropriate numerical data and to elaborate the review report which would characterise the development of the energy sector of the world and Poland, starting from the middle of 19th century, and reviewing in more detail the period after the Second World War and the first decade of 21st century. The report is based on the available materials and statistical data published by various international organisations as well as on the Polish materials and statistics, particularly those published by the Central Statistical Office and the Energy Market Agency.

Numerical data contained in the present report were already partly used in the recent years in various publications of the Polish Committee of the World Energy Council.

I express the hope that the present report, containing the review of the energy situation of the world and Poland, will be the useful source of the energy information presented in the single document, both for the members of the Polish Committee of WEC and for various readers interested in the development of the energy sector.

Recommending the present report, I would like to remind that Polish Committee is the National Committee of the World Energy Council which is the global non-governmental organisation of the energy experts, active since 1924, and that Poland was one of the founding member countries of the WEC. The objective of the WEC activities is to promote the development and the peaceful exploitation of the energy sources, to the greatest benefit of all at both national and global scales. Presently the World Energy Council associates almost 120 national Member Committees, representing almost all countries important for the global economy, which account in total for over 90% of the world's energy consumption.

Henryk Majchrzak

Chairman of the Polish Committee
of the World Energy Council

Introduction

The basic objective of the present report is to compile and to present in a single document the data on the development of the global and Polish energy sector in the period from the middle of 19th to the beginning of 21st century, i.e. for the period of time which counts approximately 150 years.

First section of the report presents the synthetic review of the past development of the energy use by mankind, starting from the ancient times and the antiquity, through the modern times to the end of 18th century. The following sections present the outline of the development of the energy production and use, caused by the industrial revolution of the 19th century as well as the description of the dynamic development of the energy sector of the world and Poland in 20th century, and particularly in its second half.

The report is composed of two Parts. Part One presents the information concerning the development of the global energy sector, and Part Two contains the review of the development of Polish energy sector.

The level of detail of the information and assessments, concerning the development of the global and Polish energy sector, is diverse for the different periods of time because of the unavailability of some necessary data for some periods.

Data on the energy production are very scarce or non-existing for the period of 19th century and the first years of 20th century, i.e. up to the First World War. Some estimated or approximate data for that period, compiled by various authors, were therefore used in the report.

The more rich and better documented energy data exist for the period between First and Second World War, though any organised systems of energy statistics were not yet elaborated or introduced during that period of time. The existing international organisations did not compile such statistics in any organised form. The first attempts to collect the energy statistical data were performed by the World Energy Council which was founded in 1924, with the participation of Poland as one of the founding member countries. This organisation started to make also the surveys of energy resources and the assessments of the power industry development.

The collection of well documented data on the development of the global energy sector and the energy sectors of individual countries started after the Second World War.

The United Nations Organisation (UNO), founded in 1945, started to collect this type of data and publish them in the reports entitled „World Energy Supply – Statistical Papers". In 1974, after the first oil crisis, the International Energy Agency was established. This Agency has created the unified and integrated system of energy statistics, and basing on this system started to publish the statistical reports concerning various aspects of the energy sector activities. Therefore the numerical data concerning the development of the global – including Polish – energy sector are unified, detailed and extensive for the years since 1970s.

Preparation of the present report was based on many various textbooks and statistical sources, both foreign and Polish.

We express the hope that the present report will be the useful source of information not only for the members of the Polish WEC Committee but also for the wider circle of people interested in the history and the modern development of the global and Polish energy sector. The English language version of the report may constitute a source of information for the other national committees of the WEC as well as for various readers interested in the development of the energy sector, and particularly of the Polish energy sector.

Part I

ENERGY SECTOR OF THE WORLD

1

GENERAL CHARACTERISTICS OF THE HISTORY OF HUMAN USE OF ENERGY

1.1. Ancient times and antiquity

Human use of the energy carrying raw materials and energy sources dates back to the ancient times – it is as old as the human civilisation. The life of mankind and of the animals would not be possible without the energy taken from the environment, because the consumption of energy is a very basis for all processes of life in the Earth. Besides food and air, the energy is one of the most important material requirements of the human being. Without the energy taking and use, a man would be fully dependent on the nature and would not achieve even a fraction of its current development. Social and economic development of the world was and still is connected with the consumption of energy.

The basic biological energy requirements of the humans and all living organisms were always satisfied through the consumption of food. Later, in order to improve his living conditions, the humans started to utilise the other simplest forms of energy, and the quantities of this energy were gradually increasing with the development of living conditions.

A review of the development of energy applications indicates that a man went a very long way from his quest for naturally occurring fire in the very old times to the current applications of energy. The primeval human performed all activities with the power of his own muscles. Subsequently, with the progress of his intellectual development, a man started to apply the natural sources of energy which were able to made his life easier [35, 37].

The oldest form of energy, applied already in the very ancient times – probably as early as 500 thousand years BC – was the thermal energy obtained from burning wood, plants or a dried manure, used in order to prepare food and heat a body.

Somewhat later than thermal energy a man started to use the lighting energy, in a form of torch or cresset. The subsequent milestones of the energy progress of mankind were, particularly in the recent millenniums, the following:

- use of animal power instead of power of human muscles,
- initiation of wind power application around 3 thousand BC (sail ships, windmills) and of hydro energy application by the end of the ancient era (water wheel),
- production and use of charcoal which in the bronze age and later in the iron age became the basic source of energy for the developing metallurgy.

1.2. Modern times to the end of 18th century

Substantial development of the energy applications took place during the Middle Ages and the Renaissance period, and particularly in the 18th century, laying the foundations for the industrial revolution. The most important applications of energy during that period comprised:

- development of marine navigation and use of wind energy to drive the sail ships,
- construction of windmills which allowed to pump water for the agricultural irrigation, to mill grain etc.,
- development of metallurgy through wide application of bloomeries and subsequently of the furnaces for the iron smelting – the first energy source for metallurgy was the charcoal, gradually substituted by hard coal and coke,
- wide application of hydro energy in the grain milling, in textile manufactures, in sawmills –

the invention of the hydro turbine in the middle of the 18th century was an important milestone in the application of hydro energy,

- local application of hard coal acquired from the shallowly located seams (China, Belgium, Saxony and other countries), and subsequently in the second half of the 18th century the rapidly increasing consumption of coal in the metallurgical industry, for coke production and for space heating.

1.3. Period of industrial revolution and of the economic development in 19th and 20th centuries

Dynamic progress of the energy applications was connected with the beginning of an industrial era at the turn of the 19th century, and with the global economic development in 19th and 20th centuries. The key factors of this development were:

- invention of steam engine (1769) and the application of coal to drive it what in the 19th century revolutionised the world through the rapid development of the industry and transportation; therefore 19th century is frequently called the century of coal;
- invention of the internal combustion engine at the end of 19th century and rapid development of automotive transport which had its consequences in high growth of oil consumption, particularly in the second half of 20th century;
- discovery of large fields of natural gas and the appreciation of its advantages as fuel and raw material which resulted in the rapid growth of its applications, particularly in the second half of 20th century;
- initiation in the 19th century of the electricity generation and consumption and its large scale application in 20th century; electricity became the most universal and the most versatile form of energy; the nuclear energy has also been applied for electricity generation in the second half of 20th century.

Particularly rapid enlargement of the energy applications and quick increase of the global energy consumption has occurred after the Second World War. Annual average growth rate of primary energy consumption amounted to 4.9% in the period 1950-1970, with the different growth rates for the individual fuels. Consumption of oil and natural gas was increasing rapidly and the growth of hard coal consumption had slowed down. Oil became the basic source of energy, particularly because its prices were the lowest.

The advantageous situation in the global supply of energy had collapsed in the 1970s. The first energy crisis occurred in 1973 and the second crisis in 1980. During both crises the availability of crude oil severely decreased and its prices had grown dramatically. High prices of oil, accompanied also by growing prices of coal and natural gas, had pushed the global economy into stagnation and recession.

The energy crisis was very severe not only for the developed countries, but for all energy importing countries. The crisis happened to be particularly painful for the poor, less developed countries in which over 1.5 billion of people still have no access to electricity.

In 1980s the energy crisis had been mitigated. The positive consequence of the crisis was the intensification of the multidirectional activities aimed at the rationalisation of the energy economy. These activities resulted in the substantial growth of energy efficiency and decrease in energy intensities of many national economies.

When characterising the energy economy of the last decades of 20th century, it should be underlined that with the rapid development of the worldwide energy sector, the new global threat, which was the consequence of the fossil fuels combustion, has occurred. Large emissions of greenhouse gases, and particularly of CO_2, from fossil fuels combustion resulted in global warming of the world atmosphere and in the dangerous climatic changes.

2

MAIN DRIVING FORCES OF THE ENERGY DEMAND GROWTH

2.1. Population growth

In the first centuries of the second millennium the growth of world population was very slow. During the period of 750 years (900-1650) the global population had increased by only 190 million, i.e. the annual average growth did not exceed 0.3 million. The quicker growth of population, by over 2 million people per year, has started during the period 1700-1800. The further acceleration of the population growth took place in 19th century, and particularly in its second half when the annual average growth has reached 9 million people. This was connected with the accelerated economic growth of the world.

Global population growth was very dynamic in the first half of 20th century – from 1.6 billion in 1900 to 2.5 billion in 1950, so the annual average growth has reached 18.6 million. Then the demographic explosion took place in the second half of 20th century, driving the global population to almost 6.1 billion in 2000. Therefore the population has increased by as much as 3.6 billion during the last five decades of 20th century.

Changes of the global population during the years 900-2014 are presented in Table 2.1.

Table 2.1. World population in the years 900-2014

Years	Population: Total [million]	Population: Annual average growth [million]	Years	Population: Total [million]	Population: Annual average growth [million]
900	320		1960	3021	
1650	510	0,3	1970	3697	67,6
1700	600	1,8	1980	4438	74,1
1750	710	2,2	1990	5262	82,4
1800	910	4,0	2000	6073	81,1
1850	1130	4,4	2005	6460	77,4
1900	1590	9,2	2008	6688	76,0
1950	2520	18,6	2014	7243	92,5

Source:: [15, 27, 34, 38]

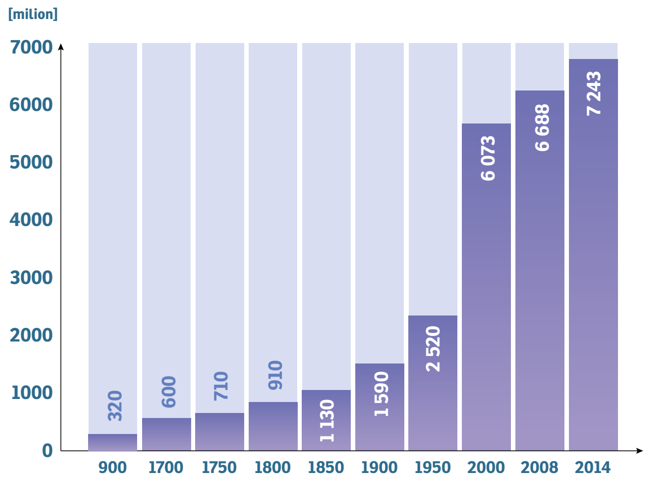

Fig. 1. World population in the years 900-2014

A dynamic growth of world population, which has occurred in the last decades of 20th century – and is still occurring presently – took place mainly in the developing countries, particularly in Africa, South Asia and Latin America. Very high growth of population has also occurred and is still occurring in the countries of Middle East.

Among the developed countries, the relatively high growth of population took place in the countries of North America, i.e. in USA, Canada and Mexico.

Growth of the world population by regions of the world in the last decades of 20th century and the first decade of 21st century is presented in Table 2.2.

2.2. Economic growth

The economic growth of the world and of the individual countries is – besides the growth of population – the main driving force of the energy demand and of the energy sector development.

A sum of Gross Domestic Products (GDP) of all countries is the synthetic measure of the global economic development.

Various international publications and statistical sources show the amounts of Gross Domestic Products most frequently in US dollars (USD):

Table 2.2. World population by regions 1971-2011

Regions	Population [million]						1971 =100 [%]
	1971	1980	1990	2000	2008	2011	
A. OECD							
North America	280	318	359	411	446	473	169
Europe	448	474	498	522	540	555	124
Pacific	154	173	187	197	204	213	138
Total OECD	882	965	1044	1130	1190	1241	141
B. Non-OECD							
Africa	372	478	635	815	984	1045	281
Latin America	238	291	356	419	462	460	193
Asia [1]	1058	1303	1607	1931	2183	2313	219
China	845	986	1141	1269	1332	1351	160
Europe [2]	53	56	59	55	53	53	100
Former USSR	245	266	289	288	285	286	117
Middle East	68	92	132	166	199	209	307
Total Non-OECD	2878	3474	4219	4943	5498	5717	199
C. World	3760	4439	5263	6073	6688	6958	185

1) Asia excluding China
2) Non-OECD Europe excluding former USSR
Source: [15, 16, 34]

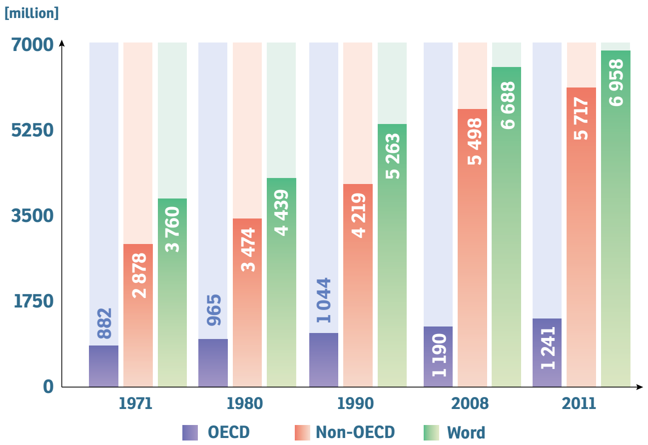

Fig. 2. World population by regions 1971-2011

- by the bank exchange rates,
- by the Purchasing Power Parities (PPP).

A total of GDPs of all countries, expressed in USD (in constant prices) with due regard to the Purchasing Power Parities for different periods constitutes the main measure of the economic growth of the world. This measure is applied also in the research of the energy sector development.

Comparable data on GDPs of many countries are available in the international statistical sources since 1971. Therefore the GDPs by world regions, expressed in USD in constant prices of 2000, are presented in Table 2.3 for the years 1971-2011.

Table 2.3. Growth of GDP by world regions 1971-2011

Regions	GDP by exchange rates [billion USD 2000]		GDP by PPP [billion USD 2000]		1971= 100 [%]
	1971	2011	1971	2011	
A. OECD					
North America	4 329	13 784	4 492	14 325	319
Europe	4 321	13 979	5 300	13 495	255
Pacific	2 153	6 080	1 676	5 727	342
Total OECD	10 802	33 843	11 467	33 547	293
B. Non-OECD					
Africa	203	1 121	771	2 490	323
Latin America	529	2 034	1 152	3 897	338
Asia [1]	320	2 997	1 253	7 743	618
China	133	3 917	471	9 103	1 933
Europe [2]	64	256	175	519	297
Former USSR	404	1 158	1 666	2 725	164
Middle East	254	1 125	446	2 203	494
Total Non-OECD	2 063	12 608	5 934	28 680	483
C. World	12 865	46 451	17 401	62 227	358

1 Asia excluding China
2 Non-OECD Europe excluding former USSR
Source: [15, 16]

The level of GDP was very different between the world regions in the considered period – high in OECD countries and considerably lower in Non-OECD. Particularly extreme differences between the GDP levels are revealed when comparing per capita indicators. In many developing countries, particu-

Tabela 2.4. Wskaźniki PKB per capita wybranych krajów OECD i Nie-OECD w latach 1971 (1970) i 2011

Country	GDP per capita by PPP [USD 2000]		1971=100 [%]
	1971[x]	2011	
A. OECD in which:	13 001	27 032	208
USA	18 151	37 511	207
Germany	13 274	30 603	231
Norway	14 330	41 384	289
Switzerland	23 189	35 043	151
Japan	12 100	27 223	225
Poland	6 065	15 899	262
B. Non-OECD in which:	2 081	5 017	241
Congo	2 353	291	12
Ethiopia	917	866	94
Sudan	805	1 818	226
Mozambique	1 010	762	75
Nigeria	942	1 980	210
Kenya	854	1 335	156
Bangladesh	1 052	1 389	132
India	1 082	2 835	262
China	558	6 565	1 177
Vietnam	938	2 667	284
South Africa	9 203	8 565	93
C. World	4 628	8 943	193

x Indicators for OECD countries refer to 1970
Source: Own calculations based on [15, 16]

larly African and South Asian, the levels of per capita GDP are still a dozen or even several dozen times lower than the levels in OECD countries.

Comparison of per capita GDPs for the selected countries – calculated by the Purchasing Power Parity – is presented in Table 2.4.

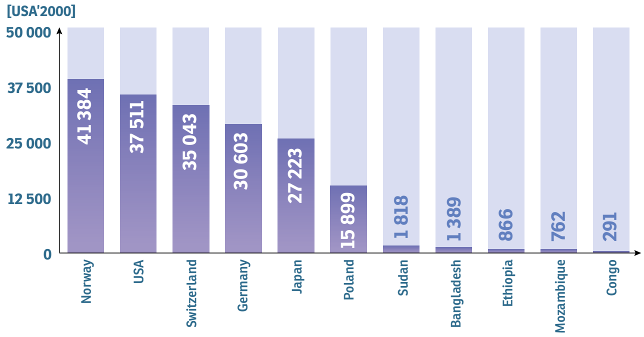

Fig. 3. Selected countries with the highest and the lowest GDP per capita in 2011 (by PPP)

3 GLOBAL RESERVES OF ENERGY COMMODITIES AND THEIR CLASSIFICATION

The basic source of information on the global resources and reserves of the energy commodities, quoted in the present report, are the cyclical publications prepared by the World Energy Council (WEC) on the occasion of the World Energy Congresses. Until the year 2010 the studies had the title *Survey of Energy Resources* and the latest publication, presented at the Energy Congress in Daegu in 2013, was published under the title *World Energy Resources*.

The Surveys of Energy Resources published by WEC apply two basic categories of fossil fuel reserves:

- Resources (Proved Amount in Place),
- Proved Recoverable Reserves.

Proved Amount in Place is the total amount of fuels that has been documented and assessed as exploitable. Proved Recoverable Reserves is the part within the Proved Amount in Place that can be recovered (extracted) under current technical and economic conditions.

WEC applies also the additional category of non-documented resources (additional amount in place), part of which may potentially be extracted under the existing conditions (additional recoverable reserves).

The information below refers mainly to the Proved Recoverable Reserves, exploitable under the present conditions.

Classification of resources and reserves of energy commodities

WEC applies in its Surveys of Energy Resources the main division of commodities into two categories:

- non-renewable (Finite Resources),
- renewable (Perpetual Resources).

Non-renewable resources and reserves of energy commodities comprise:

- hard coal and lignite,
- crude oil, including the natural gas liquids (NGL),
- oil shale,
- natural bitumen and extra-heavy oil,
- natural gas,
- uranium.

Resources and reserves of renewable energy include:

- hydro energy,
- bioenergy (wood, energy crops, agricultural waste, renewable fractions of industrial and municipal waste),
- solar energy,
- geothermal energy,
- wind energy,
- tidal energy,
- wave energy,
- ocean thermal energy.

3.1. Global reserves of non-renewable energy commodities

A comparison of the subsequent assessments of the reserves of non-renewable energy commodities reveals that despite the high production and consumption in the last decades – particularly of hydrocarbon fuels – the quantities of reserves have substantially increased. This is the result of new discoveries, technological progress in the exploration for new deposits etc. Also the comparison of the present reserves of non-renewable energy commodities with the quantities of their resources published in 1974 shows that the potential resources are many times larger than the recoverable reserves indicated in the subsequent Surveys of Energy Resources.

The global quantities of the resources and reserves of non-renewable energy commodities are presented in Table 3.1.

3.2. Hard coal and lignite

Global reserves of hard coal and lignite, classified by the World Energy Council as proved recoverable reserves, are equal to 892 billion Mg, of which

Table 3.1. World resources and reserves of fossil fuels 1974-2013 by the assessments of the World Energy Council

Fuel	Potential resources Assessment 1974 [62]	Proved recoverable reserves				
		Assessment 1974 [62]	Assessment 1986 [63]	Assessment 1995 [64]	Assessment 2010 [66]	Assessment 2013 [78]
Hard coal [billion Mg]	8100	476,0	566,0	716,5	665,6	690,5
Lignite [billion Mg]	2600	219,0	272,0	315,0	195,4	201,0
Crude oil [billion Mg]	300	89,7	94,0	140,6	163,0	182,8
Natural gas [trilion m^3]	283	64,8	85,5	141,3	185,5	209,7

Source: [62, 63, 64, 66, 78]

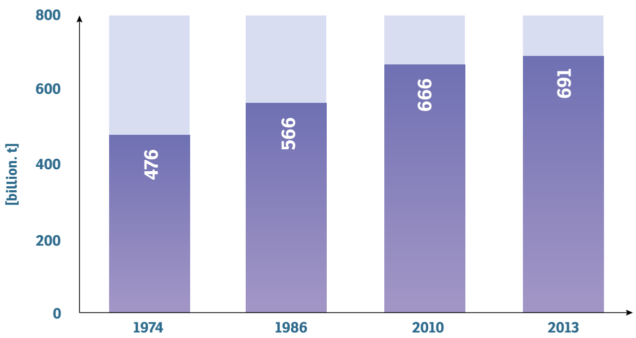

Fig. 4. World reserves of hard coal according to WEC Surveys 1974, 1986 and 2013

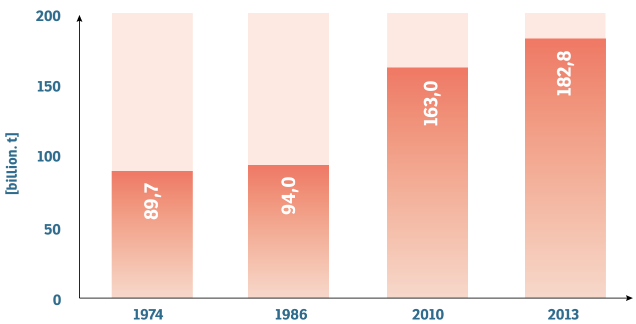

Fig. 5. World reserves of crude oil according to WEC Surveys 1974, 1986 and 2013

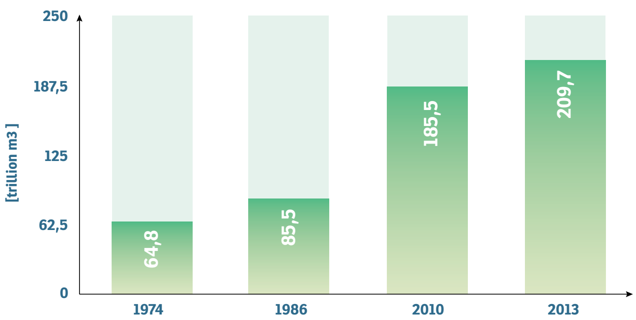

Fig. 6. World reserves of natural gas according to WEC Surveys 1974, 1986 and 2013

691 billion Mg is hard coal and 201 billion Mg lignite. By the quantity of its reserves, coal is the main energy commodity of the world.

It is estimated that the total amount in place of coal is more than 10 times higher than its proved recoverable reserves, i.e. the quantities which can be recovered under present technical and economic conditions.

It should be mentioned that the quantities of the global coal reserves are different according to the estimations by various institutions, what is a consequence of non-existence of a unified methodology of the reserves assessment. UN Economic Commission for Europe is working on the unification of such methodology of reserves classification.

Reserves of coal are present in around 75 countries of the world, but their distribution over the globe is not even. The biggest reserves of hard coal are located in USA, Russian Federation, China, India and Australia. The biggest reserves of lignite are possessed by Germany, Australia, USA, China and Serbia.

The countries having the large reserves of coal are listed in Table 3.2.

Table 3.2. Countries having the largest reserves of hard coal and lignite, as at the end of 2011

Hard coal		Lignite	
Country	Reserves [billion Mg]	Country	Reserves [billion Mg]
1. USA	207,1	1. Germany	40,5
2. Russian Fed.	146,6	2. Australia	37,2
3. China	95,9	3. USA	30,2
4. India	56,1	4. China	18,6
5. Australia	39,2	5. Serbia	13,4
6. Ukraine	31,9	6. Kazakhstan	12,1
7. South Africa	30,2	7. Russian Fed.	10,5
8. Indonesia	28,0	8. Turkey	8,4
9. Kazakhstan	21,5	9. India	4,5
10. Colombia	6,7	10. Greece	3,0
11. Brazil	6,6	11. Bosnia	2,4
12. Canada	4,3	12. Canada	2,2
Poland	4,2	Poland	1,3
Rest of the World	12,2	Rest of the World	16,7
World	690,5	World	201,0

Source: [78]

3.3. Hydrocarbons – crude oil and natural gas

Crude oil

According to the assessment by WEC, the global reserves of crude oil and natural gas liquids (NGL) were equal to 183 billion Mg in 2011. These reserves were bigger than assessed previously. In comparison with 1995 assessment, they were bigger by 42 billion Mg.

Reserves of crude oil and natural gas liquids are present principally in the countries of Middle East, where 48% of the global reserves are located. The remaining parts of the oil reserves are located in: Latin America – 19%, North America – 13%, Europe (including Russian Federation) – 9%, Africa – 8%, and Asia (excluding Middle East) – 3%.

At a current rate of global oil production the value of the R/P indicator (reserves to production) shows that the existing reserves would be sufficient for about 48 years of production.

Geographical location of the main reserves of crude oil and NGL is presented in Table 3.3.

Table 3.3. Countries having the largest reserves of crude oil and natural gas liquids, as at the end of 2011

Country	Reserves [million Mg]	Country	Reserves [million Mg]
1. Saudi Arabia	36 201	10. USA	4 215
2. Venezuela	28 780	11. Kazakhstan	4 092
3. Iran	20 624	12. Qatar	3 465
4. Iraq	15 686	13. Algeria	3 170
5. Kuwait	13 845	14. China	2 783
6. UAE	13 340	15. Brazil	2 053
7. Russian Fed.	8 184	16. Mexico	1 367
8. Libya	6 424	Rest of the World	13 455
9. Nigeria	5 074	World	182 758

Source: [78]

Natural gas

Conventional natural gas occurs in the earth in two types of fields [53]:

- non-associated or dissolved gas, which is not combined with crude oil deposits,
- associated or cap gas, which is combined with crude oil, covers the upper boundary of the oil deposit and makes a kind of cap over this oil.

Moreover, two types of deposits of the unconventional natural gas exist in many countries [27]:

- methane, contained in the seams of coal (coal-bed methane),
- shale gas, contained in the sedimentary rocks, which became the increasingly important source of natural gas in the recent years.

According to the recent assessment by WEC, the global reserves of conventional gas were equal to 209.7 trillion m^3 at the end of 2011. Similarly to crude oil, these reserves were bigger than previously. In comparison with 1995 assessment, they were bigger by 68 trillion m^3 and in comparison with 2005 bigger by 24 trillion m^3.

Total size of the world reserves of conventional natural gas, published in the WEC assessment, is confirmed also by British Petroleum and by the Italian oil and gas corporation ENI.

The reserves of natural gas, similarly to crude oil, are not distributed evenly over the globe. The largest portions of the global reserves of conventional gas are located in: Russian Federation – 22.8%, Iran – 16.1%, Turkmenistan – 12.0% and Qatar – 12.0%.

Geographical location of the main reserves of natural gas is presented in Table 3.4.

Table 3.4. Countries having the largest reserves of conventional natural gas, as at the end of 2011

Country	Reserves [billion m^3]	Country	Reserves [billion m^3]
1. Russian Fed.	47 750	9. Nigeria	5 110
2. Iran	33 790	10. Algeria	4 502
3. Turkmenistan	25 213	11. Indonesia	3 993
4. Qatar	25 200	12. Iraq	3 158
5. Saudi Arabia	8 028	13. China	3 030
6. USA	7 716	14. Kazakhstan	2 407
7. UAE	6 089	Rest of the World	28 232
8. Venezuela	5 524	World	209 742

Source: [78]

3.4. Bitumen

The Earth contains, besides crude oil, the rich deposits of bitumen, i.e. oil shale, oil sands and extra-heavy oil. All of them may be used as a raw material to produce crude oil and the petroleum products.

Oil shale

Oil shale is a rock which contains relatively large amounts of organic matter, known as kerogene, from which around 40 litres of oil may be obtained per 1 Mg of shale, applying the complicated technological processes.

World in-place resources of oil shale are huge. According to the WEC assessment, they contain almost 700 billion Mg of oil [78]. The largest resources are located in USA, and relatively big are possessed also by China, Russian Federation, Congo and Brazil. Many other countries also have some resources of oil shale. The resources are exploited at a limited scale, mainly in USA, Brazil, China and Estonia.

Little use of oil shale is a consequence of high costs of fuel production from such raw material. The world production of oil from shale amounted to 15 million Mg in 2011. In Estonia oil shale is directly used as a fuel for electricity generation.

Oil sands

Oil sands are the unconventional deposits of bitumen matter which are composed of oil, asphalt, sand and mud.

The largest deposits of oil sands are located in Canada – it is around 2/3 of the global resources. Substantial deposits of oil sands are possessed also by Russian Federation, Kazakhstan and USA.

Rich resources of oil sands located in Canada, in Alberta province, contain 1.73 trillion barrels, i.e. about 200 billion Mg of oil [67].

Presently Canada is the leading producer of oil from sands. In 2008 more than 40% of the total Canadian oil production originated from sands [67], and total national production of oil amounted to 159 million Mg [22].

High prices of crude oil at the international market have motivated the substantial intensification of the unconventional oil production from sands. Costs of such production became competitive comparing to the conventional production of oil.

Extra-heavy oil

Deposits of extra-heavy oil are possessed by 21 countries, and the largest are located in Venezuela, mainly at the Orinoco Belt. These deposits are estimated at 1.9 trillion barrels of oil (around 260 billion Mg).

Oil production from these resources is already high in Venezuela. In 2008 it amounted to 90 thousand barrels of oil per day. Costs of oil production from the extra-heavy resources in Venezuela are lower than the cost of oil production from sands in Canada.

Table 3.5. Countries having the largest resources of oil shale, oil sands and extra-heavy oil, as at the end of 2008

Resources of oil shale		Resources of oil sands and extra-heavy oil		
Country	[billion Mg of oil]	Country	[billion barrels of oil]	[billion Mg of oil]
1. USA	536,9	1. Canada	2 434,2	333,0
2. China	47,6	2. Venezuela	2 111,5	290,0
3. Russian Fed.	35,5	3. Kazakhstan	420,7	57,0
4. Congo	14,3	4. Russian Fed.	346,7	47,0
5. Brazil	11,7	5. USA	56,1	7,7
6. Morocco	8,2	6. Madagascar	16,0	2,2
7. Australia	5,5	7. Congo	5,0	0,7
8. Jordan	5,2	8. Angola	4,6	0,6
Rest of the World	24,4	Rest of the World	83,8	11,5
World	689,3	World	5 478,6	749,7

Source: [66]

Table 3.5 presents the quantities of the world resources of bitumen (oil shale, oil sands and extra-heavy oil). It should be explained that the WEC Survey of Energy Resources does not contain data on the recoverable reserves of bitumen. Moreover, the resources of oil sands and extra-heavy oil are specified in million barrels. Table 3.5 contains these data recalculated into Mg, under the assumption that 1 Mg of oil is equal to 7.3 barrels.

Data in Table 3.5 indicate that the global resources of bitumen are huge, larger than the global resources of conventional crude oil. The Canadian source [22] confirms this fact and indicates that the reserves of unconventional oil in Canada are substantially bigger than the reserves of conventional oil in Saudi Arabia.

Taking these facts into account, it may be concluded that the reserves of oil, including all types of bitumen, will cover the global demand at least to the end of 21st century.

3.5. Uranium ores

Table 3.6. Countries having the largest resources of uranium, as of 1 January 2013

Country	Uranium recoverable at [1000 Mg]			
	<40 USD/kg	<80 USD/kg	<130 USD/kg	<260 USD/kg
Namibia			248,2	296,5
Niger		14,8	325,0	325,0
South Africa		113,0	175,3	233,7
Canada	256,2	318,9	357,5	454,5
USA		39,1	207,4	472,1
Brazil	137,3	155,1	155,1	155,1
China	51,8	93,8	120,0	120,0
India				97,8
Kazakhstan	20,4	199,7	285,6	373,0
Mongolia		108,1	108,1	108,1
Uzbekistan	41,7	41,7	59,4	59,4
Russian Federation		11,8	216,5	261,9
Ukraine		42,7	84,8	141,4
Australia			1 174,0	1 208,0
Rest of the World	0,0	72,9	182,0	280,7
World	507,4	1 211,6	3 698,9	4 587,2

Source: [79]

Uranium ores are possessed by 47 countries, and the largest resources are located in Australia, USA, Canada and Kazakhstan. Resources of uranium ores are categorised according to the cost of uranium production.

The Reasonably Assured Resources, categorised according to the cost of uranium production, amount to:

< 40 USD/kg U – 507 thousand Mg,
< 80 USD/kg U – 1212 thousand Mg,
< 130 USD/kg U – 3699 thousand Mg,
< 260 USD/kg U – 4587 thousand Mg.

Besides the Reasonably Assured Resources many countries have the undiscovered or prognostic resources which are estimated to be higher than 10 million Mg of uranium.

Many countries have also the substantial resources of thorium, the alternative nuclear fuel. Its isotope Th-232 may potentially be used in the breeder reactors for the production of U-233 uranium isotope.

Major producers of uranium are presently: Kazakhstan, Canada, Australia, Niger, Namibia and Russian Federation.

The Reasonably Assured Resources of uranium, categorised by the cost of production, are presented in Table 3.6.

3.6. Renewable energy sources – general characteristics

Solar energy is the most abundant and the most permanent natural source of energy for our planet. The annual solar radiation reaching the Earth is over 7500 times higher than the annual global consumption of energy, though the intensity of solar radiation is different in various parts of the globe [66].

Solar energy reaching our planet is the primary raw material for all renewable energy sources: hydro, biomass, peat, wind, wave and tidal energy as well as ocean thermal energy. Solar energy is therefore the indirect source for originating of all existing renewable sources of energy. Solar energy is also used directly in solar thermal collectors and in photovoltaic installations.

World resources of renewable energy are huge, particularly the resources of hydro energy, wind energy and biomass. These resources already constitute an important component of the global supply of energy. It is expected that the climate change considerations as well as the technological progress in the field of renewable energy will motivate the quick growth of renewable energy applications, including the direct applications of the energy of solar radiation.

Quantities of resources and the synthetic characteristics of the renewable energy types are presented below, in subsequent sections of the report.

Table 3.7. Countries having the largest resources of hydro energy and its use

Country	Gross theoretical capability [TWh/year]	Technically exploitable capability [TWh/year]	Electricity generation [TWh]	Actual use of technically exploitable capability [%]
Congo	1 397	774	7,9	1,0
Ethiopia	650	260	6,6	2,5
Cameroon	294	115	4,5	3,9
Madagascar	321	180	0,7	0,4
Canada	3 009	1 834	391,6	21,4
Mexico	430	135	27,4	20,3
USA	2 040	1 339	271,8	20,3
Argentina	354	169	40,7	24,1
Brazil	3 040	1 250	385,4	30,8
Colombia	1 000	200	44,2	22,1
Peru	1 577	395	21,2	5,4
Venezuela	731	261	84,0	32,2
Afghanistan	394	88	1,0	1,1
China	6 083	2 474	911,7	36,9
India	2 638	660	131,7	20,0
Indonesia	2 147	402	15,5	3,9
Japan	718	136	82,2	60,4
Nepal	733	154	2,8	1,8
Pakistan	475	204	32,7	16,0
Tajikistan	527	264	16,9	6,4
Turkey	433	216	59,2	27,4
France	270	100	68,5	68,5
Norway	600	240	129,0	53,8
Russian Federation	2 295	1 670	181,2	10,9
Australia	265	100	19,9	2,0
Rest of the World	7 421	2 375	843,7	35,5
World	39 842	15 955	3 782	23,7

Source: [66, 82]; capability – 2008 data (still valid – capability does not change in time), generation – 2013 data

3.7. Hydro energy resources

Resources of hydro energy are expressed in the quantities of electricity which can be obtained annually from water flows.

According to the terminology used by the World Energy Council, the world resources of hydro energy are estimated as follows:

- gross theoretical capability – approx. 39800 TWh/year,
- technically exploitable capability – 15955 TWh/year,
- actual electricity generation in 2013 – 3782 TWh.

The world resources of hydro energy are presented in Table 3.7

Data presented in Table 3.7 indicate that the actual use of the technically exploitable capability is rather low, at the level of slightly over 20% only. Particularly low level of the actual use of capability occurs in the developing countries.

3.8. Biomass resources

Resources of biomass comprise: wood, energy crops, agricultural waste as well as renewable fractions of industrial and municipal waste which may be applied as a source of energy.

The global theoretical energy potential of biomass, including marine algae, is huge, estimated to be 1500 EJ/year (35 Gtoe). The exploitable potential is however limited to 200-500 EJ/year (5-12 Gtoe) [66].

The present global consumption of biomass for energy purposes is approx. 54 EJ/year (1.3 Gtoe), what constitutes about 10% of the global consumption of primary energy. Large part of this biomass is wood and wood waste burned mainly in the inefficient stoves used for space heating and food cooking, particularly in the developing countries. Wood consumption by world regions is presented in Table 3.8.

Table 3.8. Wood consumption for energy purposes by world regions, as of 2005

World regions	Consumption [PJ]
Africa	2 176
North America	3 150
Latin America	8 393
Asia	1 831
Europe	113
Oceania	6 354
World	22 017

Source: [65]

In developed countries biomass is used mainly for the production of electricity and heat as well as for the production of biofuels used in road transport.

3.9. Peat resources

Peat was considered in the past as a non-renewable source of energy but in the recent Surveys of Energy Resources it is described as a category located between fossil fuels and renewable sources.

World resources of peat are huge. Deposits of peat cover around 4 million km^2 of land and are estimated to have the volume of 6 000 – 19 800 billion m^3. The largest deposits of peat are located in North America and in Asia.

The role of peat as a source of energy is limited due to its low calorific value, high contents of moisture, high contents of ash and disadvantageous environmental impacts. However, in some countries peat is used for the production of electricity and heat. It is also used locally as a fuel for space heating.

Peat is quite widely applied for the non-energy purposes in horticulture and agriculture. It is also used as a raw material in the chemical industry as well as for the medical purposes.

It is expected that in the future the role of peat will increase and it will be used e.g. to produce the synthesis gas or biofuels.

The areas of peat deposits (peatlands) by world regions are presented in Table 3.9.

Table 3.9. The areas of peat deposits (peatlands) by world region

World regions	Peatlands [1000 km^2]
Africa	56,2
North and Central America	1 762,3
South America	130,8
Asia	1 490,4
Europe	525,7
Oceania	8,0
World	3 973,3

Source: [78]

3.10. Solar energy

As it was already mentioned in Section 3.6 of the report, the solar radiation reaching the Earth during a year is over 7500 times higher than the annual consumption of primary energy. A major part of the solar radiation has an indirect energy influence on the globe, manifesting itself in the form of wind energy, hydro energy, biomass energy, wave energy as well as various occurrences in the world atmosphere. Solar energy is also exploited directly, with the application of the following technologies:

- solar thermal collectors used for space heating, air conditioning, domestic water heating, drying of agricultural crops etc.,
- photovoltaic installations which transform solar energy directly into electricity.

Table 3.10. Installed capacity of photovoltaic equipment by regions and countries, as at the end of 2011

Regions and countries	Installed capacity [MW]	Regions and countries	Installed capacity [MW]
Africa	174	**Europe**	51 260
in which: Reunion	145	in which: Germany	25 039
Egypt	20	Italy	12 773
Ethiopia	5	Spain	4 332
North and Central America	5 846	France	2 760
in which: USA	5 171	Czech Rep.	1 971
Canada	559	Belgium	1 391
Mexico	37	UK	976
		Greece	612
South America	21	Switzerland	192
in which: Argentina	16	Ukraine	190
Asia	10 149	Slovakia	188
in which: Japan	4 914	Austria	187
China	3 300	Portugal	172
India	941	**Australia**	1 400
Korea (Republic)	730	**World**	68 850

Source: [78]

Use of solar thermal collectors is quite common throughout the globe. It takes place in many countries, particularly those which enjoy high solar radiation, including the less developed countries of Africa, South Asia and Latin America.

Recently the use of solar energy becomes more attractive and economically justified. Photovoltaic installations are a technology which is being developed with particular dynamism.

In 2011 the installed capacity of the photovoltaic equipment has reached 68 850 MW, and the countries leading in this technology are Germany, Italy, USA, Japan and Spain. Data are presented in Table 3.10.

3.11. Geothermal energy

Geothermal energy comes from the natural internal heat of the earth. Its resources are large but exploited in the small part only. Geothermal energy is carried by steam in case of high temperatures and by water in case of low temperatures.

Sources of high-temperature geothermal energy are applied mainly for the electricity generation. In 2011 the global installed electric capacity of geothermal power plants was close to 10 900 MW and the annual output of electricity was more than 65 000 GWh.

Geothermal sources of lower temperatures – having usually the form of hot water – are used directly for the purposes of space heating, air conditioning etc. In 2011 the global installed thermal capacity of direct geothermal installations, including heat pumps, was more than 47 000 MWt, and the annual output of heat was over 390 000 TJ.

The main advantage of geothermal energy is its constant availability for 24 hours a day and 365 days a year but high costs of exploitation are the main disadvantage.

The geothermal power plants with the highest installed capacities exist in USA, Philippines, Indonesia, Mexico, New Zealand, Italy and Iceland. The

Table 3.11. Application of geothermal energy (including heat pumps) by regions and countries, as of 2011

Regions and countries	Electricity		Thermal energy	
	[MWe]	[GWh]	[MWt]	[TJ]
Africa	176	1 440	16	127
in which: Kenya	169	1 430	16	127
Ethiopia	7	10	-	-
North and Central America	4 492	23 221	13 820	65 743
in which: USA	3 102	15 009	12 612	56 552
Canada	-	-	1 045	5 112
Mexico	887	6 502	156	4 023
El Salvador	204	1 422	-	-
South America	-	-	519	7363
in which: Brazil	-	-	360	6 622
Argentina	-	-	150	609
Asia	3 687	22 391	11 132	101 900
in which: Philippines	1 904	10 311	3	40
Indonesia	1 197	9 321	-	-
Japan	538	2 632	2 100	25 698
Turkey	114	617	2 084	36 886
China	24	125	8 898	75 348
Europe	1 698	11 564	21 115	205 149
in which: Italy	772	5 754	1 000	12 600
Iceland	665	4 465	2 003	24 621
Germany	7	19	3 485	12 765
Netherlands	-	-	1 410	10 699
Sweden	-	-	4 460	45 301
Switzerland	-	-	1 061	8 799
Oceania	793	5 551	522	10 866
in which: New Zealand	793	5 551	393	9 552
Australia	-	-	129	1 314
World	10 877	65 588	47 124	391 148

Source: [78]

leaders in the direct use of geothermal energy are USA, China, Sweden, Germany, Japan, Turkey and Iceland. Most of these countries are developing dynamically the subsector of heat pumps.

Table 3.11 presents the application of geothermal energy in the world regions and in the leading countries of these regions.

3.12. Wind energy

A theoretical global potential of wind energy is tremendous, estimated to be around a million GW. The present utilisation of wind for electricity generation is relatively small, it is however increasing rapidly in the recent years.

In 2013 the installed capacity of wind turbines has exceeded 318 GW and the annual output of electricity was around 750 TWh, constituting more than 3% of the global generation of electricity. The subsector of wind electricity is the most developed in China, USA, Germany, Spain, India and United Kingdom.

The dynamic development of the wind electricity subsector is expected in the forthcoming years, and the substantial part of the wind capacities is expected to be located at the marine sites (offshore). The attractiveness of the offshore locations is high because the average speed of wind is higher than onshore, and this fact compensates the higher investment expenditures of marine site wind farms.

The present forecasts assume the dynamic development of wind electricity in the coming years. The forecast of the sectoral association assumes that in the year 2018 the global capacity of wind turbines should reach about 596 GW [83].

Table 3.12 presents the 2013 capacities and electricity generation in the world regions and in the leading countries of these regions.

3.13. Wave energy, tidal energy, ocean thermal energy

The theoretical potential of the wave energy, tidal energy and ocean thermal energy is huge but its exploitation is low by now because of the high costs. The practical application of tidal energy takes place in France at La Rance power plant which has the electric capacity of 240 MW.

The large capital investments and high costs of the exploitation of wave energy, tidal energy and ocean thermal energy are the main barrier which prohibits the wider use of such forms of energy.

Table 3.12. Wind turbines capacity and wind electricity generation by regions and countries, as of 2013

Regions and countries	Wind turbines capacity [MWe]	Electricity generation [GWh]
Africa and Middle East	1 255	
in which: Egypt	550	
Morocco	291	
North America	70 811	186 779
in which: USA	61 091	169 537
Canada	7 803	11 643
Mexico	1 917	5 599
Latin America	4 764	-
in which: Brazil	3 461	550
Chile	335	-
Argentina	218	
Asia	115 927	
in which: China	91 412	
India	20 150	
Japan	2 661	5 094
Taiwan	614	
Korea (Republic)	561	1 136
Thailand	223	
Europe	121 474	
in which: Germany	34 250	53 400
Spain	22 959	55 767
United Kingdom	10 531	27 414
Italy	8 552	14 969
France	8 254	15 887
Denmark	4 772	11 123
Portugal	4 724	12 033
Sweden	4 470	9 891
Poland	3 390	6 041
Turkey	2 959	7 494
Oceania	3 874	9 350
in which: Australia	3 239	7 327
New Zealand	623	1 997
World	318 105	

Source: [83, 84]

4

GLOBAL PRODUCTION, INTERNATIONAL TRADE AND CONSUMPTION OF PRIMARY ENERGY

4.1. Beginnings and development of primary energy production

In the past, before the beginning of an industrial era, global production of energy was low. It was connected mainly with the coverage of the basic human needs, i.e. provision of heat and food.

Throughout the centuries the production of energy was gradually increasing, mainly for the handicraft applications. Wood was the main fuel by the middle of the 19th century.

Rapid growth of energy production had accompanied the industrialisation, particularly in the countries of North America and Europe. This growth is still continued, with the structure of consumption changing out of coal to the benefit of oil and gas. In the second half of 20th century the nuclear energy has also found its place in the global energy mix.

Accurate calculation of primary energy production and use was difficult in the past, to the middle of the 20th century. By that time there was no organisation which would compile any worldwide statistics of energy. Therefore the quantities of energy production and use might have been only roughly assessed. It is estimated that in the middle of 19th century, despite the gradual growth of fossil fuels use, the worldwide production of primary energy was only about 0.33 Gtoe, in which the share of wood was approx. 70% and the share of fossil fuels only 30%.

Since the second half of 19th century, production and use of primary energy was growing quickly, mainly for the needs of industry and railways, reaching in 1913 approx. 0.90 Gtoe and in 1937 approx. 1.38 Gtoe. This means that per capita production of energy was approx. 0.52 toe in 1913 and approx. 0.64 toe in 1937.

After the Second World War the dynamic growth of global production of primary energy took place, from approx 1.85 Gtoe in 1950 to 13.2 Gtoe in 2011. Therefore the per capita production has grown from 0.74 toe in 1950 to 1.90 toe in 2011.

Data showing the growth of primary energy production against the background of the population growth are presented in Table 4.1.

Table 4.1. Growth of world population and of primary energy production 1860-2011

Years	Population [million]	Primary energy production [Mtoe]	Production per capita [toe]
1860	1 200 ˣ	330 ˣ	0,27 ˣ
1913	1 721 ˣ	900 ˣ	0,52 ˣ
1937	2 134	1 380	0,64
1950	2 513	1 850	0,74
1960	3 027	3 135	1,04
1970	3 678	4 816	1,30
1980	4 438	7 315	1,65
1990	5 252	8 795	1,68
2000	6 073	9 990	1,64
2008	6 536	12 369	1,89
2011	6 958	13 202	1,90

ˣ *Estimated data*
Source: Population: [15, 27, 34, 38]
Primary energy: [15, 34, 40, 75]

Up to the Second World War hard coal was the main fuel covering the world energy demand, and the role of oil was gradually increasing. In the period 1950-1972 oil had substituted coal at the first place. The volume of oil production had substantially exceeded the volume of coal production at that time. The role of natural gas was also increasing, due to the quick growth of its production and thanks to its advantages.

Global production of fossil fuels in the years 1860-2013 is presented in Table 4.2.

Table 4.2. Global production of coal, crude oil and natural gas 1860-2013

Years	Hard coal [million Mg]	Lignite [million Mg]	Crude oil [million Mg]	Natural gas [billion m^3]
1860	132 ˣ	6 ˣ	0,07 ˣ	–
1913	1 216 ˣ	127 ˣ	54 ˣ	–
1937	1 310	233	279	80
1950	1 435	419	520	185
1960	1 991	692	1 052	449
1970	2 208	855	3 270	1 040
1980	2 806	978	2 979	1 522
1990	3 556	1 150	3 002	1 993
2000	3 633	889	3 560	2 538
2008	5 752	991	3 941	3 149
2013	6 983	840	4 229	3 479

ˣ *Estimated data*
Source: [7, 34, 38, 40, 41, 47, 54, 75]

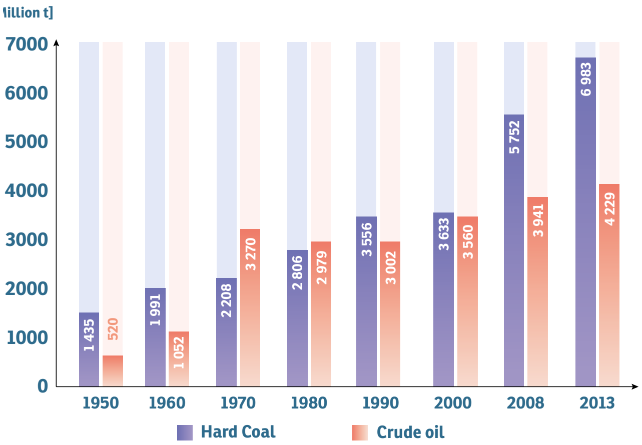

Fig. 7. Global production of hard coal and crude oil 1950-2013

4.2. Development of primary energy subsectors

4.2.1. Hard coal and lignite production

Wood was a basic fuel worldwide during many centuries, to the beginning of the 19th century. Coal was used only locally in some parts of the world, among others in China. The old Chinese manuscripts indicate that coal was used for copper smelting already in the pre-Christian era.

The sources suggest that coal was used as a fuel as early as in 9th century in West Europe (British Isles, Belgium, Saxony). Substantial production of coal started in the end of 18th century, and particularly in 19th century, with the development of metallurgy and the application of steam engine for rail and sea transportation. Coal as the energy source became an important factor of industrialisation, particularly in the West and Central Europe and in North America.

In 1800 the global production of hard coal was below 12 million Mg and in 1850 amounted to almost 50 million Mg. In the following years production was increasing rapidly, reaching 210 million Mg in 1880, approx. 500 million Mg in 1889 and almost 1110 million Mg in 1907 [37].

Substantial production of lignite started at the beginning of 20th century, reaching the level of approx. 10% of hard coal production. Before the Second World War, in 1937, global production of hard coal was 1310 million Mg and of lignite was equal to 233 million Mg.

After the Second World War production of coal was increasing rapidly, from 1435 million Mg of hard coal and 419 million Mg of lignite in 1950, to 6983 million Mg of hard coal and 840 million Mg of lignite in 2013. Global production of lignite was the highest in 1990, reaching 1150 million Mg.

Presently both hard coal and lignite are the main fuels for electricity generation. Moreover, hard coal plays a role of basic raw material for the production of coke and the production of some chemical products.

Data on global coal production are presented in Table 4.3.

Table 4.3. Global production of hard coal and lignite 1980-2013 [mln Mg]

Type of coal	1980	1990	2000	2008	2013
Hard coal	2 806	3 556	3 633	5 752	6 983
of which: steam	2 262	2 993	3 143	4 969	5 979
coking	544	538	490	783	1 004
Lignite	978	1 150	889	991	840

Source: [7, 34]

4.2.2. Crude oil production

In the ancient times people saw crude oil – frequently called mineral oil or rocky oil – at places where it was flowing spontaneously to the earth surface. Its existence in various parts of the world was confirmed by the ancient writers, such as Herodotus, Plutarch and Pliny the Elder. The peoples of Persia, Babylon, Egypt and particularly of the Caspian Sea basin had known oil from the oldest times, however the possible energy application of oil was not known to anybody. Oil was at that time used mainly for military purposes, e.g. the defenders of besieged Greek towns had poured oil on the surrounding enemies. In the Middle Ages oil was used also for medical purposes (in cases of skin diseases, rheumatism etc.).

The era of industrial application of oil has begun with the discovery of the distillation process and the invention of kerosene lamp in 1852 in Lwów by the Polish pharmacist Ignacy Łukasiewicz who also constructed the first oil producing well in 1854 at Bóbrka in Polish Sub-Carpathian region [8]. Not much later, in 1859, Colonel Edwin Drake had constructed the first modern commercial oil well in Pennsylvania, becoming a founder of the US oil industry [37].

At the beginning the global production of crude oil was small and amounted in 1860 to 69 thousand Mg. Production had increased tremendously at the end of 19th century and particularly in the beginning of 20th century, driven by the development of motor car industry, and later of the aviation. Before the First World War, in 1913, global production of crude oil was already 54 million Mg, and before the Second War, in 1937, had grown to 279 million Mg.

In 1950 the world production amounted to 520 million Mg, and the next spectacular growth of demand took place in two following decades. In 1970 production reached the level of 3270 million Mg. Oil became the most important energy commodity in the world. Subsequently, in the period 1973-1980 the global energy crisis had occurred. International market prices of oil had grown more than 10-fold, and consequently its consumption and production had decreased.

In 1990 the global production of oil was lower than in 1970 and amounted to 3002 million Mg. Substantial growth of production took however place in the last decade of the 20th century and at the turn of the centuries. In 2000 production amounted to 3560 million Mg and in 2013 to 4229 million Mg [47, 54].

4.2.3. Natural gas production

Natural gas, similarly to crude oil, was already known in the ancient times in China, Persia and Caspian Sea basin. What was known, were the natural emissions of gas which flared spontaneously and aimlessly. The flares were in some cases the objects of religious worship.

Natural gas occurs in the earth in two types of deposits: associated with crude oil and non-associated, i.e. separate from oil.

In the early times of oil industry the associated gas was not used as fuel. It was vented into the atmosphere or flared at the places of extraction.

Utilisation of gas for energy purposes was initiated in the second half of 19th century. Large scale consumption of gas has begun after the Second World War. In the last decades of the 20th century consumption of gas was growing more rapidly than consumption of coal and oil.

Currently natural gas is considered to be the most perfect fuel. In comparison with other fuels it has many advantages, is more comfortable in use and most friendly to the environment. Natural gas has also the non-energy applications, i.e. it is an important raw material for the chemical industry.

Consumption of natural gas was insignificant before the Second World War. In 1937 its global production was approx. 80 billion m^3. It increased to 1040 billion m^3 in 1970 and to 3479 billion m^3 in 2013.

4.2.4. Nuclear energy for electricity generation

Nuclear electricity generation is the youngest of the energy production subsectors. It was initiated in 1950s. The first nuclear power plant was constructed in 1954 at Obninsk (USSR). At the beginning of this technology application, in 1950s, the main purpose of such installations was however not the generation of electricity but obtaining the enriched products of nuclear fission for the military purposes.

Dynamic development of nuclear electricity generation took place in 1960s and 1970s. The development has slowed down after the accident at Three Mile Island nuclear station in 1979, and particularly after the Chernobyl catastrophe in 1986. The slowdown took place mainly in USA and in the European countries. Some countries of Asia, and particularly of the Far East, had still implemented the construction of several nuclear plants.

The renaissance of the nuclear power took place in the recent years. Several countries started to implement their nuclear programmes. The main arguments supporting the nuclear power are: depletion of fossil fuels, high prices of conventional energy commodities, and particularly lack of greenhouse gases emissions which in case of conventional power plants are responsible for the processes of climate change.

Unfortunately the serious accident at Fukushima power plant in Japan, caused by earthquake and the giant tsunami in March 2011 is a reason for the return of disadvantageous climate for the nuclear energy. After this accident some countries are revising their nuclear programmes or are shutting off the older nuclear reactors.

In 2013 the world operated 434 nuclear reactors with the total capacity of 372 GW, which have generated 11% of the global electricity. The following countries had the highest shares of nuclear electricity generation: France – 73%, Belgium – 52%, Slovakia – 52%, Hungary – 51%, Ukraine – 44%, Sweden

– 43%, Czech Republic – 36%, Switzerland – 36%, Slovenia – 34%, Finland – 33%, Bulgaria – 31% [85].

4.2.5. Use of renewable energy sources

The most important renewable sources of energy are: hydro energy, wind energy, biomass and geothermal energy.

Renewable energy sources were used by mankind from the beginning of its history. Initially it was mostly wood, and in the ancient times the use of hydro energy and wind energy was initiated [37].

Hydro energy. Exploitation of hydro energy was initiated several thousand years ago. It was originally used to drive the water wheels for the irrigation of agricultural areas, particularly in China, Mesopotamia and Egypt.

Global resources of hydro energy are significant. The largest resources of this type of energy exist in China, Russian Federation, Brazil, Canada, Congo, India, USA and Indonesia.

Wind energy. Wind energy was also exploited in the ancient times, particularly in the countries which achieved in this historical period the level of civilisation which allowed to utilise the powers and richness of the nature for the purposes of the society (China, Middle East countries, countries of Roman Empire). The energy of wind was used as driving power for sail ships during thousands of years, before the steam engine and internal combustion engine were invented and applied. The energy of wind was also used in the modern times for grain milling [37].

Biomass. The main components of biomass are wood, plants, agricultural waste of plant and animal origin as well as the energy containing municipal waste.

Wood was used by people for fuel purposes from the very ancient times. In the bronze age and in iron age wood became an important source of energy for the emerging metallurgy, i.e. for smelting of copper and iron with the use of charcoal. Such application of wood was important to the middle of the 19th century when it started to decline with the increasing application of fossil fuels [37].

Geothermal energy. Theoretical potential of geothermal energy is large. Its present utilisation is however very small, mainly because of the low temperatures of the available geothermal waters. The biggest producers of geothermal energy are USA, Philippines, Mexico, Italy and Japan. Geothermal energy is also used at some locations for the purposes of space heating and air conditioning..

4.3. Producers, exporters and importers of fossil fuels

4.3.1. Hard coal and lignite

In the decade of 1970s the main producers of hard coal were: USA, China, Soviet Union, United Kingdom, Poland and Germany. In the last decades of the 20th century, because of difficult geological conditions and high mining costs, production of coal was substantially reduced in most of the European countries, particularly in the United Kingdom, Germany, Belgium, France and Poland.

Most of the world's hard coal is consumed in the producing countries, but about 1/5 of total production is an object of export.

The largest importers of coal are presently: China, Japan, India, Korea (Republic), Taiwan, Germany and United Kingdom.

Table 4.4. Main producers, exporters and importers of hard coal in 2013

Producers		Net exporters		Net importers	
Countries	[mln Mg]	Countries	[mln Mg]	Countries	[mln Mg]
China	3 561	Indonesia	426	China	327
USA	834	Australia	336	Japan	196
India	568	Russian Federation	141	India	180
Indonesia	489	USA	107	Korea (Republic)	127
Australia	396	Colombia	74	Taiwan	68
Russian Federation	274	South Africa	72	Germany	50
South Africa	256	Canada	37	United Kingdom	49
Kazakhstan	115	Kazakhstan	33	Turkey	28
Colombia	85	Mongolia	22	Italy	20
Poland	77	Vietnam	18	France	17
Rest of the World	328	Other countries	67	Other countries	271
World	6 983	World	1 333	World	1 333

Source: [7, 34]

Table 4.5. Main producers, exporters and importers of crude oil in 2013

Producers		Net exporters		Net importers	
Countries	[mln Mg]	Countries	[mln Mg]	Countries	[mln Mg]
Saudi Arabia	540	Saudi Arabia	371	USA	442
Russian Federation	525	Russian Federation	239	China	269
USA	486	Nigeria	124	India	185
China	211	Iraq	119	Japan	179
Canada	196	United Arab Emir.	118	Korea (Republic)	129
Kuwait	165	Kuwait	103	Germany	93
Venezuela	155	Venezuela	93	Italy	74
United Arab Emir.	153	Canada	89	Spain	62
Iraq	153	Angola	84	France	57
Iran	151	Iran	67	Netherlands	57
Rest of the World	1 509	Other countries	768	Other countries	628
World	4 229	World	2 175	World	2 175

Source: [34, 47]

The lists of main producers, exporters and importers of hard coal, as of 2013, are presented in Table 4.4.

Main producers of lignite are: Germany, Russian Federation, USA, Poland, Turkey, Australia and Greece. Lignite is consumed locally in the producer countries, mainly for the electricity generation.

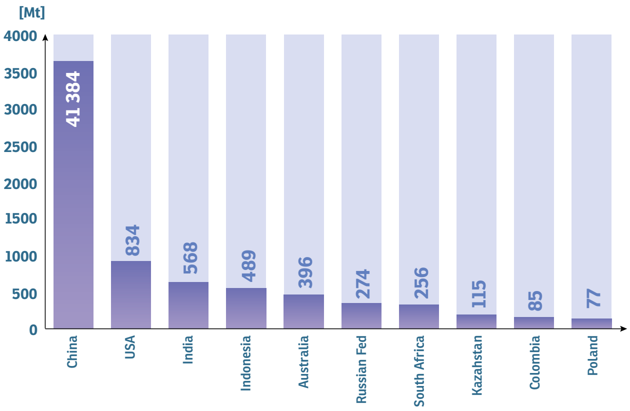

Fig. 8. Main producers of hard coal in 2013

4.3.2. Crude oil

In 1971, before the first oil crisis, the largest producers of crude oil were: USA, USSR, Saudi Arabia, Iran, Venezuela, Kuwait and Libya. During the next decades China, Canada and United Arab Emirates have joined the group of leading producers.

About 50% of produced crude oil is an object of international trade (exports and imports).

The main exporters of crude oil were in 2013: Saudi Arabia, Russian Federation, Nigeria, Iraq, United Arab Emirates and Kuwait. Many oil producing countries are exporting besides crude oil also its refined products (motor gasoline, Diesel oil, fuel oil).

The main importers of crude oil are: USA, China, India, Japan, Korea (Republic), Germany, Italy, Spain, France and Netherlands. Some countries are importing crude oil for refining and afterwards they export considerable quantities of products.

The lists of main producers, exporters and importers of crude oil, as of 2013, are presented in Table 4.5.

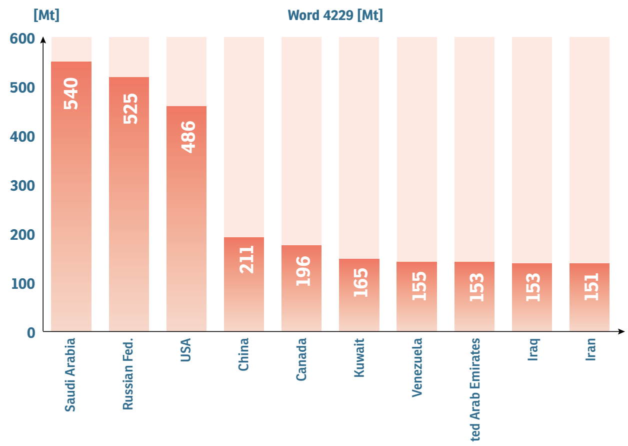

Fig. 9. Main producers of crude oil in 2013

4.3.3. Natural gas

The following countries were the leading producers of natural gas in 2013: USA, Russian Federation, Qatar, Iran, Canada, Norway, Netherlands, Saudi Arabia and Algeria. These countries produce jointly 2/3 of the world natural gas.

About 30% of produced gas is an object of export, which amounted to 1052 billion m^3 in 2013. The leading exporters of natural gas are: Russian Federation, Qatar, Norway, Canada, Algeria, Turkmenistan and Netherlands. The main importers of gas are: Japan,

Table 4.6. Main producers, exporters and importers of natural gas in 2013

Producers		Net exporters		Net importers	
Countries	[bln m³]	Countries	[bln m³]	Countries	[bln m³]
USA	689	Russian Federation	203	Japan	123
Russian Federation	671	Qatar	121	Germany	76
Qatar	161	Norway	103	Italy	62
Iran	159	Canada	54	Korea (Rep.)	53
Canada	155	Algeria	45	China	49
China	115	Turkmenistan	45	Turkey	44
Norway	109	Netherlands	40	France	43
Netherlands	86	Indonesia	35	UK	39
Saudi Arabia	84	Australia	26	USA	37
Algeria	80	Nigeria	22	Spain	30
Rest of the World	1 170	Other countries	358	Other countries	482
World	3 479	World	1 052	World	1 038

Source: [34, 41]

Table 4.7. Primary energy consumption by world regions 1971-2011

Regions	Primary energy consumption [Mtoe]						1971=100 [%]
	1971	1980	1990	2000	2008	2011	
OECD	3 378,6	4 073,4	4 521,8	5 329,4	5 422	5 305	157,0
Non-OECD	2 046,0	3 042,5	4 124,3	4 562,9	6 510	7 448	364,0
Africa	194,0	278,6	392,7	507,4	655	700	360,8
Latin America	202,7	293,9	346,3	460,2	575	589	290,6
Asia [1]	324,0	467,6	724,8	1 069,3	1 410	1 593	491,7
China	395,2	603,9	873,9	1 121,8	2 131	2 743	694,1
Europe [2]	86,2	132,4	140,3	94,8	107	99	114,8
Former USSR	790,8	1 133,3	1 417,8	920,5	1 038	1 077	136,2
Middle East	53,2	192,7	228,5	388,9	594	647	1 216,2
Bunkers	108,0	107,9	112,8	146,9	335	360	333,3
World	5 532,6	7 223,7	8 758,8	10 035,2	12 267	13 113	237,0

[1] Asia excluding China [2] Non-OECD Europe excluding former USSR
Source: [15, 34]

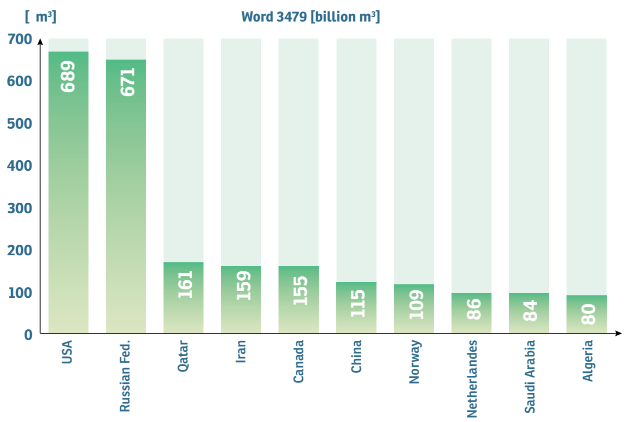

Fig. 10. Main producers of natural gas in 2013

Germany, Italy, Korea (Republic), China, Turkey and France.

The lists of main producers, exporters and importers of natural gas, as of 2013, are presented in Table 4.6.

4.4. Global consumption of primary energy and its structure

At a global scale the consumption of primary energy is similar to its production – the existing differences are attributed to the stock changes. Consumption of energy in the particular regions of the world and in particular countries is however different from its production, depending on the quantities imported and exported, particularly of fossil fuels (coal, oil and natural gas).

In the last decades of the 20th century and at the beginning of 21st century the world consumption of primary energy has increased more than twice, from 5533 Mtoe in 1971 to 13113 Mtoe in 2011. The growth rates of consumption were very different in various regions and countries of the world – moderate in the developed OECD countries and high in

Table 4.8. Structure of the global consumption of primary energy 1971-2011

Energy commodity	Consumption [Mtoe]		1971 =100 [%]	Structure [%]	
	1971	2011		1971	2011
Coal	1 442	3 776	262	26,1	28,8
Crude oil	2 437	4 136	170	44,0	31,5
Natural gas	895	2 787	311	16,2	21,3
Nuclear energy	29	674	2 324	0,5	5,1
Hydro energy	104	300	288	1,9	2,3
Other renewable sources	626	1 440	230	11,3	11,0
Total energy	5 533	13 113	237	100,0	100,0

Source: [15, 34]

the developing Non-OECD countries. Total growth amounted to 57% in OECD countries and to 264% in Non-OECD countries.

Changes of the primary energy consumption by regions of the world are presented in Table 4.7.

The exceptionally high growth of the primary energy consumption took place during the last four decades in Non-OECD countries, particularly in China, India and the countries of Middle East. In the OECD countries the growth of primary energy consumption was moderate. Despite this difference in growth rates, there still exist very high differences to the advantage of the OECD countries in the consumption per capita. This is described in Section 4.5 of the report.

Substantial changes in the structure of the primary energy consumption have occurred in the last decades – nuclear energy has established its place, consumption of natural gas has grown rapidly with simultaneous reduction in growth rate of oil consumption. There was also a considerable growth in the consumption of renewable energy, particularly of biomass and wind energy.

Changes in the primary energy consumption structure are presented in Table 4.8.

Table 4.9. Extreme levels of primary energy consumption per capita in OECD and Non-OECD countries

OECD countries with high levels of energy consumption	[(toe/*capita*]		Non-OECD countries with low levels of energy consumption	[toe/*capita*]	
	1970	2011		1971	2011
OECD average	3,89	4,27	Non-OECD average	0,75	1,30
Canada	6,50	7,30	Egypt	0,22	0,94
USA	7,59	7,02	Ethiopia	0,27	0,40
Australia	4,05	5,40	Morocco	0,17	0,54
Norway	3,47	5,68	Senegal	0,30	0,28
Sweden	4,69	5,19	Bolivia	0,27	0,76
France	2,98	3,88	Haiti	0,31	0,32
Germany	3,91	3,81	Ecuador	0,48	0,88
United Kingdom	3,73	3,00	Nicaragua	0,51	0,52
Japan	2,48	3,61	Bangladesh	0,08	0,21
Belgium	4,19	5,38	India	0,28	0,60
Netherlands	3,81	4,64	Pakistan	0,28	0,48
Denmark	4,09	3,23	Philippines	0,39	0,43
Italy	2,05	2,76	China	0,47	2,03
Austria	2,43	3,92	Albania	0,78	0,68
Poland	2,56	2,63	Iraq	0,48	1,22
Finland	3,88	6,45	Yemen	0,12	0,29
Switzerland	2,61	3,22	Jordan	0,34	1,14
Spain	1,13	2,72	Syria	0,41	0,96

Source: [15, 16, 34]

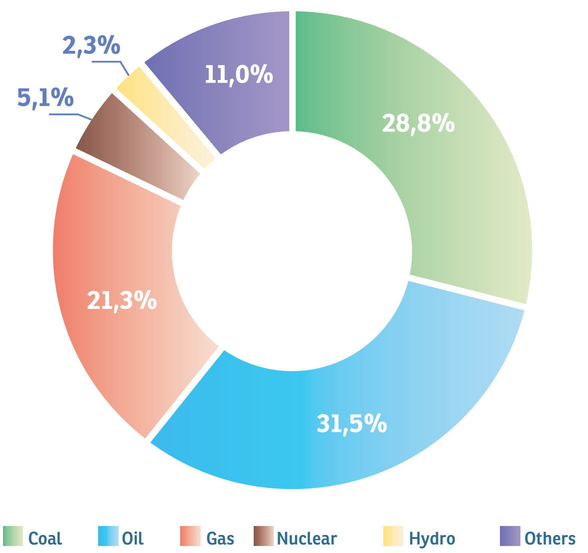

Fig. 11. Structure of the global consumption of primary energy in 2011

4.5. Indicators of per capita primary energy consumption

Large differences in per capita primary energy consumption exist between the developed OECD countries and most of the less developed countries.

The extreme differences in per capita energy consumption between the selected OECD countries and the poorest developing Non-OECD countries in the years 1970-2011 are shown in Table 4.9.

In the extreme cases, per capita consumption of primary energy is in the poorest countries, particularly African (Senegal, Ethiopia) and Asian (Yemen, Bangladesh), even several dozen times lower than in highly developed countries (Canada, USA). Moreover, in some of the least developed countries (Senegal, Haiti, Nicaragua) the consumption per capita did not grow at all during the last four decades. This is an indicator of the deep energy poverty of these countries. On the other side, in the most of the highly developed countries the energy consumption per capita has grown during the same time.

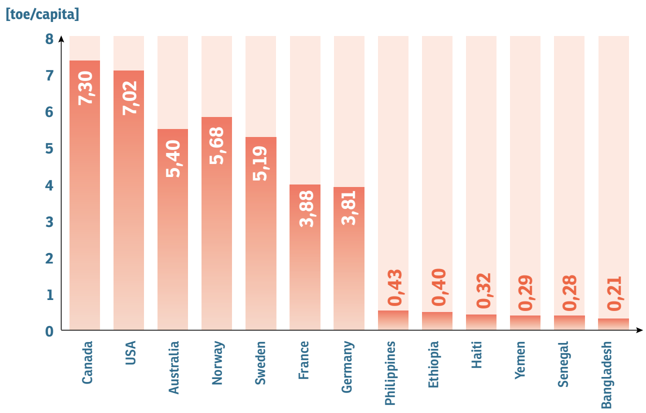

Fig. 12. Countries with the highest and the lowest primary energy consumption per capita in 2011

5

DEVELOPMENT OF THE GLOBAL ELECTRICITY INDUSTRY

5.1. Beginnings and development of the electricity industry

Electric phenomena in the form of lightning were known to mankind from the dawn of the pre-history. However only in the second half of the 19th century the application of electricity was initiated in order to facilitate people's life. Rapid development of the electricity applications took place at the turn of the 19th and 20th centuries. Mankind owes this development to many discoveries and inventions made by the scientists during the 19th century. The most important inventors of this period were [45, 73]:

- A. Volta – inventor of the first electric cell in 1800,
- A. Ampere – discoverer of the basic laws of electrodynamics in 1820,
- G. Ohm – discoverer of the dependence between the resistance, voltage and electric current in 1826,
- M. Faraday – discoverer of the electric induction and creator of the basics for an electric motor, generator and transformer in 1831,
- G. Kirchhoff – discoverer of the basic law of current flows in the electrical circuits in 1845,
- J. Maxwell – developer of the electro-magnetic field theory in 1865,
- T. Edison – inventor of the electric light bulb in 1876 and the author of many other inventions in the field of electricity,
- N. Tesla – inventor of the electric motor in 1888, of the transformer and the series of other electric devices.

Discoveries and inventions in the field of electricity have laid the foundations for the future development of the electric industry, particularly for the construction of the electricity generating devices. First power stations were built in New York in 1882, in Milan and Petersburg in 1883 and in Berlin in 1884.

Quickly, and particularly in the first years of the 20th century, many power stations were built, predominantly in large cities and industrial agglomerations. They were usually the plants of low capacity, powered by the internal combustion engines. Later the construction of power stations equipped with steam turbines was initiated.

5.2. Global capacity of power plants, its structure and level of utilisation

Before the year 1997 the complete statistical data on the global capacity of power plants were not available. The existing statistics of the International Energy Agency had comprised only the OECD countries. First complete data, including also the Non-OECD countries, were published for the year 1997. Therefore only starting from that year it is possible to compare and analyse the total capacity of all power plants of the world.

Global capacity of power plants was equal to 3221 GW in 1997 and has grown to 5456 GW in 2011. Changes of the global capacity, with the specification of its structure, are presented in Table 5.1.

Table 5.1. Global capacity of power plants 1997-2011

Power plants by fuels / technologies	Capacity [GW]				1997=100 [%]
	1997	2002	2006	2011	
Coal	1 030	1 135	1 382	1 739	169
Oil	410	454	415	439	107
Natural gas	643	893	1 124	1 414	220
Nuclear	352	359	368	391	111
Hydro	738	801	919	1 060	144
Other renewable sources	48	77	136	413	860
World	3 221	3 719	4 344	5 456	169
of which:					
- OECD countries	1 871	2 177	2 430	2 791	149
- Non-OECD countries	1 350	1 542	1 913	2 665	197

Source: [74, 76]

The level of the electric capacity utilisation, in total and in fuels / technologies groups, expressed by the annual average hours of operation, is presented in Table 5.2.

Table 5.2. Capacity utilisation of world power plants in 2011

Power plants by fuels / technologies	Capacity [GW]	Electricity generation [TWh]	Capacity utilisation [hours]
Coal	1 739	9 145	5 259
Oil	439	1 062	2 419
Natural gas	1 414	4 848	3 429
Nuclear	391	2 584	6 609
Hydro	1 060	3 565	3 363
Other renewable sources	413	998	2 416
World	5 456	22 202	4 069
of which:			
- OECD countries	2 791	10 867	3 894
- Non-OECD countries	2 665	11 335	4 253

Source: [15, 74]

5.3. Electricity production – main producers

In the first decades of the 20th century, despite quite rapid development of the electricity applications, the global production of electricity was low, reaching before the Second World War in 1937 only approx. 500 TWh [38].

Particularly fast development of electricity production took place after the Second World War. In 1950 the global production of electricity amounted to 959 TWh and in 1970 it had grown to 4908 TWh [75].

Rapid growth of global production of electricity was accompanied by its broad applications. In the second half of the 20th century the electricity has become the most perfect, most universal and most commonly used form of energy. It influenced almost all spheres of human lives and human activity. Electricity allowed the fast social and economic development of the world, particularly of industrialised countries. Due to its advantages the electricity revolutionised industry, transport, construction and municipal economy as well as facilitated the life of households.

The wide scale of electricity applications was the reason for calling the 20th century a century of electricity.

High growth of global production of electricity was still observed in the last three decades of 20th century. This growth was however very uneven in different regions of the world – high in the industrialised countries of Europe, North America, Far East and Pacific, but very low in most countries of Africa, South Asia and Latin America. These observations are confirmed by the values of the indicators of per capita electricity consumption (see Section 5.6 of the report). Moreover, still more than 1.5 billion inhabitants of less developed countries have no access to electricity. These are mainly the inhabitants of the African and South Asian countries.

Changes in the electricity generation volumes in different regions of the world during the period 1971-2012 are presented in Table 5.3.

Table 5.3. World electricity generation by regions 1971-2012

Regions	Electricity generation [TWh]		1971=100 [%]
	1971	2012	
A. OECD			
North America	1 956	5 289	270
Europe	1 403	3 635	259
Pacific	462	1 925	417
Total OECD	3 821	10 849	284
B. Non-OECD			
Africa	90	723	803
Latin America	135	1 153	854
Asia [1)]	138	2 343	1 698
China	144	5 033	3 495
Europe [2)]	92	195	212
Former ZSRR	801	1 551	194
Middle East	27	905	3 352
Total Nie-OECD	1 425	11 903	835
C. World	5 248	22 752	434

[1)] *Asia excluding China*
[2)] *Non-OECD Europe excluding former USSR*
Source: [15, 80]

The largest producers of electricity in 2012 were: China, USA, India, Russian Federation and Japan.

The lists of main producers, net exporters and net importers of electricity, as of 2012, are presented in Table 5.4.

5.4. Structure of electricity production

Coal and oil products were the main fuels used for electricity generation during the first decades after the Second World War. Afterwards, the substantial changes in the structure of primary fuels used for electricity generation were observed in the years 1971-2012. They were caused by:

- large growth of oil product prices and in consequence the maximum reduction of their use for electricity generation,
- construction of nuclear power plants, particularly in USA, USSR, France, Germany, Japan, United Kingdom, Korea (Republic) and in many other countries,

Table 5.4. Main producers, exporters and importers of electricity in 2012

Producers		Net exporters		Net importers	
Countries	[TWh]	Countries	[TWh]	Countries	[TWh]
China	4 994	Paraguay	48	USA	47
USA	4 291	Canada	47	Italy	43
India	1 128	France	45	Brazil	40
Russian Federation	1 071	Germany	21	Netherlands	17
Japan	1 034	Sweden	20	Finland	17
Canada	634	Norway	18	United Kingdom	12
Germany	630	Czech Republic	17	Belgium	10
France	564	Russian Federation	16	Hong Kong	10
Brazil	553	Ukraine	12	Iraq	8
Korea (Republic)	535	Spain	11	Thailand	8
Rest of the World	7 318	Other countries	27	Other countries	70
World	22 752	World	282	World	282

Source: [34, 80]

- gradual increase in the use of natural gas and renewable sources for electricity generation.

Coal has retained its high, exceeding 40%, share in global generation of electricity in consequence of the high growth of coal fired generation in China and India.

Changes in the structure of fuels used for electricity generation are presented in Table 5.5.

5.5. Development of global consumption of electricity

At the early stage of electrification as well as before the Second World War, the global production of electricity and its consumption were low. Dynamic growth of electricity consumption has occurred in the post-war period. During the years 1971-2012 the global consumption of electricity increased more than 4-fold – from 4830 TWh in 1971 to 21459 TWh in 2012. Growth rate of global electricity consumption was significantly higher than growth rate of primary energy consumption. This is a confirmation of the increasing role of electricity in the global economy. In OECD the consumption of electricity has grown almost 3 times in the years 1971-2012 while in Non-OECD countries over 8 times.

According to the methodology of the International Energy Agency, gross consumption of electricity is calculated as: gross production + import – export – network losses.

Changes in gross electricity consumption by world regions are presented in Table 5.6. The most rapid growth of electricity consumption took place in China and in the Middle East countries.

Table 5.5. Fuel structure of global electricity generation 1971-2012

Fuel / technology	Share [%]	
	1971	2012
Coal	40,1	40,3
Oil	20,9	5,0
Natural gas	13,3	22,4
Nuclear	2,1	10,8
Hydro	23,0	16,5
Other renewable sources	0,6	5,0
Total	100,0	100,0

Source: [34, 80]

5.6. Indicators of per capita electricity consumption

Similarly as in the case of primary energy consumption, the large differences in per capita electricity consumption exist between the developed countries of OECD and a majority of the less developed Non-OECD countries.

In the years 1970/71-2011 the indicators of per capita electricity consumption have grown as follows:

- in the group of OECD countries – from 4012 kWh in 1970 to 8226 kWh in 2011,
- in the group of Non-OECD countries – from 450 kWh in 1971 to 1785 kWh in 2011.

Therefore in the year 2011 the average value of the indicator of per capita electricity consumption was for the whole group of Non-OECD countries over 4 times lower than the average value for OECD countries.

Table 5.6. World electricity consumption by regions 1971-2012

Regions	Electricity consumption [TWh]			1971=100 [%]
	1971	2006	2012	
A. OECD				
North America	1 789	4 808	5 019	281
Europe	1 315	3 350	3 411	259
Pacific	433	1 714	1 822	421
Total OECD	3 537	9 872	10 252	290
B. Non-OECD				
Africa	87	522	694	798
Latin America	120	808	1 129	941
Asia [1)]	116	1 414	2 239	1 930
China	132	2 716	4 665	3 534
Europe [2)]	81	171	184	227
Former USSR	731	1 274	1 426	195
Middle East	26	599	870	3 346
Total Non-OECD	1 294	7 505	11 207	866
C. World	4 831	17 377	21 459	444

[1] *Asia excluding China*
[2] *Non-OECD Europe excluding former USSR*
Source: [15, 80]

Table 5.7. Countries with high and low figures of electricity consumption per capita 1970/71-2011 [kWh]

OECD countries [x)]	1970	2011	Non-OECD countries		1971	2011
Australia	-	10 514	AFRICA	Angola	89	256
Austria	3 019	8 359		Benin	11	95
Belgium	3 041	8 072		Cameroon	145	270
Canada	8 962	16 406		Congo	157	99
Czech Republic	-	6 288		Cote d'Ivoire	93	204
Denmark	2 888	6 124		Eritrea	-	53
Iceland	6 485	52 376		Ethiopia	17	55
Finland	4 571	15 742		Kenya	78	157
France	2 629	7 318		Nigeria	30	151
Germany	3 857	7 083		Senegal	71	195
Greece	1 006	5 292		Sudan	25	150
Ireland	1 755	5 701		Tanzania	30	92
Italy	2 073	5 393		Togo	63	117
Japan	3 261	7 847	LATIN AMERICA	Bolivia	176	638
Korea (Republic)	-	10 162		Guatemala	120	537
Luxembourg	10 655	15 511		Haiti	12	32
Netherlands	2 950	7 036		Nicaragua	244	525
New Zealand	4 257	9 378	ASIA	Bangladesh	10	263
Norway	13 450	23 174		Cambodia	-	168
Poland	1 815	3 833		Burma (Myanmar)	20	119
Spain	1 407	5 604		Nepal	6	94
Sweden	7 916	14 029		India	99	673
Switzerland	4 247	7 972		Pakistan	89	448
United Kingdom	4 169	5 518		Philippines	231	648
USA	7 235	13 227		Yemen	32	182
OECD average	4 012	8 223	Non-OECD average		450	1 785

[x] *Table contains data for the majority of OECD countries and for the Non-OECD countries with the lowest electricity consumption per capita*
Source: [15, 16, 34]

Such a large difference is caused by the following main reasons:

- weak economic growth in many Non-OECD countries,
- high growth of population in Non-OECD countries in comparison with the moderate growth in OECD countries.

In many Non-OECD countries the indicators of per capita electricity consumption are even several dozen times lower than the indicators for developed countries. This applies particularly to several African and South Asian countries. A comparison of high and low cases is presented in Table 5.7.

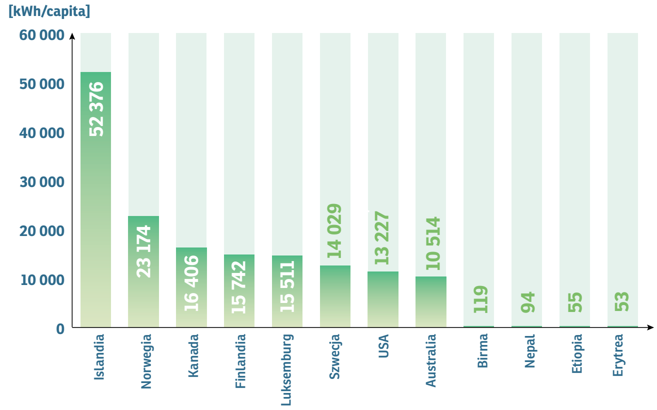

Fig. 13. Countries with the highest and the lowest electricity consumption per capita in 2011

6

ENERGY INTENSITY OF THE GLOBAL ECONOMY

6.1. Energy intensity indicators

The quantity of primary energy consumed per one unit of Gross Global Product is the synthetic measure defining the energy intensity of the global economy. Similarly, the quantity of primary energy consumed per unit of Gross Domestic Product (GDP) is the measure of the energy intensity of the national economy. However, the GDPs of the countries depend not only on their levels of economic development but also on the levels of prices of goods and services in these countries.

In the countries which have the stable market economies the prices of goods and services are quite similar and consequently the calculated figures of GDP are in principle directly comparable. In the countries which have non-market, centrally planned or bureaucratic economies with high unemployment and low wages and salaries, the figures of GDP expressed in US dollars are largely underestimated.

Because of this difficulty, the World Bank and the International Energy Agency publish two figures for GDPs expressed in US dollars: one converted to dollars by the bank exchange rates and the second converted by the Purchasing Power Parities (PPP).

Calculation of GDP by PPP makes it possible to eliminate the effects of price differences between the countries. Therefore the Gross Domestic Products calculated by PPP are more directly comparable and constitute more appropriate base for calculating and comparing the energy intensities of the national economies and world regions [16].

It should be mentioned that the energy intensity of GDP is not an ideal measure of the energy efficiency of the national economy, even when calculations are corrected with the use of PPP. It is however the only synthetic measure of the energy efficiency for which the comparable international data exist. It may be added that the level of energy intensity depends also on many other factors, such as the structure of the economy and the climatic conditions.

The indicators of energy consumption in the processes of manufacturing the energy intensive products, like steel, cement, glass, electricity itself, seem to be the more appropriate measures of the energy intensity of the economy. The assessment based on such indicators would be however fragmentary only, not aggregated to the level of the whole economy, and would also be difficult to prepare due to the unavailability of such data for many countries.

The energy intensities of GDP of the world regions are characterised below, using the indicators based on exchange rates and based on PPP. It should be underlined that such comparisons are imperfect though the only possible to be made.

6.2. Energy intensity of GDP in the macro scale

In the last decades of 20th century and in the first years of 21st century the advantageous occurrence of the energy intensity reduction and therefore the energy efficiency improvement took place in the global economy. The energy intensity of the global GDP (calculated by PPP), was reduced by almost 30% during the period 1980-2011, from 0.29 toe/1000 USD in 1980 to 0.21 toe/1000 USD in 2011.

The largest reduction of the energy intensity of GDP was achieved in the OECD countries, particularly in North America, and in China. The most energy efficient are however the countries of OECD Europe. The information on the energy intensity of GDP in the regions of the world is presented in Table 6.1.

Table 6.1. Indicators of the energy intensity of GDP 1980-2011 [toe/1000 USD 200]

Regions	Indicators related to GDP calculated by exchange rates		Indicators related to GDP calculated by PPP	
	1980	2011	1980	2011
A. OECD				
North America	0,36	0,19	0,34	0,18
Europe	0,27	0,12	0,22	0,14
Pacific	0,15	0,15	0,19	0,16
Total OECD	0,28	0,16	0,26	0,16
B. Non-OECD				
Africa	0,74	0,62	0,26	0,28
Latin America	0,29	0,29	0,16	0,15
Asia [1]	0,90	0,53	0,25	0,20
China	2,50	0,70	0,74	0,31
Europe [2]	1,14	0,38	0,40	0,19
Former USSR	1,84	0,93	0,45	0,40
Middle East	0,28	0,58	0,17	0,29
Total Non-OECD	0,91	0,59	0,33	0,26
C. World	0,39	0,28	0,29	0,21

1) Asia excluding China
2) Non-OECD Europe excluding former USSR
Source: [15, 16]

7

ENERGY PRICES

Prices of the energy commodities constitute one of the basic parameters of the economic calculations, substantially influence the costs of industrial production and services and also the expenditures of households.

Therefore the levels and trends of the energy prices are in the centre of the interest of the governments, trade unions and also of the energy producers and consumers.

7.1. Prices of energy commodities in international trade

After the Second World War up to the energy crisis in 1973 the international market prices of fuels and energy commodities were very low. Supply of the energy carriers, and particularly of crude oil, was high. Oil became the basic source of energy, substituting coal to the increasing degree.

In 1971 crude oil constituted 44% of the global consumption of primary energy, and coal 26%. In the first half of 1973, before the first energy crisis, the world price of crude oil was at the level of 2.7-2.9 USD per barrel (20-21 USD/Mg) (1 barrel = 159 litres), price of steam coal 10-12 USD/Mg and the price of natural gas 15-19 USD/1000 m^3 (18-23 USD/toe).

In the end of 1973 the advantageous condition of low energy prices had changed dramatically. An embargo imposed by the Arab petroleum exporting countries for the supplies to USA and some countries of West Europe caused the sharp increase in oil price. The increase was 4-fold, to the level of 11-12 USD per barrel (80-90 USD/Mg). The world economy experienced a shock, called the first energy crisis.

At the turn of 1980/1981 the subsequent increase in oil price took place – to approx. 36 USD per barrel (265 USD/Mg). These events were called the second energy crisis.

Very high prices of oil and the associated increase in other fuels prices became the factor limiting the development of the world economy, stimulating higher inflation, higher unemployment and the other disadvantageous occurrences.

The counteractive measures against the consequences of the crisis were taken in many countries, particularly the industrialized. Multidirectional activities and programmes were initiated aimed at the reduction of oil consumption and its substitution by other fuels – mainly coal and nuclear energy. The intensive exploration for new oil sources was also performed, particularly in the North Sea and the Gulf of Mexico. Due to these activities, in the middle of 1980s crude oil prices declined and stabilized. In 1986 the price of oil fell to 15 USD per barrel (110 USD/Mg). This caused also the associated decrease in gas and coal prices.

During the years 1987-1998 the international prices of fuels were quite stable, and in December 1998 the price of crude oil supplied to the EU countries reached the lowest level – 12.3 USD per barrel (90 USD/Mg). In this situation the member countries of OPEC (Organisation of the Petroleum Exporting Countries) had reduced the oil production, aiming at the price increase. Actually the considerable growth of price took place. In September 1999 the average price of oil imported to West Europe reached the level of 23 USD per barrel (170 USD/Mg), and in the fourth quarter of 2000 – 29 USD per barrel (215 USD/Mg).

The prices of natural gas expressed per toe had also evolved, following the oil prices, but they were lower than the prices of oil by 25-30%.

Changes in crude oil prices caused also coal price changes, though these changes had more smooth character. Since 1990, despite increasing oil prices, the price of coal was falling. Price of steam coal imported to Europe decreased from 51 USD/Mg in 1990 to 35 USD/Mg in 2000, and the price of coking coal from 64 USD/Mg in 1990 to 48 USD/Mg in 2000.

During the years 2000-2003 the prices of crude oil imported to the EU countries were at the level

Table 7.1. Annual average CIF prices of fossil fuels imported to the EU in the years 1971-2013

Years	Crude oil [USD/barrel]	Natural gas [USD/MBtu]	LNG [USD/MBtu]	Steam coal [USD/Mg]	Coking coal [USD/Mg]
1971	2,7	-	-	-	-
1974	11,0	-	-	-	-
1980	32,5	-	-	52,2	56,4
1981	36,3	-	-	64,0	71,7
1985	27,6	-	-	48,6	59,9
1990	22,7	-	-	51,4	64,1
1995	17,1	-	-	46,3	58,5
2000	27,9	1,9	3,1	34,9	47,9
2002	24,3	3,2	3,1	38,6	56,5
2003	28,4	3,2	3,6	41,9	58,1
2004	36,5	4,2	3,9	62,1	78,4
2005	51,7	5,5	5,0	69,7	109,2
2006	62,8	7,4	6,5	69,4	128,7
2007	70,8	7,1	6,5	82,2	125,7
2008	96,8	10,6	9,2	137,8	197,8
2009	61,1	7,6	6,2	100,3	187,3
2010	79,1	7,6	6,9	104,1	194,0
2011	110,5				
2012	111,6				
2013	108,9				

Source: [17]; at the end of 2010 the International Energy Agency discontinued the publication of gas and coal prices

of 27-28 USD per barrel (200 USD/Mg). In the years 2004-2008 the escalation of oil, natural gas and hard coal prices took place.

In the fourth quarter of 2004 the price of crude oil achieved the level of 41.5 USD per barrel (300 USD/Mg), during 2005 the level of 58-60 USD per barrel and in 2007 reached temporarily even 70 USD per barrel (510 USD/Mg).

The price of natural gas also increased following the price of oil. The average price of gas supplied to the EU was 1.88 USD/MBtu in 2000, 4.20 USD/MBtu in 2004 and 7.15 USD/MBtu in February 2006.

The prices of coal, both steam and coking, had also increased considerably. The average price of steam coal amounted to 34.9 USD/Mg in 2000, 62 USD/Mg in 2004 and 71 USD/Mg in 2005. The price of coking coal increased from 47.8 USD/Mg in 2000 to approx. 78 USD/Mg in 2004 and to approx. 129 USD/Mg in 2006.

The prices of oil and coal decreased slightly in 2006, particularly in the second half of that year. Since 2007 the price of oil started to rise sharply, reaching in the middle of 2008 the level of approx. 150 USD per barrel (1100 USD/Mg). In the second half of 2008 however the price of oil declined to the level of 42 USD per barrel (300 USD/Mg). In 2009 the prices of oil were stable at the level of 60-70 USD per barrel. The substantial growth of price has occurred once more in 2010, reaching the level of 120 USD per barrel in the end of this year. During the years 2011-2013 the prices of oil were stable at the level very close to 110 USD/barrel. The next phase of price decrease took place in the second half of 2014.

Concerning the coal imported to the EU, the prices of both steam and coking coal were high during the years 2005-2008 and afterwards stabilized in the first quarter of 2009 – the price of steam coal at the level of 108 USD/Mg and the price of coking coal at the level of 228 USD/Mg. Then the prices have shown the increasing trend once more in 2010. During the years 2013-2014 the large decrease of coal prices took place. It has put a question mark on the profitability of coal production in the countries having the relatively higher production costs, including Poland.

The prices of natural gas were in principle following the prices of crude oil. In July 2008 the average price of gas imported to the EU was 11 USD per MBtu.

The imports of the Liquefied Natural Gas (LNG) were increasing during the recent years. Its prices were evolving depending on the price of crude oil and on the price of the pipeline transported natural gas.

In 2000 the price of LNG imported to the EU amounted to 3.10 USD/MBtu, in 2008 has grown to 9.13 USD/MBtu and in 2009 has fallen to 6.04 USD/MBtu.

The levels of prices of fuels imported to the EU are presented in Table 7.1.

7.2. Final prices of fuels and energy in OECD countries

The basic factors which determine the levels of costs and final (retail) prices of fuels and energy are the following:

- prices of energy commodities at the international market, particularly prices of imports to the consuming countries,
- costs of production, processing, transport and distribution of the energy carriers,
- economic policy of the particular country in the area of taxation and social protection of some groups of consumers, e.g. households, application of subsidies etc.

In many countries, particularly in Non-OECD, final prices of fuels and energy frequently do not cover the supply costs. Various methods of subsidising are applied.

Rather transparent systems of fuels and energy prices creation are applied in OECD countries, and the information on these prices is available in the published statistics. On the other hand the price information for some Non-OECD countries is hardly available. Therefore the review of the final prices of fuels and energy is included in the present report only for the OECD countries.

Final prices of fuels and energy, paid by consumers, are diversified in the OECD countries. The prices depend on the production costs, energy policies of the individual countries as well as on the fiscal and customs policies. Diversification of prices depends also on the groups of consumers.

For the industrial consumption of fuels and energy, the countries apply in principle the policy of low taxation levels or even tax exemption. Liquid fuels – motor gasoline and Diesel oil – are usually taxed highest. In many countries the tax component of the final price of motor gasoline is close to 70%. Tax component of the gas and electricity supplied to households is typically in the range of 10-30% of final prices. The special case is Denmark, with its very high taxation. The lowest taxation of household electricity and gas is applied by United Kingdom (about 5%), and the highest by Denmark (60% for electricity and 50% for gas) and Italy (22% for electricity and 46% for gas).

The comparison of energy carriers prices in various countries is possible due to their presentation in the international statistics in common unit, i.e. in US dollars, converted from the national currencies by the exchange rates and by Purchasing Power Parities (PPP).

In the highly developed countries the differences between USD prices, calculated by exchange rates and by PPP, are rather insignificant (8-20%). In the less developed countries however, and particularly in the emerging market economies, these differences are higher. Therefore basing on the Purchasing Power Parities is purposeful, particularly when comparing the prices of fuels and energy for households.

Comparison of the prices in USD calculated by the exchange rates indicates that the final prices are substantially diverse between the countries. The countries with the lowest prices are:

- motor gasoline: USA and Canada,
- natural gas for households: Canada, USA, Turkey, Hungary, Poland,
- electricity: Canada, USA, Norway, Hungary.
- The following countries have the highest prices of fuels and energy:
- motor gasoline: Turkey, Norway, Italy, Netherlands, Denmark,
- natural gas for households: Japan, Sweden, Denmark,
- electricity: Denmark, Germany, Italy.

The substantial increasing trend of fuels and energy prices has occurred in the recent years. This is a disadvantageous trend. In the OECD Europe countries the average prices more than doubled during the period 2000-2013 in case of gasoline and electricity and more than tripled in case of natural gas. The background data are presented in Table 7.2.

The International Energy Agency publishes also an information on the fuels and energy prices calculated with the application of the Purchasing Power Parities. These data indicate that the prices of fuels and energy in the highly developed countries of West Europe were lower by more than a dozen per cent when expressed in USD by PPP in comparison with the prices in USD by the exchange rates. The opposed situation takes place for the less developed countries in which the prices expressed in USD by PPP are by a dozen or even several dozen per cent higher than the prices expressed in USD by the exchange rates.

Prices of fuels and energy for households calculated by PPP are presented in Table 7.3.

Table 7.2. Prices of motor gasoline, natural gas and electricity for households 2000-2013 [USD by exchange rates]

Countries	Premium 95 gasoline [USD/l]		Natural gas [USD/toe]		Electricity [USD/kWh]	
	2000	2013	2000	2013	2000	2013
Canada	0,477 [1]	1,370	199	437	0,053	0,105 [3]
Czech Republic	0,743	1,850	214	1085	0,054	0,206
Denmark	1,034	2,250	735	1680	0,197	0,394
France	1,005	2,041	348	1158	0,102	0,193
Germany	0,935	2,121	373	1223	0,121	0,388
Hungary	0,823	1,867	156	743	0,065	0,182
Italy	0,996	2,322	-	1215 [2]	0,135	0,306
Japan	-	-	1294	2192 [3]	0,214	0,242
Netherlands	1,069	2,304	359	1340	0,131	0,257
Norway	1,201	2,506	-	-	0,058	0,149
Poland	0,722	1,733	248	879	0,065	0,196
Spain	0,755	1,900	491	1399	0,117	0,247 [2]
Sweden	1,038	2,205	-	2103	-	0,234
Turkey	0,933	2,513 [3]	259	649 [3]	0,084	0,185 [3]
United Kingdom	1,210	2,097	293	991	0,107	0,229
USA	0,417	0,968	322	440	0,082	0,121
OECD Europe	0,971	2,098	328	1132	0,107	0,255
Total OECD	0,564	1,206	354	758	0,101	0,174

[1] 2002 data [2] 2010 data [3] 2012 data
Source: [17]

Table 7.3. Prices of motor gasoline, natural gas and electricity for households 2000-2013 [USD by PPP]

Countries	Premium 95 gasoline [USD/l]		Natural gas [USD/toe]		Electricity [USD/kWh]	
	2000	2013	2000	2013	2000	2013
Canada	1,171	1,143	240	364	0,064	0,085 [3]
Czech Republic	2,017	2,720	581	1594	0,148	0,302
Denmark	0,993	1,654	706	1234	0,190	0,290
France	1,159	1,829	401	1037	0,117	0,173
Germany	1,133	2,045	418	1178	-	0,374
Hungary	2,151	3,284	409	1308	0,135	0,320
Italy	1,321	2,322	-	1176 [1]	0,180	0,306
Japan	-	-	900	1671 [3]	0,149	0,230
Netherlands	1,298	2,102	436	1222	0,159	0,235
Norway	1,158	1,673	-	-	0,056	0,099
Poland	1,702	3,036	584	1540	0,154	0,344
Spain	1,114	2,105	725	1549	0,173	0,301 [2]
Sweden	1,040	1,663	-	1587	-	0,176
Turkey	2,060	4,362 [3]	572	1127 [3]	0,186	0,321 [3]
United Kingdom	1,225	1,934	304	913	0,111	0,211
USA	0,417	0,968	322	439	0,082	0,121
OECD Europe	1,222	2,091	404	1125	0,134	0,247
Total OECD	0,643	1,230	373	765	0,104	0,173

[1] 2010 data [2] 2011 data [3] 2012 data
Source: [17]

8

ENERGY AND THE ENVIRONMENT

8.1. Energy sector impacts at the natural environment

Environmental impacts of the energy use are not the new occurrences. Through the centuries burning of wood led to deforestation in many areas. High local pollution of air, water and soil occurred already in the early stages of industrialisation. The importance of energy for the improvement of life level is unquestioned but the energy production and use are closely connected with the emissions which lead to the natural environment degradation. This degradation threatens human health and quality of life and results in the greenhouse effect which consequently leads to the climatic changes at our globe.

During the last 100 years, when the global population increased over 3-fold, the environmental impacts caused by the economic activities have changed its scale from local perturbations to the global problems. These impacts – caused mainly by more than 20-fold growth in fossil fuels consumption and several times growth in the consumption of traditional energy sources like biomass – are the proof that the economic activity of mankind changes the world in a rapid way, causing also the increasing degradation of natural environment.

Intensive development of industry, creation of large urban agglomerations, increase in extraction of fossil fuels, growth in energy production and consumption, particularly during the first decades after the Second World War, caused the tremendous degradation of the environment, at both local and global scales.

The main pollutants emitted from the processes of energy combustion of fossil fuels are: sulphur oxides, nitrogen oxides, carbon dioxide, particulate matter and ashes. In the cities the main sources of pollution are: fuel combustion for space heating and food cooking as well as the engines of motor vehicles.

In 1950s and 1960s the local degradation of environment reached the alarming size, particularly in the large urban and industrial agglomerations, like the Ruhr Basin in Germany, London, New York and others. Also the wider scale negative impacts at the environment had manifested themselves in the following forms:

- acid rains caused by the excessive emissions of SO_2 and NO_x, which resulted in degradation of forests and soil, disappearance of natural life in rivers and lakes, decline in the health condition of people and all living organisms,
- depletion of the ozone layer which protects the Earth against the ultraviolet radiation, destructive for the health,
- greenhouse effect which results in the climatic changes at the global scale.

Increasing degradation of natural environment required the urgent response in order to reduce its consequences. The response was initiated by the United Nations Organisation.

8.2. Activities mitigating degradation of the natural environment

The first warning of the threats connected with the environmental degradation was included in the report of the UN Secretary General U Thant, published in 1969. This report had indicated the existing problems of human environment, connected with its degradation and intended to make the world conscious of the negative consequences of this degradation for the social and economic development as well as for the Earth nature. The report pointed out the necessity to introduce, particularly by the developed countries, the adequate means and activities aimed to protect the environment.

In the following period of time the UN had initiated the series of activities aimed to protect the natural environment. In 1988 the Intergovernmental Panel on Climate Change (IPCC) has been established. This is the organisation which groups together the experts in environment protection and in climatology. The

UN Framework Convention on Climate Change (UNFCCC) has been signed and 20 annual Conferences of this Convention parties were held.

The most important UN conferences on the environment protection were held in Stockholm, Rio de Janeiro, Kyoto and Copenhagen.

In Stockholm in 1972 the UN Conference on the Human Environment had convened under the motto „There is only one Earth". The UN Environment Programme which is the special UN agency devoted to the environmental issues was founded at this conference. The basic principles of the environment protection were also adopted at the conference.

In Rio de Janeiro in 1992 at the conference named „Earth Summit" it was recognised that the environmental impacts of the human activities have the global character, and only the international co-operation of all countries may lead to the mitigation of the environmental threats. It was underlined that the idea of sustainable development, formulated by the World Commission on Environment and Development, chaired by Mrs Gro Harlem Brundtland, has to be introduced in all economic activities. Sustainable development should assure the improvement of the quality of life and the economic development without decreasing the quality of the natural environment.

Kyoto Conference of the UNFCCC parties, which convened in December 1997, was devoted mainly to the issues of climate change and counteracting the global warming. Basing on the opinion of the Intergovernmental Panel on Climate Change, it was confirmed that the growing anthropogenic emissions of greenhouse gases, particularly of CO_2, are the main reason of global warming and the occurring climatic anomalies. The document called Kyoto Protocol was adopted at this conference. Under the Protocol, the industrialised countries agreed to reduce their collective greenhouse gases emissions in 2012 by 5.2% in comparison to 1990. The Kyoto Protocol entered into force in 2005 after its ratification by the applicable number of countries, including Russian Federation.

Copenhagen Conference of the UNFCCC parties was held in December 2009. It had two main objectives:

- negotiation of a new agreement aimed to cut the global emissions of greenhouse gases by at least 50% to the year 2050 and to limit the global level of greenhouse gases concentration in the earth atmosphere to 450 ppm of CO_2 equivalent,
- arranging the enhanced international financial assistance of developed countries to the developing countries, in order to allow them to introduce the CO_2 reduction measures in their countries and to create conditions for the sustainable development of these countries.

The goals of the Copenhagen Conference were very optimistic. The necessity to act for the reduction of global warming was not questioned but any binding levels of CO_2 emissions by the individual countries were not approved. Concerning the financial assistance it was agreed that the industrialised countries will allocate 30 billion USD in the years 2010-2012 in order to help the poor countries adapt to the climate change. This assistance will be increasing in the following years, rising to 100 billion USD by 2020. It was also confirmed that the further discussions on the outstanding issues will be continued at the following annual conferences of the parties [28].

It should be underlined that thanks to the decisions of the earlier UN conferences on the subject of environment and climate, industrialised countries have initiated the series of activities aimed to reduce the negative environmental impacts of the energy sector. In result of these activities, substantial improvement of the environmental conditions has been achieved in these countries, mainly through:

- application of the technological improvements, including growth of the electricity and heat production efficiency,
- installation of the equipment for flue gas desulphurisation, for NO_x and ash emission reduction etc.,
- combustion of better quality types of coal,
- utilisation of cleaner energy carriers – natural gas and electricity – in the urban areas,
- application of more energy efficient equipment in industry, transport, households etc.

All these activities resulted in the essential improvement of the environmental situation at the local and regional scales, and particularly reduction of the sulphur oxides, nitrogen oxides and ash emissions, improvement of water purity etc.

Reduction of CO_2 emissions to the level defined in the Kyoto Protocol was not achieved. In this situation the more radical reduction of these emissions to the level discussed at the Copenhagen Conference seems to be unrealistic. In any case it constitutes a big challenge for the world, and particularly for the global energy sector.

The proposal to limit the CO_2 emissions to the level discussed in Copenhagen would mean for the global energy sector the radical change of the en-

Table 8.1. Global CO_2 emissions by regions 1980-2011

Regions	CO_2 emissions [billion Mg]				CO_2 emissions *per capita* [Mg]			
	1980	2000	2006	2011	1980	2000	2006	2011
A. OECD								
North America	5,30	6,54	6,62	6,33	16,5	15,7	15,0	13,4
Europe	4,12	3,90	4,06	3,75	8,7	7,5	7,5	6,8
Pacific	1,23	1,99	2,11	2,27	7,1	10,7	10,5	10,7
Total OECD	10,65	12,43	12,79	12,35	11,0	11,0	10,8	10,0
B. Non-OECD								
Africa	0,41	0,69	0,85	0,97	0,9	0,9	0,9	0,9
Latin America	0,55	0,86	0,97	1,09	1,9	2,1	2,1	2,4
Asia	2,14	5,20	8,36	11,48	0,9	1,6	2,4	3,1
in which:								
- China	1,42	3,08	5,65	7,95	1,4	2,4	4,3	5,9
- India	0,29	0,97	1,29	1,75	0,4	1,0	1,1	1,4
Europe and former USSR	3,41	2,45	2,65	2,74	10,5	7,1	7,8	8,1
Middle East	0,34	0,97	1,29	1,61	3,7	5,9	6,8	7,7
Total Nie-OECD	6,85	10,17	14,17	17,89	2,0	2,1	2,6	3,1
World	18,05	23,41	27,89	31,34	4,1	3,9	4,3	4,5
in which:								
Emission from bunkers [x)]	0,56	0,81	0,93	1,11	-	-	-	

[x)] *CO_2 emission from marine and aviation fuel*
Source: [74]

ergy policy. The use of fossil fuels, and particularly of coal, for the electricity generation should be reduced. Coal will have to be substituted by the less polluting natural gas, by the nuclear electricity and the electricity from renewable sources. The necessity to limit the emissions means also the expenditure of huge financial means in order to counteract the warming of the Earth atmosphere.

Unfortunately the earthquake, which occurred in Japan in March 2011 and caused the serious accident at Fukushima nuclear power plant, has complicated the situation. In consequence some countries have revised their nuclear programmes or have even shut off the existing nuclear plants.

Concerning the influence of the CO_2 emissions on the global warming, some scientists express different opinions and oppose the findings of IPCC. They claim that the human activity is not a main reason for the present growth of an average global temperature. In the history of Earth the periods of warming and cooling were intermixed. The research of the ice layers in the Greenland and Antarctica indicates that during the past 800 thousand years there were eight glacial cycles and between them the warmer inter-glacial periods. It can be inferred that the present period is an inter-glacial one. The activity of Sun is considered by the supporters of this opinion to be the most probable reason for the natural cycles of warming and cooling. Such theory, criticizing a link between the anthropogenic CO_2 emissions and global warming, is however rejected by the IPCC.

8.3. Global emission of CO_2 and global warming of the Earth atmosphere

Currently the most important and the most difficult global problem to be solved is the necessity to reduce the CO_2 emissions, which have rapidly grown in the past decades.

According to the Intergovernmental Panel on Climate Change (IPCC), founded in 1988, and to the majority of scientists, the increasing global warming of the Earth atmosphere and various climatic anomalies are caused by the anthropogenic emissions of greenhouse gases, particularly of CO_2.

It is unquestionable that the global atmospheric emissions of CO_2 have more than doubled during the period 1971-2011. They have grown from 13.96 billion Mg in 1971 [74] to 20.95 billion Mg in 1990 and to 31.34 billion Mg in 2011 [34]. The annual average growth in CO_2 emissions was equal to 0.37 billion Mg in the years 1971-1990 and to almost 0.50 billion Mg in the years 1990-2011.

During the last decades the growth of CO_2 emissions was very diverse between the world regions. Growth was rather low in OECD countries and high in Non-OECD, particularly in Asia. The average level of per capita emissions of CO_2 is however still over 3 times higher in OECD countries than in Non-OECD. The regional data on total and per capita emissions are presented in Table 8.1. Among the OECD countries the biggest emitters of CO_2 were in 2011: USA – 5.29 billion Mg and Japan – 1.19 billion Mg. In the group of Non-OECD countries the biggest emitters were: China – 7.96 billion Mg, India – 1.75 billion Mg and Russian Federation – 1.65 billion Mg. Emissions by country are presented in Table 8.2.

The highest CO_2 emissions per capita took place in the year 2011 in the following OECD countries: Australia – 17.4 Mg, USA – 16.9 Mg, Canada – 15.4 Mg and Korea (Republic) – 11.8 Mg. In the Non-OECD countries the emissions per capita were in 2011 the highest in the following countries: Saudi Arabia – 16.3 Mg, Russian Federation – 11.7 Mg, Taiwan – 11.3 Mg, South Africa – 7.3 Mg and Iran – 7.0 Mg.

Table 8.2. Emission of CO_2 by the biggest emitter countries and the emission indicators in 2011

Countries	CO_2 emission [mln Mg]	Indicators of CO_2 emission			
		CO_2 per capita [Mg]	CO_2/TPES [x] [Mg/TJ]	CO_2/PKB [kg/USD]	CO_2/PKB (PPP) [kg/USD]
A. OECD		9,95	55,6	0,32	0,33
in which:					
USA	5 287	16,94	57,6	0,40	0,40
Japan	1 186	9,28	61,4	0,26	0,30
Germany	748	9,14	57,3	0,25	0,26
Korea (Republic)	588	11,81	53,9	0,56	0,43
Canada	530	15,37	50,2	0,43	0,43
United Kingdom	443	7,06	56,3	0,19	0,21
Mexico	432	3,96	55,5	0,45	0,30
Australia	397	17,43	77,1	0,44	0,47
Italy	393	6,47	56,1	0,22	0,24
France	328	5,04	31,0	0,15	0,17
Poland	300	7,79	70,7	0,75	0,43
Turkey	286	3,86	60,7	0,46	0,29
Spain	270	5,86	51,4	0,23	0,22
B. Non-OECD	17 888	-	-	-	-
in which:					
China	7 955	5,92	69,7	1,90	0,80
India	1 745	1,41	55,6	1,32	0,44
Russian Federation	1 653	11,65	54,0	1,75	0,79
Iran	521	6,97	58,7	2,11	0,63
Saudi Arabia	457	16,28	58,4	1,18	0,76
Indonesia	426	1,76	48,7	1,06	0,43
Brazil	408	2,07	36,1	0,36	0,20
South Africa	368	7,27	62,1	1,23	0,75
Ukraine	285	6,24	53,9	2,99	0,98
Taiwan	265	11,31	58,2	0,56	0,34
Thailand	243	3,50	48,8	1,16	0,46
World	31 342	4,50	57,1	0,60	0,45

[x] CO_2/TPES is the indicator of CO_2 emission per unit of primary energy consumption
Source: [34]

Table 8.2 presents the indicators for the countries – the biggest CO_2 emitters in relation to 1 inhabitant, to the primary energy consumption, in relation to GDP calculated by exchange rates and in relation to GDP calculated by PPP.

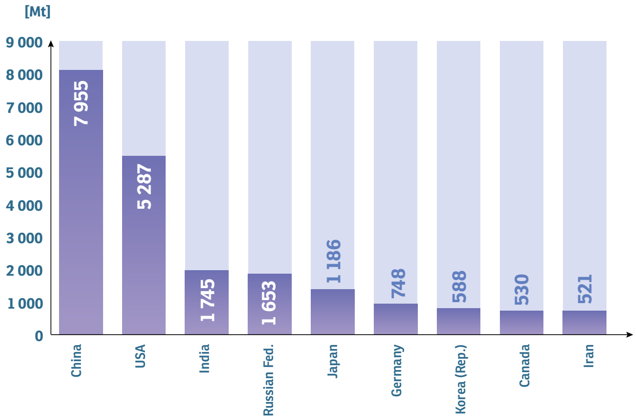

Fig. 14. Countries with the highest emissions of CO_2 in 2011

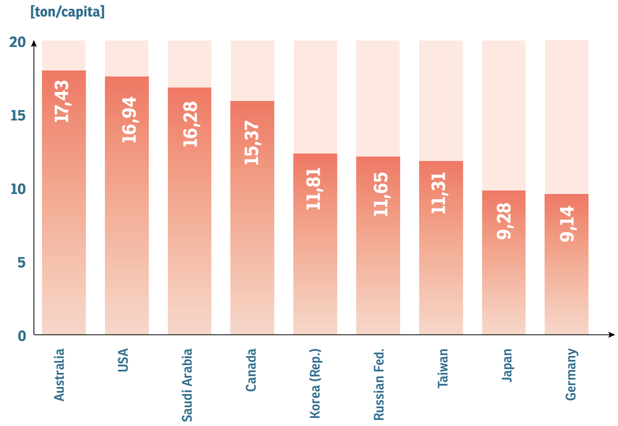

Fig. 15. Countries with the highest emissions of CO_2 per capita in 2011

9

SUMMARY OF PART I OF THE REPORT

Stages of energy development of the world

Human use of energy dates back to the ancient times and is a very basis for all processes of life in the Earth. Besides food and air, the energy is one of the most important material requirements of the human being. Without energy, mankind would be fully dependent on the nature and would not achieve even a fraction of its current development. Social and economic development of the world was and still is connected with the consumption of energy.

A man went a very long way from his quest for naturally occurring fire in the very old times to the present applications of energy. In the ancient times the milestones of the energy application were as follows:

- use of thermal energy obtained from burning wood, plants or the dried manure in order to prepare food and heat a body,
- use of lighting energy in a form of torch or cresset,
- use of animal power instead of power of human muscles,
- initiation of wind power application around 3 thousand BC (sailing) and of hydro energy application by the end of the ancient era (water wheel).
- The large scale applications of energy have accelerated in the modern times, due mainly to:
- invention of steam engine and the application of coal to drive it, what has brought in the 18th and particularly in 19th century a rapid development of the world economy, particularly of industry and transportation,
- invention of the internal combustion engine at the end of 19th century and high growth of oil consumption, particularly in 20th century, followed also by wide application of natural gas,
- initiation in the 19th century and the large scale application in 20th century of the electricity; its generation was largely supported by the nuclear energy.

Driving forces of energy demand growth

The main driving forces for the growth of the energy demand are the increasing population and the economic growth of the world.

In the past the global population was low. In the middle of the 17th century the global population exceeded 500 million. Increasing to 1 billion took almost 200 years and the next doubling to 2 billions was accomplished in 1930, after 100 years only. Very rapid growth of population took place in the second half of 20th century and in the beginning of 21st century. Global population reached 6073 million in 2000 and 6958 million in 2011. During the last decades the dynamic growth of population took place mainly in the less developed countries of Non-OECD, particularly in Africa, Asia and Latin America. During the years 1971-2011 the global population has increased as follows:

	[million]		
	1971	2011	Growth
OECD countries	882	1 241	359
Non-OECD countries	2 878	5 717	2 839
World	3 760	6 958	3 198

In the years 1971-2011 the substantial economic growth of the world took place – high in OECD countries and considerably lower in most of Non-OECD countries. Existing differences in the economic growth levels are disadvantageous to the Non-OECD countries, particularly when taking into account the growth of population.

The average GDP per capita is in the Non-OECD countries several times lower than in the OECD. In many less developing countries the GDP per capita is a dozen or even several dozen times lower than in the highly developed countries of OECD.

During the years 1971-2011 the GDP of OECD and Non-OECD countries, expressed in USD with the application of the Purchasing Power Parity (PPP), was as follows:

	Total GDP [billion USD]		GDP per capita [USD]	
	1971	2011	1971	2011
OECD countries	11 467	37 906	13 001	30 545
Non-OECD countries	5 934	32 407	2 081	5 669
World	17 401	70 313	4 628	1 010

Global resources and reserves of energy commodities

The basic source of information on the global resources and reserves of the energy commodities are the cyclical publications (Survey of Energy Resources) prepared by the World Energy Council. The Surveys of Energy Resources apply two basic categories of the fossil fuel reserves, namely:

- Resources (Proved Amount in Place), i.e. the total quantities of fuels which have been documented,
- Reserves (Proved Recoverable Reserves), i.e. a part within the Resources that can be recovered under the current technical and economic conditions.

The most recent edition of the Survey, published in 2013, indicates that the present reserves of fossil fuels are higher than they were at the time of the past Surveys publication, despite the increasing consumption of these fuels. The comparison of the 2013 Survey (data in this Survey are as at the end of 2011) with its 1974 edition reveals the following growth of recoverable reserves:

	Survey 1974	Survey 2013	1974=100 [%]
Hard coal [billion Mg]	476,0	690,5	145
Lignite [billion Mg]	219,0	201,0	92
Crude oil [billion Mg]	89,7	182,8	204
Natural gas [trillion m^3]	64,8	209,7	324

Considerable growth of reserves, particularly of hydrocarbon fuels, is a consequence of the new discoveries, progress in the exploration techniques, possibility of the exploitation from the offshore fields etc. Unfortunately all these technological innovations imply the substantial increase in fuel production costs.

Distribution of fossil fuel reserves over the globe is very uneven. The biggest reserves of hard coal are located in USA, Russian Federation, China and India, and the biggest reserves of lignite are possessed by Germany, Australia, USA and China. Rich reserves of crude oil are owned by the Arab countries, particularly Saudi Arabia, Iran, Iraq, Kuwait, United Arab Emirates, Libya, and also by Venezuela and Russian Federation. The largest reserves of natural gas are located in Russian Federation, Iran, Turkmenistan, Qatar, Saudi Arabia, USA, United Arab Emirates and Venezuela.

The Surveys of Energy Resources contain also an information on the rich resources of bitumen, i.e. oil shale, oil sands and extra-heavy oil. It is estimated that the total resources of bitumen amount to 1.5 trillion Mg of oil. The most important of these resources are the oil sands in Canada and the extra-heavy oil in Venezuela. Both oil sands in Canada and extra-heavy oil in Venezuela are already being exploited at the industrial scale, and the costs of acquiring oil from these resources are similar to the international prices of crude oil.

Taking into account all quoted facts, it may be assessed that there is no threat of depletion of fossil fuel reserves during the present century. Moreover, it can be supposed that the technological progress will lead to the re-qualification of the parts of previous Resources to the category of Reserves.

Besides the reserves of coal and hydrocarbons the world possesses also several million Mg of the uranium which is a highly concentrated fuel for electricity generation.

The world has also the huge resources of renewable energy, particularly the hydro energy, wind energy and biomass. They already constitute an important source of the global energy supply. It is expected that the climate change issues as well as the technological progress in the field of renewable energy will lead to the further rapid growth of application of these forms of energy, including the increasing application of the solar radiation.

Primary energy: production, international trade, consumption

In the past, to the middle of 19th century, wood was the main source of energy which satisfied the most direct needs of humans, i.e. space heating and food preparation. Rapid growth of the energy requirements took place in the second half of 19th century and in the beginning of 20th century, in consequence of the development of industry and transport, particularly in North America and Europe.

The acceleration of the energy demand growth has started between the World Wars, and the dynamic growth of the energy demand and its production was kept after the Second War. Such growth is still being continued in the first and second decade of 21st century.

In 1860 the global production of primary energy amounted to approx. 0.3 Gtoe, in 1913 to 0.9 Gtoe, in 1937 to 1.4 Gtoe, in 1950 to 1.9 Gtoe, in 1971 to 5.5 Gtoe, in 2000 to 10.0 Gtoe and in 2011 to 13.2 Gtoe.

Coal was the main source of primary energy in the second half of 19th century and during the first decades of 20th century. After the Second World War the hydrocarbon fuels became the major source of primary energy – first oil, and later also natural gas. Also the nuclear energy became an important component of the primary energy supply.

In 1971 and in 2011 the global primary energy consumption and its structure were as follows:

	Energy consumption [Mtoe]		Structure [%]	
	1971	2011	1971	2011
Coal	1 442	3 776	26,1	28,8
Oil	2 437	4 136	44,0	31,5
Natural gas	895	2 787	16,2	21,3
Other sources	730	2 414	13,7	18,4
Total consumption	5 533	13 113	100,0	100,0

At a global scale the consumption of primary energy is similar to its production and the differences are a consequence of stock changes. At the scales of world regions and individual countries the differences between consumption and production are a consequence of imports and exports of the primary energy components.

The largest producers of hard coal in the recent years are: China, USA, India, Indonesia, Australia, Russian Federation and South Africa. Leading exporters of coal are: Indonesia, Australia, Indonesia, Russian Federation, USA, South Africa and Colombia, and the largest importers: China, Japan, India, Korea (Republic), Taiwan, Germany and United Kingdom.

The largest producers of crude oil are: Saudi Arabia, Russian Federation, USA, China, Canada and Kuwait. Leading exporters of oil are: Saudi Arabia, Russian Federation, Nigeria, Iraq, United Arab Emirates and Kuwait, and the largest importers: USA, China, India, Japan, Korea (Republic) and Germany.

The largest producers of natural gas are: Russian Federation, USA, Qatar, Iran and Canada. Leading exporters of gas are: Russian Federation, Qatar, Norway, Canada and Algeria, and the largest importers: Japan, Germany, Italy, Korea (Republic), China, Turkey and France.

Substantial quantities of fossil fuels are an object of international trade. In the recent years this was almost 20% of worldwide produced coal, 50% of oil as well as approx. 30% of natural gas.

During the years 1971-2011 the growth in primary energy consumption was very uneven among the regions of the world – moderate in OECD countries and high in Non-OECD, namely:

	1971 [Mtoe]	2011 [Mtoe]	1971=100[%]
World	5 533	13 113	237
OECD countries	3 379	5 305	157
Non-OECD countries	2 046	7 448	364
Bunkers	108	360	333

The exceptionally high growth of the primary energy consumption took place during the last decades in China, India and the countries of Middle East. However, despite this growth, the average consumption per capita in the Non-OECD countries is still more than 3 times lower than the average in the OECD.

In the extreme cases, per capita consumption of primary energy is in the poorest countries, particularly African (Senegal, Ethiopia) and Asian (Yemen, Bangladesh), more than 20 times lower than in highly developed countries (Canada, USA, Australia, Norway). In some least developed countries (Senegal, Haiti, Nicaragua) the consumption per capita did not grow at all during the last four decades.

Electricity production and consumption

Though the electric phenomena in the form of lightning were known to the mankind since the pre-history, production and use of electric energy has been initiated only in the end of the 19th century. Rapid growth of electricity production took place in the 20th century and particularly after the Second World War.

Global production of electricity in 1937 amounted to only approx. 500 TWh and in 1970 it had achieved 4908 TWh. The dynamic growth of global production of electricity has been still taking place in the last decades. In 2006 the global production amounted to 18 930 TWh and in 2012 to 22 752 TWh. Therefore it has increased almost 5 times during 42 years.

It should be underlined that the growth of electricity production was higher in Non-OECD countries where it has grown over 8 times than in OECD where the growth was below 3 times during the period 1971-2012. The exceptionally high, more than 30-fold, growth has been achieved during the last 40 years in China which advanced to the first place in the worldwide ranking of the main producers of electricity, overtaking USA. The next three places in this ranking belong to India, Russian Federation and Japan, with almost equal quantities of production.

Despite the quicker growth of electricity production and consumption in the Non-OECD countries, the large differences in per capita electricity consumption still exist between the developed countries of OECD and most of the less developed Non-OECD countries. In the years 1970/71-2011 the indicators of per capita electricity consumption have grown as follows:

- in OECD countries – from 4012 kWh in 1970 to 8226 kWh in 2011,
- in Non-OECD countries – from 450 kWh in 1971 to 1785 kWh in 2011.

Many African and South Asian countries have exceptionally low indicators of electricity consumption. In several countries, particularly African (Ethiopia, Eritrea, Benin, Tanzania, Congo), the annual per capita consumption stays at the level below 100 kWh. This is an indicator of the extreme energy poverty of these countries. Moreover, more than 1.5 billion inhabitants of the less developed countries have no access to electricity at all.

The highest per capita consumption of electricity has been achieved in 2011 by the following countries: Iceland – 52.4 MWh, Norway – 23.2 MWh, Canada – 16.4 MWh, Finland – 15.7 MWh, Luxembourg – 15.5 MWh, Sweden – 14.0 MWh, USA – 13.2 MWh.

Coal was in the past and is still presently the main fuel used for electricity generation. In 2012 the share of coal in the fuel structure of global electricity generation was 40.3%. Natural gas fired power plants have generated 22.4%, hydro plants 16.5% and nuclear plants 10.8% of the globally produced electricity. Oil and renewable sources other than hydro had the shares of 5.0% each.

Prices of fuels in international trade

Before the first energy crisis, up to the year 1973, the international prices of energy commodities were low. Oil was the main source of energy for the global economy. Its prices were very low and the prices of other energy commodities stayed at the comparably low levels.

The embargo for oil supplies to the western countries, imposed in 1973 by the Arab exporters, was the reason for the first oil crisis. The second oil crisis had occurred in 1980. As a consequence of both crises the world prices of crude oil had grown dramatically, from 2.9 USD/barrel to approx. 36 USD/barrel. Prices of other fuels have followed, what resulted in high inflation, growth of unemployment and slowdown of the global economic development.

Counteracting the negative consequences of the oil crises, the industrialised countries had initiated the multidirectional activities aimed at the rationalisation of the energy economy. These activities lead to the substantial drop in oil prices and consequently also in the prices of natural gas and coal.

During the next years the prices of oil were fluctuating at the low levels, following the production cuts or surges by the OPEC producers. The strong increasing trend of prices started from the year 2000. During the years 2002-2008 the world prices of oil were on the stable increasing trend, reaching in the middle of 2008 the historical maximum of almost 150 USD/barrel. After the temporary sharp fall the price of oil has stabilised in the years 2011-2013 at a level close to 110 USD/barrel.

World prices of coal and gas were following the trends of oil prices, with some delays in time. Particularly high growth of both steam and coking coal prices took place in 2008. After a period of the relative stabilisation, the prices of coal have fallen to very low levels in the years 2013-2014.

Since 2000 the price of natural gas supplied to the EU countries was also on the rapidly increasing trend, from 1.9 USD/MBtu in 2000 to 10.6 USD/MBtu in 2008. This price has however decreased rapidly in the next years.

Final prices of fuels and energy in OECD countries

Rather transparent systems of fuels and energy prices creation, which ensure the profitability of the energy subsectors, are applied in OECD countries. On the other hand the final prices of fuels and energy frequently do not cover the company costs in the Non-OECD countries. Various forms of subsidising, particularly of household prices, are applied in these countries. Also the price information for some Non-OECD countries is hardly available.

Final (retail) prices of fuels and energy in the OECD countries are quite diverse. They depend on the costs of fuel and energy production as well as on the energy policies and taxation policies of the individual countries.

For the industrial consumption of fuels and energy, the countries apply in principle the policy of low taxation or even exemption from the selected taxes. Liquid fuels are taxed highest. In many countries the tax component of the final price of motor gasoline is close to 70%. Tax component of the gas and electricity supplied to households is typically in the range of 10-30% of final prices.

The following countries have presently the lowest prices:

- motor gasoline: USA and Canada,
- natural gas for households: Canada, USA, Turkey, Hungary, Poland,

- electricity for households: Canada, USA, Norway, Hungary.

The following countries have the highest prices:

- motor gasoline: Turkey, Norway, Italy, Netherlands, Denmark,
- natural gas for households: Japan, Sweden, Denmark,
- electricity for households: Denmark, Germany, Italy.

Comparison of fuels and energy prices with the application of the Purchasing Power Parities indicates that the prices in the highly developed countries of West Europe are lower by more than a dozen per cent when expressed in USD by PPP than the prices expressed in USD by the exchange rates. The opposed situation takes place for the less developed countries in which the prices expressed in USD by PPP are by a dozen or even several dozen per cent higher than the prices expressed in USD by the exchange rates.

High growth of fuels and energy prices for households is a disadvantageous occurrence in the recent years. In the European countries of OECD these prices calculated in USD by the exchange rates were in 2013 more than 2 times higher for gasoline and electricity and more than 3 times higher for natural gas than in 2000.

Energy and the environment

Development of industry, creation of large urban agglomerations, increase in extraction and consumption of fossil fuels caused, particularly in the second half of the 20th century, tremendous degradation of the natural environment, at both local and global scales. Degradation has manifested itself in the following forms:

- acid rains caused by the emission of SO_2 and NO_x from fossil fuels combustion, which resulted in degradation of forests and soil, disappearance of life in rivers and lakes and decline in the health condition of people and animals,
- depletion of the ozone layer which protects the Earth against the ultraviolet radiation,
- pollution of rivers and lakes by the industrial and municipal sewage,
- emission of greenhouse gases, particularly of CO_2, which results in a growth of the average global temperature and in the climate change.

The multidirectional activities aimed at the environment protection have lead to the reduction of SO_2 emissions, substantial improvement of water purity and also to the reduction of the rate of the ozone layer depletion. Unfortunately, the growth of the anthropogenic emissions of CO_2, considered to be the main reason for the global warming and climate change, was not stopped. This emission has grown rapidly, from 13.96 billion Mg in 1971 to 31.34 billion Mg in 2011.

The problem of the limitation of the anthropogenic emissions of CO_2 is tackled by the annual Conferences of the UNFCCC parties as well as by the Intergovernmental Panel on Climate Change, World Energy Council and the European Union. Unfortunately, the counteracting measures happened to be insufficient and the anthropogenic emissions of greenhouse gases, and particularly of CO_2, were still rapidly increasing. Some slowdown in the CO_2 emissions growth rate has occurred in the OECD countries, but the growth rate has accelerated in Non-OECD countries, particularly in China and India.

In 2011 the biggest emitters of CO_2 were among the OECD countries: USA – 5.29 billion Mg and Japan – 1.19 billion Mg. In the group of Non-OECD countries the biggest emitters were: China – 7.96 billion Mg, India – 1.75 billion Mg and Russian Federation – 1.65 billion Mg.

The highest CO_2 emissions per capita took place in the following OECD countries: Australia – 17.4 Mg, USA – 16.9 Mg, Canada – 15.4 Mg and Korea (Republic) – 11.8 Mg. In the Non-OECD the emissions per capita were the highest in: Saudi Arabia – 16.3 Mg, Russian Federation – 11.7 Mg, Taiwan – 11.3 Mg, South Africa – 7.3 Mg, Iran – 7.0 Mg.

Sharp increase in the global emissions of greenhouse gases, and particularly of CO_2, constitutes a large threat to the world, because the global warming and various climatic anomalies are its consequences. It is absolutely necessary to counteract this threat, and counteracting requires the international coordination.

The activities aimed to reduce the global emissions of greenhouse gases, and particularly of CO_2, are coordinated by the United Nations which organise the annual Conferences of the UNFCCC parties. The main objective of these Conferences is to negotiate the international agreement for the reduction of the global CO_2 emissions by at least 50% to the year 2050 and to limit the global level of greenhouse gases concentration in the earth atmosphere to 450 ppm of CO_2 equivalent. Reaching this objective would require the agreement of all countries for the necessary activities and spending the huge financial means for the investments in the global energy sector as well as for assistance to the developing countries expenditures for the CO_2 reducing technologies and for the adaptation to the climate change. All these activities would cause the further growth of the energy costs.

Recently the additional obstacle to the plans of limiting the global emissions of CO_2 has occurred. It is the resignation of several countries from their nuclear programmes in consequence of the serious accident at Fukushima nuclear power plant, caused by the earthquake and tsunami. In these conditions the reaching of the UN proposed objectives of the radical reduction of CO_2 emissions constitutes the great challenge to the global economy.

It should be also underlined that not all the experts are agreeable as to the influence of the CO_2 emissions on the global warming. These scientists claim that the human activity has low influence on the climatic changes, which are induced by the natural activity of Sun. An important argument for this theory is the knowledge that the warmer and colder periods, and the glacial and inter-glacial cycles have occurred in the known history of the Earth.

Table 9.1 contains the synthetic summary of the main figures and indicators which characterise the development of the global energy sector in the years 1971-2011.

Table 9.1. Main figures and indicators characterising the global energy sector development 1971-2011

Figures and indicators	Unit of measure	1971	1980	1990	2000	2006	2011	1971=100 [%]
1. Population	million	3 760	4 439	5 263	6 073	6 536	6 958	185
OECD countries	million	882	965	1 044	1 130	1 178	1 241	141
Non-OECD countries	million	2 878	3 474	5 218	4 943	5 258	5 717	199
2. GDP by PPP	billion USD	17 401	24 890	33 070	45 240	57 565	70 313	404
OECD countries	billion USD	11 467	15 509	20 917	27 246	31 157	37 906	331
Non-OECD countries	billion USD	5 934	9 281	12 153	17 994	26 408	32 407	546
3. World reserves of fossil fuels								
Hard coal	billion Mg	476[x)]	-	-	-	665,6[xx)]	690,5	145
Lignite	billion Mg	219[x)]	-	-	-	195,4[xx)]	201,0	92
Crude oil	billion Mg	89,7[x)]	-	-	-	163 ,0[xx)]	182,8	204
Natural gas	trillion m^3	64,8[x)]	-	-	-	185,5[xx)]	209,7	324
4. Global primary energy consumption	Mtoe	5 532	7 224	8 759	10 035	11 740	13 113	237
Hard coal and lignite	Mtoe	1 442	1 788	2 219	2 295	3 054	3 776	262
Crude oil	Mtoe	2 436	3 107	3 218	3 650	4 029	4 136	170
Natural gas	Mtoe	895	1 234	1 673	2 088	2 408	2 787	311
Nuclear energy	Mtoe	29	186	525	576	728	674	2 324
Hydro energy	Mtoe	104	148	184	225	261	300	288
Other sources of energy	Mtoe	629	761	935	1 201	1 260	1 440	229
5. Electricity generation	GWh	5 246	8 269	11 811	15 380	18 930	22 202	423
coal-fired	%	40,1	38,0	37,5	39,0	41,0	41,2	-
oil-fired	%	20,9	19,9	11,3	7,7	5,8	4,8	-
gas-fired	%	13,3	12,1	14,6	17,8	20,1	21,8	-
nuclear	%	2,1	8,6	17,0	16,8	14,8	11,6	-
hydro	%	23,0	20,8	18,2	17,0	16,0	16,1	-
other sources	%	0,6	0,6	1,4	1,7	2,3	4,5	-
6. Electricity consumption	GWh	4 831	7 610	10 855	14 088	17 377	20 407	422
OECD countries	GWh	3 537	5 238	7 054	9 072	9 872	10 205	289
Non-OECD countries	GWh	1 294	2 372	3 801	5 016	7 505	10 202	788
7. Primary ener. consumption per capita	toe	1,47	1,63	1,66	1,65	1,80	1,88	128
OECD countries	toe	3,83	4,22	4,33	4,71	4,70	4,27	111
Non-OECD countries	toe	0,71	0,88	0,98	0,92	1,12	1,30	183
8. Electricity consumption per capita	kWh	1 285	1 715	2 063	2 320	2 659	2 933	228
OECD countries	kWh	4 012	5 430	6 760	8 029	8 381	8 223	205
Non-OECD countries	kWh	450	683	901	1 015	1 401	1 785	397
9. Electricity intensity of GDP	kWh/USD	0,38	0,42	0,45	0,44	0,46	0,39	-
OECD countries	kWh/USD	0,33	0,36	0,35	0,35	0,34	0,27	-
Non-OECD countries	kWh/USD	0,63	0,71	0,91	0,82	0,87	0,72	–

[x)] 1974 data [xx)] 2008 data
Source: [15, 34, 66, 78, 80]

Part II

ENERGY SECTOR OF POLAND

10

BASIC INFORMATION ON POLAND

10.1. Social and economic situation of Poland in the years 1918-2013

In 1918, after the First World War, Poland regained independence after 123 years of being partitioned. The country was badly destroyed at that time. It is estimated that the war caused a destruction of about 30% of the national assets as well as the substantial losses in population.

During the years 1919-1939 Poland as an independent country had reconstructed its economy, which started to develop with dynamism. The country's population had grown from 26.7 million inhabitants in 1920 to 34.8 million in 1938 [38].

The outbreak of the Second World War in 1939 erased the successes achieved in the years 1919-1939. War losses were even higher than during the First War – 40% of the national assets was destroyed and 6 million people lost their lives. The energy sector infrastructure was also substantially destroyed.

First years after the war had brought the reconstruction and later the quick economic development has occurred. However, the existing system of centrally planned economy proved to be very inefficient. Development of heavy industry was a priority, and production of consumer goods was considered less important. Such approach caused the shortages of many goods and in consequence the serious social unrest. In 1989 the central planning system was abandoned. Since 1990 the process of deep reforms and structural transformation was initiated in the economy. Its main aim was to replace the centrally planned structures by the principles of market economy.

The first years of the reform were difficult. Industrial production dropped considerably, high inflation occurred and the Gross Domestic Product (GDP) decreased by more than 20%. As early as in 1992 the downward economic trends have been however stopped and since 1993 the economy started to develop, reaching in 1995–1998 the annual growth rate of GDP at the level of 4-7 %. Reduction of the heavy industry activity caused the associated reduction in the fuels and energy demand. The surplus of the electric capacity has occurred in the national power system.

During the next years the economic conditions were favourable and the growth rate of GDP was higher in Poland than in many other countries of Europe. The economy slowed down in the years 2008-2013 because of the global economic crisis.

10.2. Country area, population, borders, membership in international organisations

Poland is a medium-size country, with an area of 312 700 km^2, situated in the central-eastern part of Europe.

In 2008 the population of the country was 38.2 million, of which 62% was urban and 38% rural population. The average density of population was 124 inhabitants per 1 km^2. In comparison with 1999 the population of Poland decreased by about 0.5 million of inhabitants.

The neighbours of Poland are: Germany at the west (border length 467 km), Czech Republic (796 km) and Slovakia (541 km) at the south, Ukraine (535 km) and Belarus (418 km) at the east, Lithuania (104 km), the Kaliningrad Area of the Russian Federation (210 km) and the Baltic Sea (440 km) at the north [39].

Poland is an industrial and agricultural country with large areas of agricultural land and forests. In 2008 the share of agricultural land in the total area of the country was 61% and the share of forests 30%.

According to the country area and population Poland is the sixth country of the EU-28, and according to the GDP absolute value is the seventh economy of the European Union.

Poland is a member country of the following most important international organisations:

- Organisation of the Economic Cooperation and Development (OECD) – since 1996,
- North Atlantic Treaty Organisation (NATO) – since 1999,
- European Union (EU) – since 2004,
- International Energy Agency (IEA) – since 2008.

Poland belongs also to many sectoral international organisations. In 1995 the electric system of Poland was interconnected with the Western European system (UCTE).

11

HISTORICAL OUTLINE OF THE ENERGY DEVELOPMENT OF POLAND

11.1. Beginnings and development of energy use at the lands of Poland up to the First World War

In the old times, up to the middle of 19th century, wood was a main source of energy used by the population of Poland, as it was also in the other countries. Wood was used for heating of living places and for food preparation. Wood was also a major building material.

In the ancient times a charcoal was also produced from wood. Charcoal was a source of energy for the iron smelting in so-called bloomeries. This early metallurgy was developing considerably on the lands of Poland, particularly in the Holy Cross Mountains, in the beginning of the second millennium.

In the middle of the second millennium the wind energy was also being exploited, with the use of windmills which came to Poland from West Europe, particularly from the Netherlands. Hydro energy was also applied for grain milling.

The major breakthrough in the wider scale application of energy took place in the 18th century. It was connected mainly with the use of coal in a developing metallurgy and with the application of coke for iron and zinc smelting.

In the second half of 19th century oil became a source of energy. The beginnings of its application were connected with the invention of the kerosene lamp by Ignacy Łukasiewicz and with the invention of the oil refining process.

In the second half of 19th century the first gas works were built. They manufactured gas from coal. Gas was used in the beginning mainly for street lighting in big cities, and later more widely for various applications in households and in industry.

In the last years of 19th century the first generators of electricity were installed in power stations and in various industrial plants. Initially they had low capacities and the electricity was at the beginning used mainly for lighting. In the first years of 20th century several more advanced power stations were built in big cities. Their capacities were gradually increasing but nevertheless the production of electricity was in Poland low before the First World War.

11.2. Energy sector in the period of independence 1918-1939

Before the First World War, in 1913, hard coal production on the lands of Poland amounted to 52 million Mg and crude oil production was 1.1 million Mg.

Damages during the First War caused a considerable decline in production and consumption of fossil fuels. In the interwar period 1918-1939 a production of coal and oil was rebuilt, reaching the level similar to the previously achieved before 1913.

The electricity supply industry started to develop quickly in this period. Many small power plants were constructed, both coal-fired and hydro plants. Electricity generation was increasing quickly. Also the natural gas production and oil refining were developing.

In 1938 hard coal production was equal to 38 million Mg what situated Poland at seventh place in the world and at the fifth in Europe. Electricity generation was 3977 GWh, natural gas production 584 million m^3 and crude oil production 507 thousand Mg. Oil was processed in 27 Polish refineries.

Before the Second World War the energy sector installations in Poland were owned principally by private entrepreneurs. Coal mines, power stations, gas works and oil refineries were owned by foreign capital, by municipalities (public utilities) or by private industrial companies.

Electricity supply industry was highly dispersed. In 1938 electricity was generated by as many as 3198 plants, and 998 of them had the capacities not exceeding 100 kW. Few plants had the capacities of dozen or several dozen MW. Power plants had the local character, they supplied electricity to the industrial plants and to the consumers in bigger towns. There was no nationwide power system.

11.3. Development of energy sector in the period of centrally planned economy 1945-1989

During the Second World War the assets of the energy sector were substantially destroyed. Though coal mines did not suffer much from the war operations, the production of coal declined because of excessive exploitation and devastation of equipment. Power plants, gas works and network infrastructure were seriously destroyed.

During the first years after the war the destroyed equipment has been gradually reconstructed. Thanks to that, already in 1950 hard coal production reached 78 million Mg, crude oil production 162 000 Mg, natural gas production 183 million m^3. Also 9422 GWh of electricity was generated.

The principal changes in ownership were introduced. Main industries, including the energy sector, were nationalised. After the period of the post-war reconstruction, during the years 1960-1980, the large and modern production capacities were developed in hard coal and lignite mining. Several modern power plants with high installed capacities have been constructed. An integrated national power system was created and connected with the systems of the neighbouring countries. Also an integrated national gas system and the system of transit gas pipelines which enables to import gas to Poland have been built. A modern refining and petrochemical industry, with the oil transportation system, products distribution system and other necessary associated infrastructure has been constructed. In big towns the district heating systems have been built which supply consumers with thermal energy, in large part cogenerated with electricity.

High production of hard coal enabled to export its substantial quantities, giving the country large revenues which were the important source for financing the general development. Production of hard coal peaked in 1979, reaching 201 million Mg, of which 42 million Mg were exported.

Hard coal production decreased in 1980s because of the recession, to 148 million Mg in 1990. In 1990s coal production was still decreasing due to the reform and restructuring of the mining industry. In 2000 production volume was 102 million Mg. Large production of coal ensured in the years 1970-1990 the high levels of energy self-sufficiency of the country. Therefore the economy of Poland did not suffer from the oil crises of that period.

The highest production of lignite was achieved in 1989 – 71.8 million Mg. Later the production decreased to the level of 59.5 million Mg in 2000.

The largest production of high-methane natural gas – at the level of 5.4 billion m^3 – was achieved at the beginning of 1970s. Later it gradually declined, to the level of 2.0 billion m^3 in the year 2000. Simultaneously the production of nitrified natural gas reached its highest level of 4.2 billion m^3 in 1985 and subsequently decreased to 2.9 billion m^3 in 2000.

Electricity generation reached in 1989 the level of 145.5 TWh, slightly decreased in the period 1990-1992 and afterwards was stable at 140-145 TWh through the decade to the year 2000. Stabilisation or small growth of electricity generation in this decade was the result of reduced demand from the industry, particularly heavy industry, and of the various rationalisation activities implemented in this period.

The rapid development of fuels and energy sector in the post-war period, and particularly large production of hard coal and its high exports, enabled the general development of national economy. However the doubtless achievements of the Polish energy sector during the post-war period were until the beginning of 1990s accompanied by many disadvantageous occurrences which were the effects of the general economic policies. The following occurrences should be particularly listed:

- high energy intensity of GDP, higher than in the OECD countries,
- excessive dependence on coal and disadvantageous structure of primary energy consumption; in 1988 coal covered almost 78% of primary energy requirements of the country and the hydrocarbon fuels only 22%; consumption of hydrocarbon fuels per capita was 3-4 times lower than in Western European countries,
- high dependence of economy on imports of oil and gas from the single supplier (the former Soviet Union),
- large degradation of the natural environment, caused mainly by the excessive share of coal in the primary energy balance, lack of flue gas desulphurisation equipment and high energy intensity of the economy,
- low prices of energy commodities, substantially incompatible with their production costs, what resulted in the wastage of fuels and energy.

Domination of coal in Polish economy as well as the wastage of fuels and energy contributed to the high energy intensity of the economy and were substantially decreasing its competitiveness. The negative impacts of the energy sector at the environment caused some areas of Poland to be among the most seriously devastated in Europe (e.g. „the black triangle", where the emissions from Czechoslovakia and GDR were also concentrated).

11.4. Development of energy sector in the conditions of market economy 1990-2013

Social and economic changes and the reform of Polish economy in 1990s have created conditions for the advantageous changes also in the energy sector [57].

Within the economic structures, the activities of the energy intensive heavy industries were considerably reduced and consequently the fuel and energy demand has declined, particularly the demand for coal and electricity.

Difficult process of the energy price reform was initiated. The role of the economic parameter has been restored to the prices. Moreover, prices became an important factor in rationalisation of the energy economy.

Various rationalisation programmes, both on fuels and energy supply side and on demand side, were introduced. Quality of coal supplied to power plants has been considerably improved. The efficiency of electricity generation has increased. In the municipal economy the losses of heat were substantially reduced, among others due to the implementation of wide programme of buildings thermo-modernisation.

The series of activities aimed at the reduction of environment degradation by the energy sector had been initiated. Power stations started to implement a very expensive programme of the modernisation of coal burning equipment. Thanks to that, the emissions of SO_2, NO_x and ash were radically reduced. Multi-billion means for this goal were received from the so-called „long-term contracts".

The difficult and very expensive process of hard coal mining reform was initiated – many unprofitable mines were closed, coal production was reduced, the employment in mines was radically reduced with the associated increase in labour productivity.

With the economic growth, which started since 1993, the structure of the national energy balance began to change. Consumption of energy, both primary and electric, also started to increase slowly.

The restructuring activities have driven the energy prices to the realistic levels as well as caused the considerable reduction of the GDP energy intensity and substantial improvements in the environment, through reduction of harmful emissions of SO_2, NO_x, particulate matter and ashes.

12

RESERVES OF ENERGY COMMODITIES IN POLAND

Poland has relatively large resources of solid fuels (hard coal and lignite), modest reserves of natural gas, insignificant of crude oil, small hydro energy potential and considerable resources of biomass and geothermal energy. The country has no uranium ores with high concentration of this element. Substantial quantities of uranium are however present in a dispersed form. According to the experts, uranium production for the energy purposes would be possible from such deposits but at the costs much higher than in case of concentrated ores.

12.1. Reserves of fossil fuels

Total quantities of fossil fuels located in underground deposits are considered to be the geological resources. The in-balance resources and out-of-balance resources are separated within the geological resources.

The in-balance resources are these which may be recovered under the present technical and economic conditions.

The out-of-balance resources are those which may not be recovered under the present conditions but it is expected that their recovery would be possible in the future in consequence of the technical and economic progress.

In more detail, Polish classification of fossil fuel deposits contains seven categories of their applicability for production. From the lowest to the highest level of applicability, the categories are named: E, D2, D1, C2, C1, B and A [33].

12.1.1. Hard coal

Resources of hard coal are substantial in Poland. They are located in two basins: Upper Silesian Coal Basin – about 80% and Lublin Coal Basin – about 20% of all resources. Small reserves are also located in the Lower Silesian Coal Basin where the exploitation was finished due to the unprofitability.

The in-balance resources of hard coal have been considerably scaled down in the recent years, because of closing of the high cost mines. Resources located at the closed mines have been re-classified to the category of out-of-balance.

According to the assessments by the Polish Geological Institute, the resources of hard coal were (as of 31 December 2013) the following:

- in-balance resources 51.4 billion Mg
  of which: recoverable 19.5 billion Mg
  non-recoverable 27.9 billion Mg
- out-of-balance resources 19.1 billion Mg
  of which: recoverable 7.9 billion Mg
  non-recoverable 10.5 billion Mg

Within the in-balance resources, steam coal amounted to 37.1 billion Mg (72%), and coking coal to 13.5 billion Mg (26%).

Detailed data on the geological and industrial resources of hard coal, including their more detailed classification, are presented in Table 12.1.

12.1.2. Lignite

The in-balance resources of lignite are substantial in Poland. Recoverable reserves are located mainly in three basins: Bełchatów, Turów and Pątnów-Adamów-Konin. The non-recoverable reserves exist in the areas located near Legnica, Zielona Góra, Poznań and Łódź. From the yet undeveloped resources, the exploitation is most realistic in the Zielona Góra area. Exploitation of Poznań area deposits is less probable because of their location and because of the environmental conditions (the area of Poznań Graben). Also the probability of the exploitation of Łódź area deposits is low due to the high salt content in this lignite.

According to the assessments by the Polish Geological Institute, the resources of lignite were (as of 31 December 2013) the following:

- in-balance resources 22.7 billion Mg
  of which: recoverable 1.5 billion Mg
  non-recoverable 21.2 billion Mg

Table 12.1. Hard coal resources and its structure, as of 31 December 2013 [million Mg]

Specification	Geological resources					Industrial resources
	In-balance resources				Out-of-balance resources	
	Total	A+B	C1	C2+D		
Total resources	51 414	5 954	15 232	30 228	19 056	3 840
of which:						
Steam coal	37 122	3 965	9 833	23 324	14 408	2 263
Coking coal	13 504	1 982	5 347	6 174	4 612	1 577
Other coal	788	8	52	729	37	-
of which recoverable resources						
Total	19 485	4 530	8 444	6 511	7 922	3 828
of which:						
Steam coal	11 407	2 734	5 043	3 630	5 545	2 251
Coking coal	8 075	1 796	3 401	2 879	2 377	1 577
Other coal	2	-	-	2	-	-
of which non-recoverable resources						
Total	27 946	306	5 197	22 443	10 511	12
of which:						
Steam coal	22 698	289	3 473	18 936	8 516	-
Coking coal	4 617	17	1 724	2 876	1 995	12
Other coal	631	-	-	631	-	-

Source: [81]

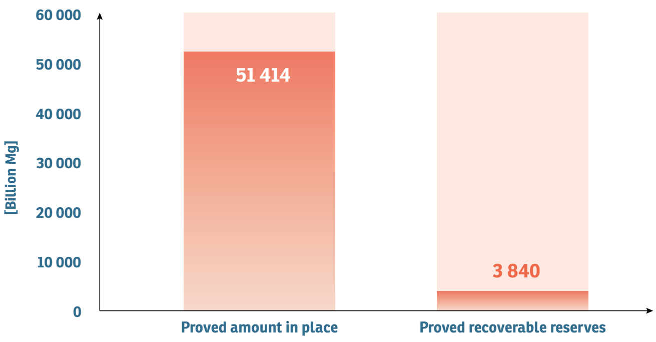

Fig. 16. Hard coal resources in Poland, as of 31.12.2013

- out-of-balance resources 3.5 billion Mg
  of which: recoverable 0.1 billion Mg
  industrial resources 1.4 billion Mg

Detailed data are presented in Table 12.2.

The separate assessments of lignite resources, conducted in the recent years by the Polish Association of Lignite Resources, indicate that Poland possesses much larger resources of lignite than the resources recognised by the Polish Geological Institute.

Table 12.2. Lignite resources and its structure, as of 31 December 2013 [million Mg]

Specification	Geological resources				Industrial resources
	In balance resources			Out-of-balance resources	
	Total	A+B+C1	C2+D		
Total resources	22 684	5 523	17 161	3 523	1 165
of which recoverable resources					
Total	1 514	1 498	16	70	1 148
Deposits at working mines	1 509	1 493	16	51	1 148
of which non-recoverable resources					
Total	21 158	4 014	17 144	3 445	17
Deposits assessed in detail	4 703	4 014	689	809	17
Deposits preliminary assessed	16 455		16 455	2 636	-
deposits with finished exploitation					
Total	11	10	1	8	-
Finished exploitation	11	10	1	8	-

Source: [81]

According to the Polish Association of Lignite Producers the total resources of lignite are as follows [32]:

	[billion Mg]		
	Geological resources	In-balance resources	Out-of-balance resources
Documented deposits	24,6	14,0	4,9
Prospective deposits	58,2	-	-
Lignite containing areas	141,7	-	-
Total	224,5	14,0	4,9

12.1.3. Crude oil

Documented resources of oil are very small in Poland. According to the assessments by the Polish Geological Institute, they were at the end of 2009 as follows:

- recoverable in-balance resources 24.4 million Mg
- of which: developed deposits 23.9 million Mg
- out-of-balance resources 0.4 million Mg

Deposits of crude oil are located mainly at the Polish Lowlands, in the Carpathian and Sub-Carpathian region as well as offshore at the Baltic Shelf. The results of all surveys exclude the possibility of large discoveries of oil in Poland. Detailed data on crude oil resources in Poland are presented in Table 12.3.

12.1.4. Natural gas

Documented resources of natural gas were at the end of 2013 as follows:

- recoverable in-balance resources 132.1 billion m^3
- out-of-balance resources 2.2 billion m^3

More than 80% of the in-balance resources are located in the developed deposits, mainly at the area of Lowlands. Natural gas is present also in the Sub-Carpathian region.

Natural gas from the Sub-Carpathian region has high calorific value and high content of methane while gas from Lowlands is mainly low calorific with a high content of nitrogen.

Detailed data on natural gas resources and its locations in Poland are presented in Table 12.4.

There is a high probability that besides the con-

Table 12.3. Crude oil resources by categories and locations, as of 31 December 2013 [million Mg]

Specification	Recoverable resources				Industrial resources
	In-balance resources			Out-of-balance resources	
	Total	A+B	C		
Total resources	24,4	10,6	13,8	0,4	15,4
in which:					
Developed deposits	23,9	10,4	13,5	0,03	15,4
Baltic (offshore)	4,8	1,4	3,5	-	4,8
Carpathian region	0,5	0,4	0,1	0,02	0,1
Polish Lowlands	18,1	8,4	9,7	0,01	10,5
Sub-Carpathian region	0,4	0,3	0,2	-	0,1

Source: [81]

Table 12.4. Natural gas resources by categories and locations, as of 31 December 2013 [billion m^3]

Specification	Recoverable resources				Industrial resources
	In-balance resources			Out-of-balance resources	
	Razem	A+B	C		
Total resources	132,1	83,8	48,2	2,2	62,2
in which:					
Developed deposits	110,4	78,1	32,3	0,7	57,9
Baltic (offshore)	0,6	0,1	0,4	-	1,3
Carpathian region	0,9	0,6	0,3	0,01	0,3
Polish Lowlands	75,8	56,7	19,1	0,7	47,7
Sub-Carpathian region	33,1	20,6	12,5	-	8,6
Undeveloped deposits	21,4	5,8	15,6	1,4	4,2

Source: [81]

ventional natural gas the large resources of shale gas are present at the territory of Poland. The US companies preliminarily estimated the shale gas quantities at 1.5–3.0 trillion m^3. If these estimates were confirmed, shale gas would cover the national requirements for 100-200 years [23]. Shale gas exploration is conducted by several companies, mostly US as well as by Polish Oil and Gas Company.

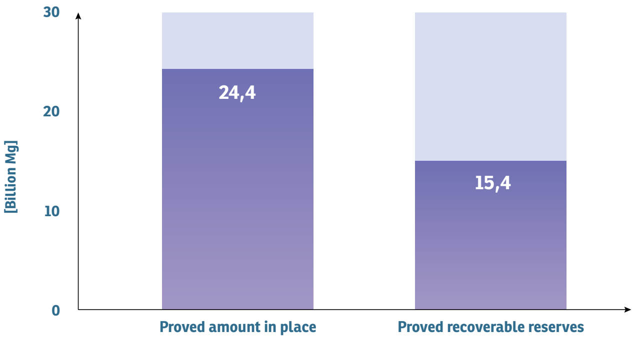

Fig. 17. Crude oil resources in Poland, as of 31.12.2013

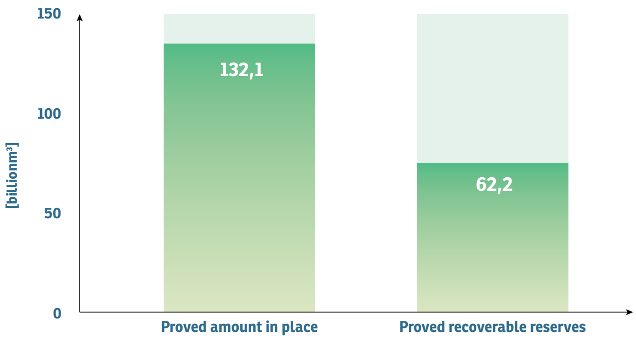

Fig. 18. Natural gas resources in Poland, as of 31.12.2013

12.2. Resources of renewable energy

12.2.1. Hydro energy

Poland has no advantageous conditions for the hydro energy exploitation. The energy potential of water flows is small, mainly due to the low gradients of these flows.

The theoretical potential, measured by the quantity of electricity which may be acquired from water flows, is estimated at about 23 TWh/year (17.4 TWh from Vistula basin, 5.2 TWh from Odra and 0.5 TWh from the Baltic coast rivers) [40].

The technically exploitable capability is estimated at 12-15 TWh/year. The present exploitation is 2.5-3.0 TWh/year.

Such a small share of hydro energy in the Polish power system implies its low importance for the system. Only the pumped-storage hydro plants are more important, due to the provision of the regulatory services and generation of electricity during the peak hours.

12.2.2. Geothermal energy

Poland has a considerable potential of geothermal waters. The temperature of geothermal water depends mainly on the depth of wells from which water is exploited.

A possibility of geothermal waters acquisition exists on 40% of the country territory. It is assumed that the exploitation is economic when the well depth does not exceed 2 km, water temperature achieves at least 65°C and the salt content does not exceed 30 g/l.

It is assessed that the geothermal resources are big and their technical potential is at the level of 625 PJ/year. The exploitation of geothermal resources is however small and the low temperature of waters is the main objection to the wide exploitation. Thermal capacity of the existing geothermal installations is only about 200 MWt.

There are four bigger geothermal installations in Poland, namely:

- Geotermia Podhalańska at Bańska Niżna near Zakopane, with the capacity of 125 MWt and annual heat production at the level of 400 TJ,
- Geothermal Plant at Mszczonów, with the capacity of 12 MWt and annual heat production of about 17 TJ,
- Geothermal Plant at Uniejów, with the capacity of 4.6 MWt and annual heat production of about 17 TJ,
- Geothermal Plant at Pyrzyce, with the capacity of 50 MWt and annual heat production of about 50 TJ.

Because the geothermal waters in Poland have mostly the low temperatures, they can be more widely and more economically utilised in combination with heat pumps which become more economic because of the increasing prices of the conventional energy carriers.

12.2.3. Biomass

Biomass is defined as the solid or liquid substances of plant or animal origin which are subject to bio-degradation. The main types of biomass are the products, wastes and residues from the agricultural production, forests and the industry which processes such products. Also the bio-degradable fractions of other waste, e.g. municipal, are considered biomass [55].

Main detailed types of biomass used for the energy purposes are as follows:

- wood and wood waste (wood chops, sawdust, chips, bark, other wood waste),

- plants from the energy crops:
  - rapidly growing trees (willow, poplar),
  - perennial bush, e.g. common reed,
  - agricultural products and organic wastes, e.g. straw, hay, residues of sugar beet, potatoes and rape, animal manure,
- organic fractions of municipal waste,
- selected types of industrial waste, e.g. from the pulp and paper industry.

Technical potential of biomass resources is substantial in Poland. The Institute of Renewable Energy estimated this potential at 755 PJ/year [24]. The Wrocław University of Environmental and Life Sciences estimates the technical potential of solid biomass at 407.5 PJ/year and the potential of liquid biomass at 200–700 million l/year (depending on the area at which oilseed plants are grown) [68]. The other authors and research centres publish the similar estimates of the biomass resources.

12.2.4. Wind energy

Wind is a transformed energy of Sun. The theoretical potential of wind energy is substantial in Poland. The locations most advantageous for the installation of wind farms are the following [26]:

- central and northern part of Baltic Sea coast, from Koszalin to Hel,
- Usedom island,
- region of Suwałki.

The other areas relatively advantageous for wind energy are:

- middle Greater Poland and Mazovia,
- Silesian and Żywiec Beskidy mountains,
- Bieszczady mountains and Dynów region.

Practical exploitation of wind energy depends on many factors, and particularly on:

- numbers and capacities of existing wind turbines,
- height of wind turbines over the ground,
- size of wind turbine blades.

The experts estimate that more than a dozen per cent of the electricity requirements of Poland may be covered by wind energy, under the optimistic assumptions.

13

DEVELOPMENT OF THE FUEL AND ENERGY SUBSECTORS

13.1. Hard coal mining

The resources of hard coal are located in Poland in three basins of different size: Upper Silesian, Lower Silesian and Lublin.

Existence of coal at the areas of Lower and Upper Silesia was known for a long time. Coal was extracted by the local population already in 14th and 15th centuries, in small quantities by the simple techniques. Coal was used to cover the requirements of local population. At the beginning coal was extracted by opencast technique in the locations where it was present close to the earth surface. Production of coal was very small on the lands of Poland to the end of 18th century.

In Lower Silesia the extraction of coal was initiated already in 14th century. Extraction was slightly intensified at the beginning of 18th century. Fifteen small opencast mines existed there already in 1742, but the larger scale production started only in the middle of 19th century [8].

The presence of hard coal in the Upper Silesia was known already at the end of 16th century but the oldest written information on its extraction comes from the first half of 18th century. According to this information, the Murcki mine existed in 1740 and employed 8 people. It is considered to be the oldest coal mine in this region.

The first deep mine was built in this area in 1791. At that time the use of coal was widening. Its consumers were the neighbouring iron mills, small plants of various branches, forges etc. [8].

Substantial increase of coal demand took place at the turn of 18th and 19th century, both in Lower and Upper Silesia. This was connected with the development of industry, particularly with the application of coke for the smelting of iron and zinc. In the middle of 19th century the total production of hard coal in both basins reached 1.5 million Mg, and Upper Silesia was leading before the Lower Silesian region.

Dynamic development of coal production had occurred in the second half of 19th and in the beginning of 20th century. A demand for coal rapidly increased, driven by the development of railways, iron and non-ferrous metals industry, power generation and various other branches of economy. In 1900 coal production in both Silesian basins – divided at that time between Prussian, Austrian and Russian empires – reached almost 35 million Mg and in 1913 approx. 52 million Mg. Upper Silesian Basin accounted for 85% of that production [8].

As a result of First World War, the Upper Silesian Basin has been divided between Poland and Germany. Fourteen mines with 26% of production were located at the German side of border.

Between the wars the production of coal in the mines, which belonged to Poland, was stable at the level close to this achieved before the First World War, except for the 1929-1933 crisis when it substantially decreased [8].

A period of Second World War was characterised by the wasteful exploitation by German occupants. The mining economy was aimed at the maximum production with very low expenditures, what caused the reduction of mining capacities and considerable decline in production volumes. Fortunately the mines were not seriously damaged when the war operations took place in Upper Silesia in 1945.

During the first difficult post-war years all mines quickly started their operation. Construction of new shafts has been initiated, the existing shafts were modernised, new departments were prepared in the existing mines. Two new mines were also built in the first post-war years. Thanks to all these investments, the 1938 level of production was achieved already in 1948, and in 1950 production increased to 78 million Mg.

In 1960s and 1970s a dynamic increase of coal production was achieved, due to the construction of

25 new mines, additional investments in the existing mines and introduction of new mining techniques.

In 1984 production of coal was initiated in Lublin Basin where the new mine Bogdanka was constructed. Due to these activities the total national coal production reached: 104.4 million Mg in 1960, 140.1 million Mg in 1970 and 201 million Mg in 1979 [2].

During 1980s hard coal production was decreasing to the level of 148 million Mg in 1990 [2]. This decrease was caused by the economic recession, reduced national demand, deterioration of technical and geological conditions of the mines, and increase of production costs. The quality of coal improved however considerably in 1980s.

During the years 1945-1980 hard coal was the main natural wealth of Poland. It was the basic fuel for electricity generation and for various branches of industry as well as the important raw material for chemical industry. Hard coal was also an important export commodity. Its mines were employing hundreds of thousands of people, particularly in the area of Upper Silesian Basin. Since 1980s however, and particularly in the decade of 1990s, the importance of hard coal for Polish economy started to decline. Production volume in the year 2000 amounted to only 103 million Mg, just about a half of the end-1970s quantity [3].

Reduction of hard coal output at the beginning of 1990s as well as the deteriorating economic situation of mines (indebtedness and negative financial results of coal sales) caused the necessity for the overall reform of the coal branch. The first restructuring programme has been formulated in 1992 and gradually implemented during the next years. In 1998 the Council of Ministers adopted the programme „Reform of Hard Coal Mining in the years 1998-2002", giving it a high priority of implementation. Large expenditures from the State budget were spent for this programme (7.2 billion PLN), mainly on closing down the mines and on compensations for the dismissed employees (so-called Social Package for Miners) [31].

The main objectives of the governmental programme of the mining reform were as follows: adjustment of the mining capacities to the market requirements, improvement of coal quality, reduction of employment and economic recovery through the achievement of mines profitability. The programme assumed further decrease of production volumes to about 80 million Mg in 2020 and reduction of coal exports to the level implied by the production and the requirements of domestic economy.

The results of coal mining reforms implemented during the years 1990-2003 were as follows [49]:

- closing of 30 mines and total liquidation of the Lower Silesian Basin;
- reduction of employment by 280 000 people, from 416 000 in 1989 to 136 000 in 2003;
- decrease of production volume by 77 million Mg, from 177 million Mg in 1989 to 100 million Mg in 2003;
- improvement of the economic standing of mines and achievement of the positive financial result of the whole hard coal subsector in the year 2000; the problem of serious indebtedness has not been however yet sold;
- substantial improvement of coal quality, among others due to the construction of modern coal processing and de-sulphurisation plants as well as modernisation of formerly existing plants.

The reform of Polish coal mining sector, implemented in so short time period, should be recognised as a big economic and organisational achievement – the similar reforms required longer times of implementation in other countries (France and United Kingdom). Unfortunately, the social side of the reform was the loss of jobs by hundreds of thousands of people and substantial growth of unemployment in the Lower and Upper Silesian regions.

The next stage of the reform, implemented during the years 2003-2005, resulted in the reduction of the excessive mining capacities, by about 6.6 million Mg/year and reduction of the workforce by 17 100 employees to the level of 119 300 people at the end of 2006. The debts of the mines were also largely reduced.

In the process of implementing the coal mining reforms the appropriate attention was not paid to the new investments. In consequence the operating resources available for exploitation dropped quickly in the recent years and the availability of domestic coal for electricity generation decreased, giving the field for the quick growth of steam coal imports. Acceleration of new investments in hard coal mines became the urgent necessity.

In 2007 the Ministry of Economy adopted „The Strategy of Hard Coal Mining Industry Activities in Poland for 2007-2015" which took into account the existing economic situation of the country and its consequences for the hard coal mining subsector. The main aim of this strategy was to adjust coal production to the level of national demand and the economically justified exports, with the simultaneous improvement of coal quality. The Strategy was approved by the Council of Ministers in July 2007.

During the latest 24 years (1990-2013), i.e. in the period of market economy in Poland, production,

Table 13.1. Balance of hard coal 1950-2013 [million Mg]

Specification	1950	1960	1970	1980	1990	2000	2010	2013
Production	78,0	104,4	140,1	193,1	147,7	103,3	76,7	77,0
Import	-	0,8	1,1	1,0	0,6	1,4	13,6	10,8
Export	25,6	17,5	28,8	31,1	28,1	23,2	10,6	10,6
Stock change	-0,4	-0,6	0,1	-1,0	0,3	2,7	-4,9	-1,7
Consumption	51,8	88,3	112,3	164,0	119,9	84,1	84,6	79,0

Source: [2, 4, 50]

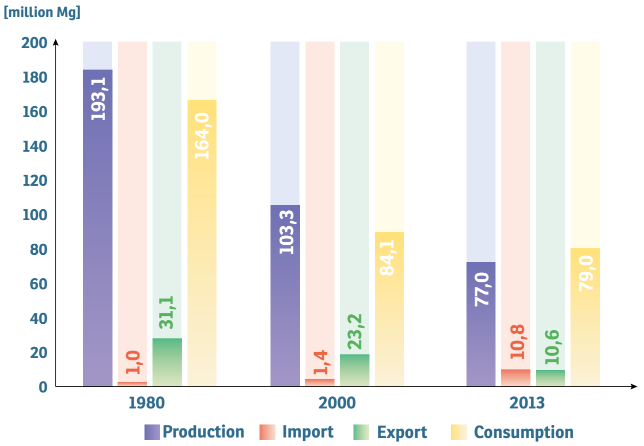

Fig. 19. Hard coal balance in Poland 1980-2013

exports and consumption of hard coal were radically reduced in consequence of many factors, including the general economic reforms and the specific reform of the coal mining. Poland became the net importer of coal instead of being the large net exporter. Hard coal production dropped from 147.7 million Mg in 1990 to 77.0 million Mg in 2010. However, Poland is still the biggest producer of hard coal in the European Union.

Statistical data on hard coal production, imports, exports and national consumption in the years 1950-2013 are presented in Table 13.1.

13.2. Lignite mining

The beginnings of lignite mining on the lands of Poland are dated back to the 18th century. Production developed mainly in the Lower Silesia, though the volumes of lignite were small. It was consumed by local population and small industry, mainly brick manufactures.

Some intensification of lignite extraction occurred in the 19th century. A dozen small mines were built in the vicinities of Zgorzelec, Lubań and Zielona Góra. They produced in the middle of 19th century about 130 thousand Mg of lignite per annum.

At the beginning the seams were exploited which touched the ground, and since about 1900 the more advanced technique of mining was introduced, which included removal of the layer of soil. Lignite production increased substantially in the first decades of 20th century in the regions of Lower Silesia, Pomerania and locations around Zielona Góra. The main centres of exploitation were: Turoszów, Lubań, Węgliniec, Żary and Sulęcin. Total production of these centres achieved approx. 3 million Mg in 1935 [8].

Between the wars the interest in lignite was rather low in Poland because of the competitiveness of hard coal. Lignite was extracted at small mines, mainly in the provinces of Poznań, Pomerania, Kielce and Kraków. Total production was declining, from 270 thousand Mg in 1921 to 10 thousand Mg in 1938 [8, 20].

After the Second War the interest in lignite has grown in Poland as in some other countries. A large resource base has been acquired by Poland when the Western lands joined the country after the war. The reserves were extensively surveyed during 1950s and 1960s. Construction of several large opencast mines and associated power plants has been initiated.

The mine Turów II started exploitation in 1963. Several mines were constructed in Konin-Turek Basin: Gosławice in 1958, Pątnów I and II in 1962, Adamów in 1964, Kazimierz in 1966 and Jóźwin in 1971. At the beginning of 1980s the largest mine Bełchatów started its activity [36]. Thanks to these investments, lignite became the second, after hard coal, fuel for Polish power industry. Production of lignite was increasing very rapidly, from 4.8 million Mg in 1950 to 32.8 million Mg in 1970 and to 67.8 million Mg in 1990. Up to 1980 lignite was also exported to German Democratic Republic in the quantity of few million Mg annually.

Lignite is cheaper in Poland (in relation to the energy unit) than hard coal. Lignite is extracted in 100% by opencast technique. Production is however accompanied by the negative environmental impacts. Also during lignite combustion the large quantities of CO_2, SO_2 and ash are released. Opencast mining causes degradation of considerable areas of agricultural land and forests, change in the levels of underground waters, reduction of agricultural yields around mines etc. Big post-production areas require land reclamation.

Thanks to the large financial expenditures the negative impacts associated with the extraction of lig-

Table 13.2. Balance of lignite 1950-2013 [million Mg]

Specification	1950	1960	1970	1980	1990	2000	2010	2013
Production	4,8	9,3	32,8	36,9	67,6	59,5	56,5	65,8
Import	-	-	-	-	-	-	-	0,2
Export	3,8	5,4	4,0	1,6	0,2	-	0,1	0,2
Stock change	-	-	-	-	-	0,2	-0,2	-
Consumption	1,0	3,9	28,8	35,3	67,4	59,3	56,6	65,8

Source: [2, 4, 50]

nite as well as with its combustion were brought under control. This applies to both land reclamation and the mitigation of SO_2 emissions from power plants.

Statistical data on lignite production, export and national consumption are presented in Table 13.2.

It should be underlined that the lignite mining subsector has initiated the multidirectional activities aimed at minimising the negative environmental impacts of its activities. Large progress has been achieved in this field. Many activities were implemented, concerning the reclamation and revitalisation of the post-mining areas. Such achievements are an important aspect of the social responsibility of Polish lignite mining subsector.

The land reclamation and revitalisation activities are conducted by all major lignite mines, i.e. Adamów, Konin, Turów and Bełchatów. By now the mines have reclaimed approx. 11000 hectares of the post-mining land. New forest areas, agricultural fields, water reservoirs as well as the tourist areas were created on the reclaimed land [33].

Lignite constitutes in Poland an important fuel for electricity generation. Over 1/3 of electricity is generated in Poland from lignite. The energy forecasts indicate that also in the future lignite should be an important component of the national energy balance, due to the existing resources and the low cost of electricity generation from this fuel. Lignite is however one of the main sources of CO_2 emissions and the EU policy provides for the radical reduction of these emissions in order to stop the process of climate change.

Having in mind the positive characteristics of lignite as an important source of primary energy, one should hope that a problem of CO_2 emissions reduction would be solved and that lignite will remain an important component of the national energy security also in the future.

13.3. Oil industry

Crude oil is a main raw material for the production of liquid fuels. The oldest information on crude oil at the Polish territories date from 16th and 17th century. The oil, called then „rocky oil", was acquired by the population first from natural leaks and later from the simple, only few meters deep, wells. At the beginning oil was used as a medicine, and later for leather processing, lubricating the carts, impregnation of wood etc. Candles were manufactured from the natural wax which associated crude oil. The place where oil was earliest extracted was Drohobycz.

The first surveys of oil fields in the Sub-Carpathian region were conducted by Stanisław Staszic, „the father of Polish geology". The interest in oil rose in the middle of 19th century due to the inventions of Ignacy Łukasiewicz who constructed the first small distillery of oil at his pharmacy in Gorlice. He obtained kerosene as a product of distillation. He also invented the kerosene lamp. Therefore he is recognised as a founder of oil industry in Poland.

At that time the oil wells were installed at Polanka and Bóbrka in Carpathian region and later in Borysław and Drohobycz. Production and consumption of oil started to increase rapidly, achieving approx. 2 million Mg in 1909 [38]. A growth of oil requirements was associated mainly with a development of transportation.

During the First World War and between the wars the production declined because of resource depletion and in 1938 only 507 thousand Mg of oil have been produced [38].

As a consequence of territorial changes after the Second World War only the western part of Sub-Carpathian oil basin belongs to Poland. Oil production was small at this area and never exceeded 200 thousand Mg.

New small fields were discovered at the Polish Lowlands in the beginning of 1970s and on the Polish sector of Baltic Sea in 1980s. These discoveries allowed the production to increase to 500 thousand Mg for some period of time but later production once more fell to the level of 200 thousand Mg. At the turn of the centuries, due to the development of Lowlands and submarine fields, total production has grown, achieving 653 thousand Mg in 2000 and 962 thousand Mg in 2013 [4].

The surveys and discoveries indicate that Poland has no „big oil" and is almost fully dependent on its imports. In the year 2000 the national consumption of crude oil was approx. 18 million Mg and in 2012 exceeded 25 million Mg. Therefore around 96% of consumed oil had to be imported.

Both before the First World War and in the interwar period, crude oil extracted on the lands of Poland was processed by domestic refineries.

Between the wars, in 1938 Poland had in its contemporary borders 27 rather small refineries. After the Second World War 5 relatively small refineries remained, the biggest being located at Czechowice.

The major breakthrough in the development of Polish oil industry has occurred in 1960 when the construction of large refining and petrochemical plant in Płock was initiated. The refinery achieved 5.5 million Mg of annual capacity in 1968 and 9 million Mg in 1971. Oil is imported to Płock mainly from the Russian Federation, through the „Friendship" pipeline. The next important step in the development of Polish oil industry was the construction of Gdańsk refinery at the Baltic coast. The large oil port is located near this refinery. It has the annual unloading capacity of 33 million Mg and enables to import oil from different origins. The pipeline interconnecting Gdańsk and Płock refineries has also been constructed.

After the year 1990 both Płock and Gdańsk refineries were enlarged and modernised. Also the other small refineries located at the south of Poland were modernised. Consequently the total capacity of all Polish refineries amounted in 2000 to 19.4 million Mg, of which Płock had 13.3 million Mg, Gdańsk – 4.2 million Mg, Czechowice – 0.7 million Mg and the other four refineries – 1.2 million Mg of capacity.

In the new century the further major extension of the oil refining capacities has been implemented. Thanks to that, in the year 2014 the capacities of the main refineries were as follows:

- PKN Orlen refinery in Płock – 17.8 million Mg [29],
- Lotos Group refinery in Gdańsk – 10.7 million Mg [28].

In 1990s many new petrol stations were built, both by domestic refiners and by the multinational corporations. The network of product pipelines which connect Płock refinery with main storage bases has been constructed. In the year 2000 the retail distribution of motor fuels was conducted by more than 6000 filling stations, of which about 500 belonged to the foreign companies (Shell, Aral, BP, Statoil, Preem).

PKN Orlen is presently one of the largest motor fuel distributors in Europe, having 1700 stations in Poland, 500 in Germany, 330 in Czech Republic and 35 in Lithuania [29].

Because of the rapid development of road transport in Poland, domestic production of motor fuels is insufficient for the growing require-

Table 13.3. Balance of crude oil 1950-2013 [million Mg]

Specification	1950	1960	1970	1980	1990	2000	2010	2013
Production	0,16	0,10	0,42	0,32	0,16	0,65	0,69	0,96
Import	0,19	0,71	7,01	16,35	13,13	18,00	22,95	23,35
Export	-	-	-	-	-	-	0,21	0,40
Stock change	-0,08	-	+0,10	-0,52	-0,44	-0,07	+0,33	-0,39
Consumption	0,27	0,90	7,53	16,15	12,85	18,08	23,10	24,30

Source: [2, 4, 50]

Table 13.4. Import and export of liquid fuels 1950-2013 [million Mg]

Specification	1950	1960	1970	1980	1990	2000	2010	2013
Import								
Gasoline	0,12	0,69	0,64	1,01	1,58	0,90	0,42	0,41
Diesel oil	0,12	0,58	0,79	1,54	1,69	0,70	2,10	0,75
Fuel oil	-	0,18	1,00	1,19	0,91	0,20	0,10	0,06
Export								
Gasoline	-	-	-	0,24	0,03	0,08	0,46	0,89
Diesel oil	-	0,16	0,51	1,05	0,20	0,07	0,04	0,58
Fuel oil	-	0,04	0,73	1,29	0,98	1,62	1,64	2,59

Source: [2, 4, 50]

ments. Therefore besides crude oil Poland imports considerable quantities of Diesel oil. In 2010 Poland imported 23 million Mg of crude oil and 2.1 million Mg of Diesel oil.

Balance of crude oil in the years 1950-2013 is presented in Table 13.3 and the imports and exports of products in Table 13.4.

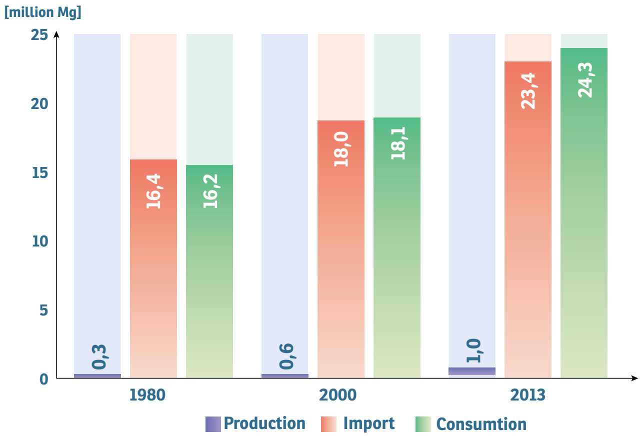

Fig. 20. Crude oil balance in Poland 1980-2013

13.4. Gas industry

he beginnings of gas industry in Poland were connected with the emergence of the coking industry which manufactured coke oven gas, and with production of town gas from hard coal.

Manufacturing of coke for the metallurgical uses was initiated in Gliwice in 1796. First big coking plant was built in Upper Silesia in 1846. Several other cokeries were also built there in the following years, mainly near the hard coal mines. The coke oven gas produced in these cokeries was treated as by-product and at the beginning used mainly for heating of the coke ovens themselves [71]. Later gas was used also by the external consumers in the neighbouring towns.

First gas works which manufactured town gas, and also coke as by-product, were built in the years 1856-1858 in Warsaw, Kraków and Poznań. Town gas produced in these works was initially used for street lighting and later also in households and for industrial purposes.

In the last decades of 19th century, with a development of crude oil production and processing, the exploitation of natural gas was also initiated. Natural gas was used at the beginning to fire the boilers in oil refineries, and later also for industrial purposes and at households.

Larger scale gas industry was developing in Poland gradually between the wars. Production of coke oven and town gases was however not big and in 1937 amounted to 885 million m^3 of coke oven gas and 163 million m^3 of town gas [20]. Coke oven gas was utilised by the industry and towns of Silesia, and town gas mainly in the towns of central and northern regions of Poland.

Before the Second World War the production and consumption of natural gas developed quite rapidly, particularly when the gas field was discovered near Jasło. First pipelines were built and the gas network has been created which supplied the industrial plants and towns of the Central Industrial Region. Production of natural gas was 584 million m^3 in 1938. Considerable part of gas was converted to the gasoline [38].

After the war Poland acquired existing gas works and cokeries with the gas networks on the Western lands. They were quickly repaired after the war and put into operation.

Creation of the integrated national gas system was initiated in 1950s. A development of gas industry was particularly dynamic in 1970s and 1980s. Natural gas became the basic type of gas supplied to the consumers. Its domestic production had increased and the large scale imports of high-methane gas from Soviet Union were initiated.

New gas fields were discovered at Polish Lowlands, transportation network was constructed which supplies gas to some thousands of localities. Simultaneously the formerly dominating coke oven and town gases were gradually substituted by natural gas.

The national gas system consisted for some years of three subsystems: high-methane gas, nitrified (low-methane) gas and coke oven gas. Transmission system of high-methane gas was connected by major pipelines with Soviet Union, the main supplier of natural gas. The system of high-methane gas is currently dominating and supplies gas to more than 6.5 millions of consumers [52].

The system of low-methane gas is limited only to the western part of Poland and is presently supplying approx. 0.35 million of consumers (10% of the national consumption).

The former system of coke oven gas had finished its operation at the turn of the centuries. Most consumers of this gas switched into natural gas, and coke oven gas is now used only by some consumers located close to the coking plants. In 1998 only 8 million m^3 of coke oven gas was transmitted to consumers [52].

In the second half of 1980s and in the beginning of 1990s the development of gas industry slowed down. Domestic production of high-methane gas decreased substantially because of fields depletion. Also the total national consumption of gas decreased. Since 1994 the consumption started however to recover

Table 13.5. Balance of natural gas 1950-2013 [PJ]

Specification	1950	1960	1970	1980	1990	2000	2010	2013
Indigenous production	6,5	19,5	184,3	190,2	99,5	138,4	153,6	152,0
High-methane gas	6,5	19,5	183,9	100,9	38,1	66,6	63,9	55,2
Low-methane gas	-	-	0,4	89,3	61,4	71,8	89,7	96,8
Import	2,9	8,2	33,4	180,3	283,6	278,0	372,0	429,2
Consumption	9,4	27,7	217,7	367,3	374,2	416,7	534,8	563,7

Source: [2, 4, 50]

and the gas network was further extended, including the construction of large underground storage sites. The new large transmission pipeline for gas imports from the Russian Federation via the territory of Poland to Western Europe was constructed. This pipeline was put into operation in 2000.

In 1990s the distribution system of LPG (propane-butane) was developed. Small settlements and villages not connected to the natural gas grid are being supplied with bottled LPG. A growth of its consumption was very dynamic. Simultaneously in 1998 the manufacturing of town gas was definitely stopped [4].

Polish Oil and Gas Company (PGNiG) is a leading company of gas sector which deals with all issues connected with gas trading as well as with gas and oil exploration and production.

PGNiG was reorganised several times during the previous decades. In the period of the centrally planned economy two separate entities existed, i.e. Association of Oil Industry and Association of Gas Industry. In 1982 both entities were merged into the state-owned company PGNiG which had the multi-unit structure. Since 1996 PGNiG acts as a joint stock company, with State Treasury being the main shareholder. Since 2005 the minority package is traded at the Warsaw Stock Exchange. Presently PGNiG is a large capital group, the unique entity which deals with all gas activities, from exploration through natural gas and crude oil production, to gas trading and storage. Through its subsidiary company PGNiG is active also in natural gas distribution on the territory of Poland [52].

After the year 2000 the consumption of natural gas has grown in Poland by 35%, from 416.7 PJ in 2000 to 563.7 PJ in 2013. Simultaneously the consumption of LPG has also grown dynamically, from 866 thousand Mg in 2000 to 2150 thousand Mg in 2013, i.e. by 148%.

In 2013 the national consumption of natural gas was covered in 27% by indigenous production and in 73% by imports.

Synthetic balance of natural gas is presented in Table 13.5.

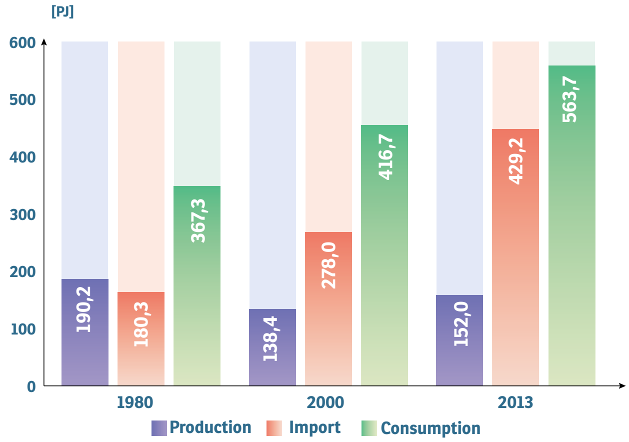

Fig. 21. Natural gas balance in Poland 1980-2013

Concerning the imports of natural gas, Poland is highly dependent on Russian Federation. Dependence on Russian imports will be reduced when the LNG regasification terminal in Świnoujście is put into operation. The terminal will have the regasification capacity of 5 billion m^3 after the first stage of construction and 7.5 billion m^3 after the second stage [25].

There is a high probability that besides the conventional natural gas the large resources of shale gas are present at the territory of Poland. Shale gas exploration is presently conducted by several companies, mostly US as well as by PGNiG.

13.5. Electricity supply industry

First attempts to utilise electricity took place in Poland in the last two decades of 19th century. The attempts were made mostly by the industrial plants, sugar works etc. They were installing small, of several kW or several dozen kW capacity, generators driven by steam engines, Diesel engines or hydro power. Electricity generated by these sources was consumed initially for lighting, mainly with the use of arc lamps.

The major step forward in the development of the electric industry was a construction of several municipal power stations, of few MW capacity each, at the beginning of 20th century. They supplied electricity for lighting, and later also for industrial and city transport purposes.

An example may be Powiśle Station built in Warsaw in 1904. It initially had a capacity of 2 MW and in

1911 was extended to 11.6 MW [51]. Łódź Power Station was constructed in 1907 with the initial capacity of 2.1 MW [12]. At the same time the other electric plants were built in the following cities of Poland: Gdańsk (Ołowianka), Chorzów, Zabrze, Wrocław, Wałbrzych (Victoria), Poznań and Kraków. Many small industrial power stations were also built at that time, particularly in Silesia, Łódź and Warsaw [12].

After the First World War about 280 stations, mostly industrial, were operating in Poland, with the total capacity of 210 MW and annual output around 500 GWh [38]. Between wars the electricity supply industry was growing moderately. The number of plants active in 1938 was 3 198, with total capacity of 1 668 MW and total generation of 3 974 GWh. The biggest public plants were at this moment: Powiśle – 83 MW, Pruszków – 31.5 MW, Łaziska – 105 MW, Będzin – 23.5 MW, Zabrze – 70.3 MW, Szombierki – 51.2 MW, Łódź – 101 MW, Poznań Garbary – 42 MW. These plants were however not integrated into the unified system, the national grid has not yet been created. Only some parts of first 150 kV transmission line were constructed, from Rożnów hydro plant to Warsaw, with branches to Stalowa Wola and Ostrowiec Świętokrzyski.

Many local companies were active in generation, distribution and sales of electricity [30].

The Second World War was very destructive for the electricity supply industry. The equipment was used in the excessive way and many plants were destroyed during the war operations, particularly in Warsaw and on Western lands of Poland. Since 1945 the equipment was being reconstructed and put into operation.

In 1946 the total capacity of all plants was not big. There were 361 plants in operation, with total capacity of 2553 MW and annual generation 5.8 TWh, of which 191 plants were public, with 1296 MW capacity and 3.4 TWh annual output [20].

A period since 1950 was an age of the development of modern electricity industry in Poland and of intensive electrification of the country. New big power plants were constructed, with hundreds or thousands MW of capacity. In 1960s the integrated national power system has been created, with transmission lines of the capacity 220 kV and later also of 400 kV. The voltages of the network were unified. The large district heating systems were also created, with CHP plants producing both energy carriers in the process of cogeneration.

In 1950s and 1960s the programme of universal electrification was implemented. Only few households, remotely located in mountains or inside forests, remained outside the national grid.

Since 1960 the co-operation of Polish electric system with the systems of USSR, German Democratic Republic and Czechoslovakia was initiated. In 1995 Polish system was interconnected with the electric system of Western Europe (UCTE). The underwater DC cable connecting Poland with Sweden was put into operation in the year 2000.

The post-war development of Polish power industry can be divided into several stages which are generally equal to the successive calendar decades.

Years 1945-1949 were a period of reconstruction of the plants and networks destroyed during the war.

Years 1950-1960 were a period of construction of several collector-type power stations, mainly with the generators of 25 and 50 MW capacity, construction of first CHP stations, unification of network voltages, creation of the first elements of 220 kV grid and implementation of the universal electrification programme. Many thermal power stations were built during this period, main of them being: Gorzów, Jaworzno II, Żerań, Czechowice, Ostrołęka, Blachownia, Skawina, Konin, Łódź II, Pomorzany, Bielsko-Biała. Several hydro plants and industrial stations were also constructed. Installed capacity of power stations increased in 1950-1960 by 3 684 MW, of which 3 037 MW were public thermal plants, 100 MW hydro plants and 547 MW industrial stations [11].

Years 1961-1970 were characterised mainly by the construction of power plants with the units of 125 and 200 MW capacity, creation of national 220 kV transmission grid, construction of first 400 kV line and completion of the universal electrification of the country. The following power stations were built during this decade: Siersza, Turów, Łagisza, Adamów, Konin, Łaziska, Pątnów. Installed capacity increased by 7 575 MW during the 1961-1970 period, of which 6 649 MW were public thermal plants, 509 MW hydro plants and 417 MW industrial installations [11].

Years 1971-1980 brought the beginning of construction of 360 MW and 500 MW units (2 such units were built) as well as further extension of 220 kV and 400 kV network. The following stations have been constructed or extended in this decade: Turów, Łagisza, Łaziska, Pątnów, Rybnik, Ostrołęka B, Kozienice, Jaworzno III and Połaniec (first units). Total growth of capacities was 11 401 MW in this period, of which 10 070 MW were public thermal plants, 557 MW hydro plants and 774 MW autoproducers [11].

Years 1981-1990 were characterised mainly by the construction of the largest power station in Poland (Bełchatów, 12 x 360 MW). Also the construction of Połaniec station was completed. Construction of first nuclear plant at Żarnowiec was initiated but stopped in 1990 and never completed. The networks of 400 and 110 kV as well as medium and low voltage networks were extended. Total growth of the installed capacities was 6 660 MW in this decade, of which 5 844 MW were public thermal power stations, 678 MW hydro and 138 MW industrial plants [66].

Years 1991-2000. A growth of installed capacities was relatively low during this period and amounted to 2 590 MW. New public thermal units with total capacity of 2 998 MW and new hydro units of 115 MW were built. The capacity of autoproducers was however reduced by 519 MW because of liquidations of old plants. Main investments were: 4 units at Opole (4 x 360 MW), 3 reconstructed units at Turów (3 x 200 MW) and several units of lower capacities at various power and CHP stations [60].

well as biomass and biogas fired.

The growth of electric capacities and the growth of peak load in the years 1950-2013 are presented in Table 13.6.

In 2013 the installed capacity of power plants was equal to 38.7 GW and the peak power demand to 24.8 GW. An arithmetical comparison of these figures indicates the substantial surplus of capacity. The calculated surplus is however an illusion because at least 10 GW is the capacity of decapitalised units which exceeded 40 years and in some cases even 50 years of operation. Such units do not constitute the real reserve of power. They should be liquidated and the relatively younger units modernised.

The situation indicates the necessity of urgent construction of new capacities in Polish power system, and particularly:

- increase of peak capacities through the construction of gas-fired units,
- construction of highly efficient coal-fired units with supercritical parameters of operation,
- construction of nuclear plants,
- construction of renewable electric capacities.

In 2013 the length of the electric lines which compose Polish transmission and distribution grid was the following:

Table 13.6. Components of power balance 1950-2013 [GW]

Specification	1950	1960	1970	1980	1990	2000	2010	2013
Total installed capacity of which:	2,7	6,3	13,9	25,3	32,0	34,6	36,0	38,7
public power plants	1,6	4,5	11,6	22,2	28,8	31,9	34,0	36,8
of which: thermal	1,4	4,2	10,8	20,9	26,8	29,7	30,6	30,9
hydro	0,2	0,3	0,8	1,3	2,0	2,2	2,3	2,3
autoproducers	1,1	1,8	2,3	3,0	3,2	2,7	2,0	1,9
Peak load	-	5,3	10,7	20,8	23,4	22,3	25,4	24,8

Source: [10, 11]

Despite large additions of new capacities, mainly in the years 1960-1990, a rapid increase of electricity requirements caused that the demand was not fully covered and up to the end of 1980s the supplies of power and electricity were periodically subject to limitations. This was caused by a large demand of industry, and particularly of heavy industry, as well as by inefficient use of energy in the whole economy.

During the period 1989-1992, due to economic recession and the structural transformation which was initiated in 1990, the peak power demand dropped from 22.9 GW in 1988 to 21.5 GW in 1992. Electricity generation also decreased, from 145.5 TWh in 1989 to 132.7 TWh in 1992. Since 1993, with economic recovery, the generation of electricity started to grow gradually, reaching 145.2 TWh in 2000. Reduction of power and electricity demand, accompanied by the growth of installed capacities and also by keeping the old installations in operation, resulted in relatively high surplus of power in the national electric system. It is estimated that this surplus amounted to 3-4 GW.

Years 2001-2013. Net growth of electric capacities amounted to 4.1 GW. Substantial part of the additions were the renewable sources, mainly wind as

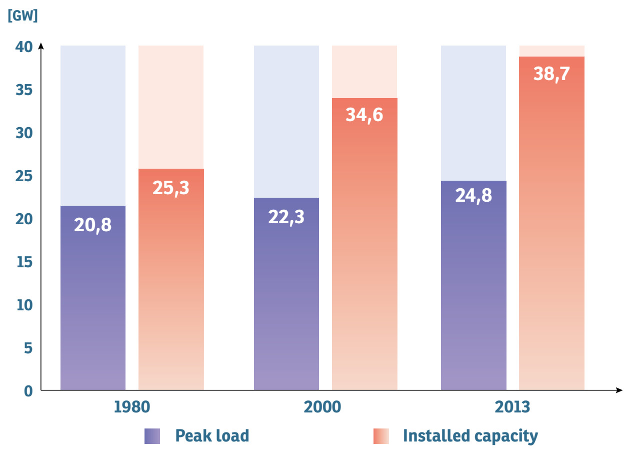

Fig. 22. Installed capacity of power plants and peak load in Poland 1980-2013

- highest voltage lines (750-400-220 kV) – 13 600 km,
- 110 kV lines – 32 800 km,
- medium voltage lines – 234 000 km.

The electric system comprises also the network transformers with the total capacity of 150 924 MVA.

The development of the transmission and distribution grid in the post-war period is presented in Table 13.7.

National transmission system, composed of the highest voltages 220/400/750 kV lines, is interconnected with the transmission systems of the neighbouring countries. There exist the following interconnections [70]:

- at the western border – 2 double-circuit 400 kV lines and 1 single-circuit 110 kV line,
- at the southern border – 2 double-circuit 400 kV lines, 1 double-circuit 220 kV line as well as 3 double-circuit and 1 single-circuit 110 kV lines,
- at the northern border with Sweden – the underwater DC cable of 450 kV voltage,
- at the eastern border – 2 single-circuit 220 kV lines and 1 double-circuit 110 kV line.

Table 13.7. Overhead electric lines 1950-2013 [1000 km]

Specification	1950	1960	1970	1980	1990	2000	2009	2013
Transmission lines								
750-400-220 kV	0,1	1,7	5,8	9,4	12,3	12,9	13,4	13,6
110 kV lines	2,3	9,2	17,2	24,8	30,5	32,3	32,5	32,8
Total MV lines	50,8	93,0	153,4	197,0	216,1	223,8	234,4	234,0
Total LV lines	54,0	121,7	227,5	265,2	274,6	284,1	290,4	321,2

Source: [10, 60]

There exists also an inactive line of 750 kV between Ukraine and Poland.

It should be underlined that the existing system of interconnections is insufficient and does not create conditions for the construction of the single European market of electricity. Therefore the plans were prepared for the next decade to extend substantially both the interconnections and the national transmission grid which is also insufficiently developed.

13.6. Heat production and supply

A man used fire for heating of his living place and for food cooking from the very ancient times.

Thermal energy for space heating and for food cooking was in the past obtained from firing wood, and later also coal in the simple equipment characterised by very low efficiency (kitchen ovens, various stoves etc.).

The first steps towards the improvement of space heating, particularly in big residen-tial and public buildings, consisted in the attempts to heat them with the warm air. In Poland the first installation for air-based heating was used at the Wawel Castle in 14th century [70].

At the end of 19th and beginning of 20th century in some big towns the new radiator-type heating was introduced, supplied with hot water heated by boilers located in the same buildings.

The next step was the construction of local heating plants which supplied steam or hot water to the external consumers.

Between the wars such heating plants were constructed mainly in the industrial areas of Silesia, Łódź, Warsaw etc. They were the relatively small devices, with the capacities of several hundred MJ/h, rarely few GJ/h. They supplied heat in the form of steam and hot water, mainly for technological and space heating purposes. Residential buildings in the towns were however at that time in almost 100% heated with the individual stoves burning the solid fuels.

First district heating plants and district heating networks were constructed in Polish cities in the years 1948-1952. They had the capacities of several dozen GJ/h and supplied groups of local buildings. Already in 1950 approx. 17% of Warsaw's buildings had some form of central heating [40].

Individual heating and numerous small heating plants did not motivate the rational fuel economy and caused a large threat to the environment. In this situation a decision was made to build the Combined Heat and Power plants which would cogenerate heat and electricity.

Construction of first heat transmission pipeline in Warsaw in 1953, supplied by Powiśle CHP plant, was recognised as a beginning date of cogeneration in the municipal economy. The first newly constructed public CHP plant was Żerań in Warsaw, put into operation in 1954 and extended during the next years. The bigger Siekierki CHP plant was constructed in 1961 [40]. Several CHP stations were also built in the other industrial regions of Poland and in big cities. An example of rapid development of cogeneration is Łódź where the first CHP plant Łódź I was reconstructed from the old power station in 1959. Three new big CHP plants were later successively constructed: Łódź II in 1961, Łódź III in 1968 and Łódź IV in 1977 which supplied mainly the industry. Thanks to that many old local boilers were eliminated [12].

Also in the other urban centres the existing condensing-type power stations were reconstructed as CHP, and new CHP plants have been constructed starting from 1950s. In Upper Silesia the new CHP plants Bielsko I, Bielsko II and Katowice have been built and several condensing-type plants (Szombierki, Chorzów, Zabrze, Będzin, Miechowice, Katowice) were reconstructed for heat generation. In Kraków the Skawina plant was converted and Kraków Łęg CHP constructed. Similarly in other cities many condensing turbines were converted into heating-type and back-pressure as well as the new heating units were built. They supply the district heating networks of Wrocław, Bydgoszcz, Gdańsk, Gdynia, Elbląg, Szczecin, Gorzów, Białystok, Lublin, Ostrołęka.

The decades of 1970s and 1980s were the period of dynamic development of public CHP plants in Poland. Many cogenerating units were constructed, with electric capacities up to 120 MW and thermal up to 230 MW. The most common were the units with 50-55 MW electric capacity. Several large heat-only plants were also constructed during this period of time. These were mainly: Warsaw-Wola, Warsaw-Kawęczyn, Tychy and Cieszyn. In some CHP plants the separate heat-only boilers were also constructed which serve to cover the peak heat demand during particularly cold winters.

Currently the largest groups of public cogenerating plants, with the annual heat generation above 10 PJ, are the following: CHP Warsaw – approx. 35 PJ, CHP Łódź – approx. 20 PJ, CHP Wybrzeże – approx. 14 PJ, CHP Wrocław – approx. 11 PJ, CHP Bydgoszcz – approx. 10 PJ [60].

The Energy Market Agency estimates that in 2012 the available thermal capacity of CHP plants was equal to 27.9 GWt, of which 9.4 GWt were the heat-only boilers located at these plants, and the available thermal capacity of district heating enterprises was 16.5 GWt. Heat production by all sources, i.e. the public CHP plants, industrial CHP plants and district heating enterprises amounted in 2012 to 521 PJ [59].

It should be underlined that the quantities of heat produced by industrial plants and by district heating enterprises (belonging to municipalities, housing cooperatives etc.) are the estimated figures. Compiling the exact figures of heat production is difficult because of:

- ownership transformations and existence of heat producers having various organisational and legal forms,
- methodological changes in heat statistics.

During the last decades the demand for heat was substantially reduced, particularly in industry and in municipal heating systems. This reduction of demand was caused by the considerable decrease of industrial production, particularly in heavy, chemical and textile industries. In 1990s also the heat demand of residential and commercial customers has been substantially reduced. This was caused by: rationalisation of heat and hot water consumption, increase of heat prices, implementation of large programme of buildings thermo-renovation, introduction of heat and hot water metering, reduction of heat transmission losses etc.

Heating requirements of towns (space heating, air conditioning and domestic hot water) are covered mainly from the central and municipal sources of heat. In the rural regions and in small towns the individual sources of covering heat demand, i.e. various boilers and stoves, are still dominating. These sources use a variety of fuels for thermal energy production: coal, natural gas, LPG, wood and fuel oil. It is estimated that the central heating systems (heat produced by various central sources) cover about 73% of the heat requirements of residential and commercial sectors while the individual heating sources cover approximately 26% of these requirements [6].

14

PRIMARY ENERGY – PRODUCTION AND CONSUMPTION 1950-2013

14.1. Production, import, export and consumption of primary energy

During the interwar period the primary energy balances were not compiled in the presently used form. Taking into account the available data on production and consumption of individual energy carriers, it is estimated that the total national production of primary energy, expressed in tonnes of oil equivalent (1 toe = 41,868 GJ), was in 1938 equal to 22.8 Mtoe, exports to 7.0 Mtoe and national consumption to 15.8 Mtoe [38].

The quantity of consumption did not comprise the non-commercial energy carriers consumed by the population (peat, straw, agricultural waste etc.).

After the Second World War, with the economic development and the growth of energy requirements, production and consumption of energy were increasing rapidly. Also the exports of coal were growing as well as the imports of crude oil and natural gas. Up to the end of 1970s Poland was the net exporter of fuels and energy.

Since 1980 however the imports of fuels started to exceed their exports. The indicator of country's energy self-sufficiency decreased to the level of 0.67 in 2010. This was caused by a drop in coal production and the simultaneous growth in imports of hydrocarbon fuels (crude oil and natural gas).

The increasing negative balance of the international trade in fuels and energy had the disadvantageous influence on the country balance of payments, particularly because a price of exported coal, calculated per toe, was 3-4 times lower than a price of imported oil.

In the years 1950-1988 the total consumption of primary energy was increasing rapidly, to the level of 128.6 Mtoe in 1988. After 1989 consumption dropped substantially, to 89.8 Mtoe in 2000 [3]. Since 2000 the moderate growth of consumption took place, to approx. 100 Mtoe in the years 2010-2012 [1].

A drop in the primary energy consumption in 1990s was a result of the economic reform, multidirectional activities aimed at the rationalisation of energy consumption, reduction of the energy intensive industries activity as well as the mild winters during this period. It is estimated that in 2000, due to warm weather, primary energy consumption was lower by 4-5 Mtoe in comparison with the average climatic conditions. The consumption would amount to 94-95 Mtoe at average weather conditions.

During the years 2001-2010 the national production of primary energy was decreasing, with the simultaneous increase in imports of primary fuels (crude oil, natural gas and coal). Consumption of primary energy was however on the increasing trajectory. In consequence of these occurrences the country's dependency on primary energy imports has increased to 33% in 2010.

The main reasons for the increasing fuel import dependency of Poland are as follows:

- reduction of hard coal production from 193 million Mg in 1990 to 76.7 million Mg in 2010, substantial reduction of coal exports and increase in coal imports (in 2010 import of coal was higher than export by 3 million Mg),
- growth of crude oil imports from 13.1 million Mg in 1990 to 23 million Mg in 2010 and growth of oil products imports,
- growth of natural gas imports from 7.8 billion m^3 in 1990 to 10.3 billion m^3 in 2010.

Synthetic balance of primary energy is presented in Table 14.1. The corresponding balances of individual fuels were shown in Tables 13.1-13.5.

14.2. Structure of primary energy consumption

The structure of primary energy consumption has changed significantly during the last 50 years. Share of solid fuels dropped with the simultane-

Table 14.1. Synthetic balance of primary energy 1950-2012 [Mtoe]

Specification	1950	1960	1970	1980	1990	2000	2010	2012
Production	47,0	64,8	95,6	121,9	98,3	79,5	67,4	71,6
Import	0,7	3,4	11,8	25,8	25,3	30,0	47,3	47,4
Export	19,3	14,1	22,6	23,1	21,8	20,8	14,8	16,1
Stock change	0,2	0,3	-0,1	-0,1	-1,2	1,1	2,0	3,9
Consumption	28,6	54,4	84,7	124,5	100,6	89,8	101,1	98,4

Source: [1, 2, 4]

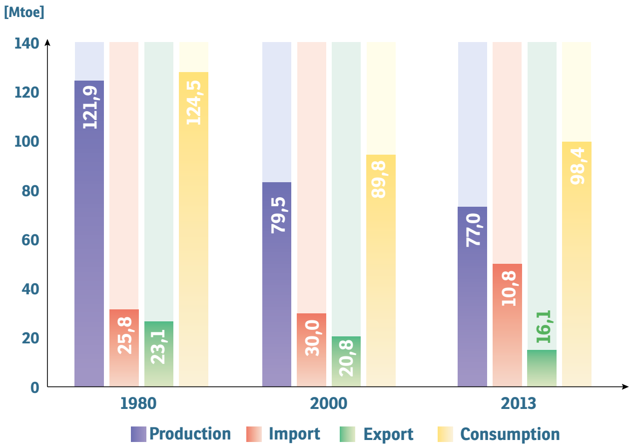

Fig. 23. Primary energy balance of Poland 1980-2012

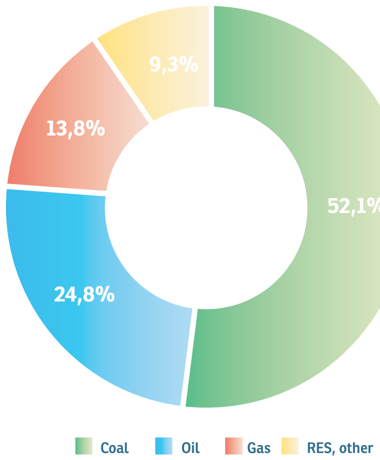

Fig. 24. Structure of primary energy consumption in Poland in 2012

ous gradual increase in hydrocarbon fuels share. In 1950 coal covered almost 97% of the country's energy requirements while crude oil and natural gas less than 3%.

The advantageous change of primary energy consumption structure in favour of hydrocarbon fuels was initiated in 1970s. In 2000 a share of crude oil and natural gas reached the level of 1/3 of total primary energy consumption while a share of hard coal and lignite was 63%. The other components of the energy balance, mainly renewables and among them hydro energy, were insignificant. Their share was 3.5% in the year 2000.

During the years 2001-2012 the advantageous changes in the primary energy consumption structure were continued. The share of solid fuels was further reduced, the shares of hydrocarbon fuels were increasing and the importance of renewables has grown substantially.

Changes in the primary energy consumption structure in the years 1950-2010 are presented in Table 14.2.

Table 14.2. Structure of primary energy consumption 1950-2012

Wyszczególnienie		1950	1960	1970	1980	1990	2000	2010	2012
Hard coal	Mtoe	27,3	49,4	63,2	89,4	61,8	44,8	43,3	38,6
	%	95,5	90,8	74,7	71,8	61,5	49,9	42,8	39,2
Lignite	Mtoe	0,3	1,0	5,9	6,6	13,3	12,1	11,6	12,7
	%	1,0	1,8	7,0	5,3	13,2	13,5	11,5	12,9
Crude oil	Mtoe	0,6	2,3	8,8	18,4	15,3	19,8	23,2	24,4
	%	2,0	4,3	10,4	14,8	15,2	22,0	23,0	24,8
Natural gas	Mtoe	0,2	0,7	5,2	8,8	8,9	10,0	15,4	13,6
	%	0,7	1,3	6,1	7,1	8,8	11,1	15,2	13,8
Other sources	Mtoe	0,2	1,0	1,5	1,3	1,3	3,1	7,6	9,1
	%	0,7	1,8	1,8	1,0	1,3	3,5	7,5	9,3
Total consumption	Mtoe	28,6	54,4	84,7	124,5	100,6	89,8	101,1	98,4
	%	100,0	100,0	100,0	100,4	100,0	100,0	100,0	100,0

Source: [1, 2, 4]

15

ELECTRICITY 1950-2013

15.1. Main components of electricity balance

For the period between the wars there are not many data on the electricity sector development in Poland. The national system of energy statistics did not yet function in this period. Many local electric companies were active in the field of electricity generation and its supply to the customers. These were among others the following entities [30]:

- Municipal Association for the Electrification of Warsaw Area,
- Electrical Association of Radom-Kielce Region,
- Municipal Association for the Electrification of Poznań Area,
- Pomeranian Power Plant Gródek,
- OEW (Oberschlesische Elektrizitätswerke) – German company which operated the electric system in the Upper Silesia region.

In 1919 the national electricity production was low – only 1050 GWh. It has grown to 3977 GWh by the year 1938. This quantity of electricity was generated by more than 3000 small plants, the majority of which belonged to the industrial companies. Total capacity of the existing power plants was 1668 MW [20].

No data on electricity are available for the World War years 1939-1945. The electricity industry was seriously destroyed at that time as the whole country was. In consequence of the war and post-war political decisions the geographical area of Poland was reduced by about 20%.

In 1946, due to the war destruction and change of the country borders, only 361 power stations were in operation. They were mostly the small plants, with total capacity of 2553 MW and annual generation equal to 5.8 TWh. The first post-war years were devoted to the most necessary reconstruction of economy and to the organisation of the new economic system. Some statistical data collection was initiated in this period. Since 1950 there exists the numerical base for the assessments and comparisons of the electric system development.

During the years 1950-2013 the electricity generation has grown in Poland from 10.7 TWh to 164.4 TWh. The dynamic growth of generation took place mainly in 1970s. Growth has slowed down particularly in 1990s.

During the first post-war decades (1950-1970) the industrial autoproducers had substantially participated in electricity generation. Production had however grown mostly in public plants, from 22.4 TWh in 1960 to 156.4 TWh in 2013. The growth in autoproducing plants was marginal, from 6.9 TWh in 1960 to 8.0 TWh in 2013 [2, 11, 60].

Due to the low hydro energy resources and the absence of nuclear plants, solid fuels (hard coal and lignite) are the dominating fuels for electricity and heat production in power plants and CHP plants. As much as 96-97% of the total national electricity production was obtained from coal and lignite in some years. Recently the shares of biomass, wind and natural gas in fuel mix have grown moderately. In 2009 coal and lignite accounted for about 90% of electricity generation.

It should be underlined that the electricity production by wind turbines and from biomass has grown in the recent years. In 2013 production by wind turbines was 6.0 TWh while production from biomass and biogas 4.2 TWh.

The foreign exchanges of electricity were rather small during the years 1950-2013. Imports and exports were at the level of few per cent of the national generation. For most of the years, imports and exports were approximately equal.

Network losses of electricity amounted to approximately 10% of national consumption for most of the years.

Table 15.1. Synthetic balance of electricity 1950-2013 [TWh]

Specification	1950	1960	1970	1980	1990	2000	2010	2013
Gross generation	10,7	29,4	64,6	121,9	136,3	145,2	157,7	164,4
of which plants:								
- public thermal	5,3	21,8	54,2	108,3	124,9	132,8	144,5	143,2
- autoproducers	5,0	6,9	8,5	10,3	8,1	7,2	7,5	8,0
- hydro	0,4	0,7	1,9	3,3	3,3	3,0	3,5	3,0
- wind + biomass	-	-	-	-	-	-	2,1	10,2
Import	0,08	0,7	1,6	4,2	10,4	3,3	6,3	7,8
Export	0,07	0,4	1,5	4,4	11,4	9,7	7,7	12,3
Network losses	0,32	2,0	5,6	12,2	11,4	14,2	11,9	10,2
Gross consumption	10,4	26,8	59,1	109,4	123,9	124,6	144,4	149,7

Source: [2, 60]

National consumption of electricity has grown in the years 1950-2013 almost 15 times, from 10.4 TWh to 149.7 TWh. Synthetic balance of electricity for the analysed period is presented in Table 15.1.

15.2. Development of electricity consumption and its structure

Before the year 1990 the electricity consumption in Poland was characterised by high shares of industry and low shares of the consumption by households and services. Some changes in these shares, mainly to the advantage of services, were initiated after 1990.

In the beginning of 1990s a decrease of industrial electricity consumption took place, caused mainly by the activity reduction in the energy intensive heavy industry. Price increase to the realistic levels was also an important reason for a drop in consumption. Higher prices stimulated rationalisation of the consumption. Simultaneously, consumption has significantly increased in service sector and in households.

Despite the growth of electricity consumption in households the average consumption per one household is still significantly lower in Poland than in the countries of West Europe.

Changes in the sectoral structure of electricity consumption are presented in Table 15.2.

Table 15.2. Sectoral structure of electricity consumption 1985-2009 [GWh]

Specification	1985	1990	1995	2000	2005	2009	1985=100 [%]
Total consumption	100 220	102 509	96 119	100 506	106 523	112 843	111,8
of which:							
- industry and large consumers	61 908	57 312	56 087	57 628	54 289	49 169	79,4
- railways	4 760	4 651	3 952	3 678	2 913	2 251	47,3
- tramways	717	695	623	651	657	610	85,7
- street lighting	1 274	1 325	1 699	1 825	1 842	1 792	140,7
- households and agriculture	22 939	28 711	23 592	25 787	26 564	29 015	126,5

Source: [60]

16

ENERGY AND THE NATURAL ENVIRONMENT

16.1. Main problems of environment protection in Poland and in the national energy sector

The sector of fuels and energy has a negative impact on the natural environment. Intensive development of industry, creation of large urban and industrial agglomerations, growth of fossil fuels extraction as well as growth of energy production and consumption which had occurred particularly in the first decades after the Second World War, resulted in the large degradation of the natural environment.

In this period, up to the 1980s, the environment protection activities had no priority character in Poland. The effects of insufficient protection of environment occurred particularly in the areas of south-western Poland and in large urban and industrial agglomerations throughout the whole country.

At some areas, mainly in the Upper Silesia and so-called „black triangle" near Turów, the situation was catastrophic. This was caused not only by the emissions from Polish industries but also by the transboundary pollution coming from our southern and western neighbours. The mentioned areas were ranked among the most polluted regions of Europe.

The sector of fuels and energy had seriously contributed to the environmental degradation in Poland, through:

- emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and carbon dioxide (CO_2),
- polluting of Vistula and Odra rivers with the saline waters discharged from hard coal mines and with insufficiently cleaned sewage from the refineries,
- polluting a ground with solid wastes from coal mines and post-combustion wastes from power stations, CHP plants and heat plants, both public and industrial, as well as from household stoves.

Difficult environmental situation may be characterised by the figures describing the emissions of gases and ash by the whole national economy and by the energy sector. The emissions were particularly high in 1988, i.e. the last year of the centrally planned economy. The emissions of gases and ash in 1988 are presented in Table 16.1.

Table 16.1. Emissions of gases and ash in Poland in 1988.

Specification	Country total	Energy sector	Energy sector share [%]
SO_2 [1000 Mg]	4 180	2 745	65,7
NO_x [1000 Mg]	1 550	640	41,3
CO_2 [million Mg]	477	261	54,7
Ash [1000 Mg]	3 400	730	21,5

Source: [56]

16.2. Activities in the energy sector aimed to reduce the negative environmental impacts and the results of these activities

The political and economic transformation, initiated in 1989, has brought the substantially different approach to the environment protection in the whole economy, and particularly in the energy sector.

With the beginning of Polish economy transformation and reforming of the fuels and energy sector, the adequate regulations were introduced and multidirectional activities initiated in order to reduce the environmental impacts of the energy sector. Poland became a signatory to many international conventions, among others the Geneva Convention and its Protocols (Second Sulphur Protocol, Second Protocol on Emissions of Nitrogen), UN Convention on Climate Change and its Kyoto Protocol.

The Ordinance of 12 February 1990 on the Protection of Air against Pollution, issued by the Minister of Environmental Protection, played an important role in setting the standards. Also the Directive 88/609/EEC of the European Council constituted a base for the activities aimed at reducing the emissions of atmospheric pollutants by large combustion plants.

Basic activities implemented in 1990s by Polish fuels and energy sector in order to reduce the environmental pollution were as follows:

- steam coal processing and enrichment in the mines, what allowed to reduce considerably the contents of sulphur and ash and to increase the calorific value of coal (average calorific value of hard coal burned in the power plants had grown from 18 220 kJ/kg in 1988 to 21 780 kJ/kg in 2000, i.e. by almost 20%); average ash content in the coal fell from 28.6% to 19.6% and sulphur content from 1.14% to 0.74% [10, 60],
- reduction of SO_2 emissions through burning of higher quality coal with reduced sulphur content or installation of the FGD equipment (desulphurisation equipment was installed at Bełchatów, Jaworzno III, Połaniec, Rybnik, Łaziska, Siersza, Opole and Dolna Odra plants); several fluidised boilers were also installed (Turów, Żerań, Bielsko-Biała, Jaworzno II and Siersza plants),
- further reduction of ash emissions from power and CHP plants through modernisation or replacement of electrofilters,
- reduction of NO_x emissions through installation of low emission burners and modernisation of burning equipment in power and CHP plants,
- various modernisations of industrial power and heat plants,
- modernisation of old inefficient municipal heat plants or their liquidation in many towns,
- replacement of coal fired stoves in residential buildings by highly efficient gas boilers.

Implementation of the initiated activities, decrease in coal production and consumption, reduction of total primary energy consumption and the change of its structure allowed to decrease substantially the emissions of environmental pollutants already in 1990. Further reductions of these emissions have been achieved in the following years.

The EU requirements concerning a quality of liquid fuels have been implemented. Płock and Gdańsk refineries improved their technological processes in order to manufacture the products compatible with the EU standards. The refineries ended production of leaded gasoline and introduced to the market the environment friendly Diesel oils, conforming to the EU requirements.

A comparison of total volumes of emissions in the recent years with the volumes in the end of 1980s indicates that all kinds of emissions were reduced considerably. This indicates also that the large efforts were necessary to reduce the emissions and that the activities aimed to reduce them were effective.

Public power industry has reduced emissions particularly largely. In the years 1988-2012 the following reduction of emissions has been achieved in public power industry: SO_2 – by almost 1.7 million Mg, NO_x – by about 0.2 million Mg, CO_2 – by about 13 million Mg, ash – by more than 0.7 million Mg [30].

Changes in the emission volumes of air pollutants in Poland (country total and public power industry) in the years 1988-2012 are presented in Table 16.2.

Table 16.2. Emissions of air pollutants in Poland 1988-2012

Specification	1988	1990	2000	2009	2012
SO_2 [1000 Mg]					
- country total	4180	3210	1511	861	853
- public power industry	1990	1540	805	337	334
NO_x [1000 Mg]					
- country total	1550	1280	838	820	817
- public power industry	420	386	237	232	217
CO_2 [million Mg]					
- country total	477	381	315	310	321
- public power industry	160	150	-	144	147
Ash [1000 Mg]					
- country total	3400	1950	464	394	428
- public power industry	770	560	65	21	17

Source: [39, 56, 60]

16.3. Real possibilities of CO_2 emissions reduction by the electricity sector in the forthcoming decades

The economy of Poland faces presently the large challenge of the further radical reduction of CO_2 emissions, according to the policy of the European Union. The reality of fulfilling such objective in the relatively short time is under large doubt, due to the following characteristics of the Polish energy sector:

- hard coal and lignite are the main fuels for electricity generation – about 90% of electricity is produced from these fuels; domestic reserves of natural gas are low and more than 70% of natural gas consumed in Poland is imported,
- Poland has no nuclear plants; a substantial share of nuclear electricity production can be achieved in the time horizon of 3-4 decades under the condition that the construction of the first nuclear plant would be started in few years,

- Poland has no considerable hydro energy resources and the resources of the other types of renewable energy are not rich; therefore despite the ongoing development of the wind generation and biomass fired generation these source may cover no more than a dozen per cent of the electricity requirements,
- transformation of Polish power sector into the low emission sources of electricity and the application of CCS (Carbon Capture and Storage) technology in coal fired plants requires time and the huge expenditures for the construction of low emission fossil fuel fired plants, construction of the nuclear power stations, import of the large quantities of gas etc.

At present time Poland does not belong to the biggest emitters of CO_2 in the absolute terms. However, Poland has the high indicators of this gas emissions because of the relatively high consumption of coal in comparison with the most developed countries of Europe. Therefore the energy policy of Poland should comprise the activities aimed at the substantial reduction of these emissions, though such process should last a long time and should take into account the realities of the Polish economy.

Table 16.3 presents the CO_2 emission indicators for the selected countries of Europe and the world, for the year 2011.

Table 16.3. Primary energy consumption and the indicators of CO_2 emission for the selected countries of Europe and the world in 2011

Countries	Primary energy consumption [Mtoe]	CO_2 emissions [million Mg]	CO_2 / primary energy consum. [Mg/toe]	CO_2 / population [Mg/capita]	CO_2 / GDP by PPP [kg/USD]
EEUROPE					
- Austria	33,0	68,5	2,07	8,1	0,23
- Belgium	59,1	108,6	1,84	9,9	0,30
- Czech Republic	43,4	112,7	2,59	10,7	0,45
- France	252,8	328,3	1,30	5,0	0,17
- Spain	125,6	270,3	2,15	5,9	0,22
- Netherlands	77,4	174,5	2,25	10,5	0,28
- Germany	311,8	747,6	2,40	9,1	0,26
- Poland	101,3	300,0	2,96	7,8	0,43
- Sweden	49,0	44,9	0,92	4,8	0,14
- Italy	167,4	393,0	2,35	6,5	0,24
- United Kingdom	188,1	443,0	2,36	7,1	0,21
OTHER BIGGEST EMITTERS OF CO_2					
- Australia	122,9	396,8	3,23	17,4	0,47
- Brazil	270,0	408,0	1,51	2,1	0,20
- China	2 727,7	7 954,6	2,92	5,9	0,80
- India	749,5	1 745,1	2,33	1,4	0,44
- Canada	251,9	529,8	2,10	15,4	0,43
- Korea (Republic)	260,4	587,7	2,26	11,8	0,43
- Mexico	186,2	432,3	2,32	4,0	0,30
- Russian Federation	731,0	1 653,2	2,26	11,7	0,79
- USA	2 191,2	5 287,2	2,41	16,9	0,40

Source: [34]

17

KEY ENERGY INDICATORS

The most synthetic indicators which characterise the levels of the country energy requirements and the macro efficiency of the energy use are the following:

- consumption of primary energy and of electricity per one inhabitant of the country,
- energy- and electricity intensity, measured by the energy and electricity use per unit of Gross Domestic Product.

17.1. Consumption of primary energy and electricity per capita

Before the Second World War, in 1938, consumption of primary energy per 1 inhabitant amounted in Poland to approx. 0.6 toe [38]. After the War a value of this indicator was growing rapidly, from 1.1 toe in 1950 to 3.5 toe in 1980. Later, in consequence of the economic reform and the implemented rationalisation activities, it decreased to the level of 2.3 toe in 2000 and stabilized in 2011 at 2.63 toe [2, 3, 4]. It should be underlined that the quick economic growth took place in Poland after the year 1990.

In 2011 the OECD average consumption of primary energy per capita was 4.27 toe, and in almost all of the EU-15 countries it was higher than in Poland. The detailed data are presented in Table 4.9 in Part I of the report.

Electricity consumption per 1 inhabitant was very low in Poland in 1938 – 103 kWh. After the Second World War a value of this indicator was growing rapidly, achieving 3565 kWh in 1988. Subsequently in 1990s it slightly decreased and in the later years recovered to the level of 3833 kWh in 2011.

It should be underlined that despite quite rapid growth of electricity consumption per capita after the year 1995, the value of this indicator is still considerably lower than in the EU-15 and OECD countries. Detailed data are presented in Table 5.7 in Part I of the report.

17.2. Energy intensity of Polish economy at the background of the other European countries

Energy intensity is usually measured at two levels:

- at a micro level of the individual products or economy branches, the energy intensity is measured as a specific consumption of energy for the production of a single unit of product or for the unit of a production value of a given branch of the economy,
- at a macro level of the whole economy, the energy intensity is measured as a consumption of energy per unit of the produced Gross Domestic Product (GDP).

The calculation of energy intensity at a level of single products or economy branches is relatively simple. It requires only the availability of the necessary statistical data concerning the quantities of consumed energy and the physical or monetary expression of production of a given product or economic branch.

The calculation of energy intensity at a macro level and the international comparability of calculated indicators is a more compound issue, due to the difficulties with comparing the GDP values and due to structural differences between the national economies and the climate differences between the countries.

As it was already mentioned in Chapter 6 of Part I of the report, two methods of GDP expression in USD or EUR are used for the countries which have the other currencies [16]:

- calculation by the official exchange rates,
- calculation with a consideration of the purchasing power of the given currency (Purchasing Power Parity method, in short PPP).

Conducting the energy intensity calculations only with the official exchange rates may result in errors or misinterpretation of the calculated indicators. For this reason the views on the very high energy intensity of the Polish economy, even almost 3 times higher than in the leading countries of the EU or OECD, are quite common. The views on so high energy intensity of Polish economy should be assessed as being mistaken, disadvantageous for the national economy and misleading the public opinion.

Therefore the synthetic measure of the energy intensity, most adequate for the inter-national comparisons, is the quantity of primary energy, expressed in toe, consumed per one unit of GDP, expressed usually in USD or EUR (in fixed prices), calculated by the Purchasing Power Parity (PPP). The energy intensity data for the individual countries, based on PPP calculations, are published by the World Bank, International Energy Agency and Eurostat.

Table 17.1. Energy intensity of GDP (calculated by PPP) in the European OECD countries in the years 1990-2013

Countries	Energy intensity of GDP [toe/1000 USD by PPP, fixed prices of 2000]				1990=100 [%]
	1990	2000	2006	2013	
Austria	0,138	0,124	0,132	0,122	88,4
Belgium	0,218	0,219	0,194	0,174	79,8
Czech Republic	0,327	0,263	0,234	0,189	57,8
Denmark	0,151	0,126	0,123	0,110	72,8
Finland	0,263	0,264	0,237	0,216	82,1
France	0,181	0,168	0,161	0,146	80,7
Germany	0,206	0,161	0,155	0,123	59,7
Greece	0,140	0,138	0,120	0,120	85,7
Hungary	0,246	0,200	0,172	0,151	61,4
Iceland	0,344	0,400	0,424	0,545	158,4
Ireland	0,187	0,131	0,103	0,092	49,2
Italy	0,119	0,119	0,120	0,111	93,3
Netherlands	0,196	0,163	0,157	0,144	73,5
Norway	0,190	0,159	0,141	0,155	81,6
Poland	0,359	0,221	0,196	0,153	42,6
Portugal	0,131	0,145	0,138	0,114	87,0
Slovakia	0,390	0,299	0,232	0,165	42,3
Spain	0,140	0,145	0,138	0,110	78,6
Sweden	0,236	0,196	0,177	0,160	67,8
Switzerland	0,121	0,114	0,113	0,094	77,7
Turkey	0,171	0,175	0,163	0,124	72,5
United Kingdom	0,179	0,155	0,132	0,102	57,0
OECD Europe	0,184	0,160	0,150	0,128	69,6

Source: [16]

Table 17.1 presents the energy intensity data, calculated by the International Energy Agency with the use of PPP, for the European countries of OECD

The above data indicate that the energy intensity of Poland was in 2013 higher by only 20% than the average energy intensity of the European OECD countries.

Results of the research conducted by the Central Statistical Office and the National Energy Conservation Agency [9] indicate that the primary energy intensity of Polish GDP, expressed in fixed prices of the year 2005 with the use of PPP was in 2011 higher by 18% than the European average. In case of final energy intensity of GDP a difference was only 14% (Poland 0.112 kgoe/EUR, EU-27 average 0.096 kgoe/EUR) [9].

For the manufacturing industry the final energy intensity of Polish GDP was in 2008 by only 8% higher than the European average, when using the PPP calculations. The studies of both International Energy Agency and Polish Central Statistical Office confirm that the substantial progress has been achieved in Poland during the last 20 years in the field of the efficient use of energy. The sector of industry has the largest achievements in this task. Thanks to that, the energy efficiency gap of Polish economy was reduced to a dozen per cent, comparing with the European average [72].

The improvement of the energy intensity was particularly big in the industrial production of steel, cement and paper. The corresponding figures were reduced in the years 1998-2012 in the following scale [9]:

- for steel from 0.370 toe/Mg to 0.223 toe/Mg,
- for cement from 0.124 toe/Mg to 0.087 toe/Mg,
- for paper from 0.797 toe/Mg to 0.452 toe/Mg.

Thanks to the implementation of the wide programme of buildings thermo-modernisation, the indicator of energy consumption for space heating was also largely reduced, from 19.9 kgoe/m^2 in 1998 to 13.5 kgoe/m^2 in 2012.

All comparisons indicate therefore that:

- during the last 20 years the Polish economy has achieved large reduction of the energy intensity,
- energy intensity of Polish GDP is still higher than the average for the EU countries by a dozen per cent.

The opinions on the Polish energy intensity being 3 times higher than the energy intensity of the leading EU countries are definitely mistaken.

18

PRICES OF FUELS AND ENERGY

18.1. Policy of fuels and energy prices in the period of centrally planned economy

Before the Second World War the prices of fuels and energy were set by market forces. The level of prices was different in various towns and regions of Poland.

The following prices were applied in Warsaw in August 1939 for sales to households [38]:

- hard coal – 0.48 zł per 10 kg (48 zł/Mg),
- gas – 3.20 zł per 10 m^3 (0.32 zł/m3),
- electricity – 5.30 zł per 10 kWh (0.53 zł/kWh).

In Silesia the prices of coal and electricity were lower by about 40%.

After the Second World War, up to the year 1989, the policy of low prices of fuels and energy was conducted in Poland. These prices were officially set by the government and were the instrument of centrally planned economy. They were often kept below the real costs of energy production and supply. This led to the following negative consequences:

- invalidation of universal economic mechanisms,
- creation of a common view of cheap fuels and energy what favoured the development of the energy intensive industry branches and resulted in high energy intensity of GDP,
- lack of consumers interest in rational utilisation of fuels and energy what resulted in wastage and low efficiency of energy consumption.

The authorities tried for several times to introduce the realistic prices of fuels and energy. One of the attempts took place in 1982 together with more general attempt to reform the economy. Yet at the end of 1980s, despite the several steps of price increases, fuels and energy became particularly cheap in relation to the industrial goods and agricultural products. Price relations deteriorated, particularly the retail prices of fuels and energy for households were extremely low in relation to other groups of products.

Hard coal mining found itself in particularly critical financial situation at the end of 1980s. In 1989 the losses on coal sales totalled the huge amount of 3.5 trillion złotys, with the sales revenues achieving only 2.4 trillion złotys.

Also the prices of electricity and natural gas were absolutely incompatible with their costs [58].

18.2. Reform of fuels and energy prices 1990-2000 and its results

In 1990, with the general reform of the economy, the radical reform of fuels and energy prices started. The objective of this reform was to make the prices realistic and to regain the appropriate relations between the prices for industrial consumers and prices for households. In the first stage of reform which took place in 1990 the increase of prices was actually very high.

Furthermore, the process of price reform was continued during the years 1991-1993 but then it had more smooth character. The prices of electricity and natural gas for households increased by the highest factors what made them realistic and allowed to set the more appropriate relations between the prices for industry and for households.

In the years 1994-2000 the reform of fuels and energy prices was continued but the indices of growth were then similar to the general inflation indices.

Presently the prices of coal and liquid fuels are set by the market forces. Prices for the network energy commodities are however regulated, subject to the approval by the Energy Regulatory Office.

In 2008 the prices of fuels and energy, calculated in USD using the exchange rate, were in Poland by 5-20% lower than the average prices in EU countries. The same prices expressed in USD by PPP were however by 30-40% higher than the prices in the European OECD countries [27].

When analysing the problems of fuels and energy prices, one should take into account the levels of household expenditures on the energy commodities. With the current incomes of population, a share of energy expenditures in the family budgets is in Poland 2-3 times higher than in the leading EU countries. In Poland this share amounts to approx. 10% and in the countries of West Europe is around 4%.

With the reforms of fuels and energy prices the elements of energy markets were created. The appropriate functioning of market mechanisms in the energy economy was a main target in this area of activity.

18.3. Prices of fuels and energy in the years 2000-2013

After the year 2000 the high growth of the energy prices took place in Poland and in all European countries. This growth comprised all energy commodities and all categories of consumers, including industry and households.

The growth was caused mainly by escalation of international prices of energy commodities but also by the fiscal policies. More detailed description of this issue is presented in Section 7.2 of Part I of the report.

During the period 2000-2013 the prices of main energy commodities, expressed in Polish złotys, have grown in Poland by:

- for industry (excluding VAT): steam coal by 100%, Diesel oil by 112%, natural gas by 169%, electricity by 116%,
- for households (including VAT): gasoline by 75%, Diesel oil by 114%, natural gas by 132%, electricity by 118%.

Comparison of prices of the selected fuels and energy commodities for industry and for households in the years 2000-2013 is shown in Table 18.1 in USD (calculated by exchange rate) and in Table 18.2 in Polish złotys.

Table 18.1. Prices of the main energy commodities for industry and for households 2000-2013 [USD by exchange rate]

Specification	Unit of measure	2000	2008	2013	2000=100%
A. Industry					
- hard coal for electricity generation	USD/t	28,9	79,2	77,7	269
- Diesel oil	USD/l	0,462	1,435	1,408	305
- natural gas	USD/toe	133,0	590,8	546,3	411
- electricity	USD/kWh	0,037	0,119	0,110	297
B. Households					
- gasoline 95	USD/l	0,722	1,783	1,733	240
- Diesel oil	USD/l	0,588	1,751	1,732	295
- natural gas	USD/toe	247,5	1037,0	879,3	355
- electricity	USD/kWh	0,065	0,193	0,196	302

Source: [17]

Table 18.2. Prices of the main energy commodities for industry and for households 2000-2013 [PLN]

Specification	Unit of measure	2000	2008	2013	2000=100%
A. Industry					
- hard coal for electricity generation	PLN/t	122,7	190,9	245,5	200
- Diesel oil	PLN/l	2,10	3,46	4,45	212
- natural gas	PLN/toe	578,1	1281,5	1553,8	269
- electricity	PLN/kWh	0,160	0,287	0,346	216
B. Households					
- gasoline 95	PLN/l	3,14	4,30	5,48	175
- Diesel oil	PLN/l	2,56	4,22	5,47	214
- natural gas	PLN/toe	1076	2249	2500	232
- electricity	PLN/kWh	0,285	0,465	0,620	218

Source: [17]

19 EVOLUTION OF THE ORGANISATION AND MANAGEMENT OF COMPANIES IN THE ENERGY SECTOR

19.1. Management and the organisational transformations

During the interwar period the Polish energy sector was composed mainly of the private entities belonging to the foreign capital. There were 60 hard coal mines in 1929. Oil was extracted in 1929 in 655 entities and in 1938 in 854 entities. The electricity industry was also very fragmented. It was composed mainly of small power plants belonging to the industrial companies, municipalities and to private owners [38].

After the Second World War all entities of the energy sector were nationalised. Following nationalisation, they were subject to many reorganisations. In 1945 the 14 electric utility associations were created and subordinated to the Ministry of Industry. In 1952 the associations were merged into 6 Regional Energy Boards, subordinated to the newly created Ministry of Energy. In 1957 the Boards were transformed into more self-governing regional energy companies: Central, Eastern, Southern, Western, Northern and Lower Silesian. Regional companies were supervised by the Ministry which evolved in several steps: first it was the Ministry of Energy, next Ministry of Mining and Energy, later Ministry of Energy and Nuclear Power and subsequently once more the Ministry of Mining and Energy. In the meantime the Electricity Association was created, Regional Energy Boards were dissolved and all power stations and distribution utilities had regained some degree of self-governing [21].

In 1990s the process of the economic reforms was initiated in Poland, including the organisational reform of the energy sector. Old structures were dissolved within the whole sector of fuels and energy, i.e. in the coal mining, gas industry, oil industry, electricity industry and district heating. New economic entities were established and started to function according to the rules of the Commercial Code.

The key assumption for the reform and for the organisational transformation of the fuels and energy sector was to reduce the ownership engagement of the State Treasury. However, due to the importance of fuels and energy sector for the national economy, the energy policy and energy development issues were kept within the competence of the government.

In the first stage of the reform the essential organisational changes were introduced in the energy sector. Ministry of Industry was made responsible for the energy policy issues and the Ministry of State Treasury for the ownership issues. Various entities of the energy sector (coal mines, power plants, distribution utilities, oil refineries), grouped earlier within the Associations, became the separate companies.

In the coal subsector the State Agency for Hard Coal Restructuring was created. Its goal was to coordinate the activities of the subsector. Seven mining companies, each of them grouping several mines, were created. More than 30 inefficient mines were closed down in the following years. The governmental programme „Reform of Hard Coal Mining" was implemented in several stages. Subsequently three large corporations were established in place of seven companies and several other existing entities. They are: Coal Company, Katowice Coal Holding and Jastrzębie Coal Company. Tauron Mining (previously named Southern Coal Concern), Lubelski Węgiel Bogdanka and few smaller companies are also active in hard coal mining.

Polish Oil and Gas Company (PGNiG) was transformed into the State Treasury company in the first stage of restructuring. Ancillary activities were separated from the main company. EuRoPol Gaz company has been created in order to build and operate the new transmission pipeline from Russia. In the next stage the national gas transmission activity was separated from PGNiG. The new company Gaz-System Transmission System Operator, owned by the State Treasury, was created. PGNiG is presently the joint stock company listed at the Warsaw Stock Exchange.

The oil refining and petrochemical sector comprises two large vertically integrated corporations:

- PKN Orlen, with its headquarters in Płock, which was created through the merger of the Płock Refinery and the distributor Oil Products Centre (CPN),
- Lotos Group, with headquarters in Gdańsk, which was created on the base of Gdańsk Refinery.

PKN Orlen is the biggest oil corporation in Central Europe. It owns also three refineries in Czech Republic and the Mazeikiu refinery in Lithuania.

In the electric sector the Polish Power Grid Company was created in the first stage of the reform, and the power plants, CHP plants and distribution utilities were transformed into the separate companies, belonging to the State Treasury. However, it happened in practice that many of the created entities were economically weak. Therefore in the later years the reverse process was initiated, i.e. the process of creating the large consolidated companies, which would be able to conduct the capital intensive investments. The Southern Power Company was created which grouped most power plants from the region of Upper Silesia. The second large entity was BOT Mining and Energy which associated the large power stations Bełchatów, Turów and Opole as well as two large lignite mines.

In the next stage of the power industry consolidation four large capital groups (PGE, Tauron, Enea and Energa), associating the majority of the electric sector entities, were established. The Transmission System Operator has also been created as a separate company which manages the national electric transmission grid.

The described legal and organisational transformation has also created the background to the ownership transformations.

19.2. Energy Law – basic legal act for the energy sector

With the general economic transition initiated in the beginning of 1990s, the transformation of the energy sector and the implementation of the new energy policy were also initiated.

The superior goal of the national energy policy is to ensure the energy security of the country, which is understood as:

- ensuring the stable supplies of fuels and energy which allow to cover the present and future demand of the economy and population for the fuels and energy of appropriate types and quality,
- application of the socially and economically justified prices of energy commodities which respect the market mechanisms and ensure the equilibrium between the interests of the energy suppliers and consumers,
- minimisation of the environmental impacts of the energy sector, i.e. following the principles of the eco-development.
- The key elements of the policy of reform are:
- restructuring and the organisational and ownership transformations of the energy companies,
- reform of the energy prices and creation of the energy markets,
- activities aimed at the improvement of the energy efficiency and reduction of the energy intensity of GDP,
- improvement of the natural environment condition through the reduction of the pollution emitted by the energy sector.
- Implementation of the new energy policy, and particularly the policy of reform and transformation in the energy sector, has achieved the new pace after the introduction of new legal regulation, i.e. the Energy Law [69].

The Energy Law is a basic legal act which defines the principles of the state energy policy, the rules and conditions for fuels and energy supply as well as the principles of the energy companies activity. The Law was approved by the Parliament in 1997.

The goals of the Energy Law are as follows: defining the principles and conditions for the sustainable development of the country, ensuring the energy security of the country, ensuring the appropriate conservation and the rational consumption of fuels and energy, promotion of the competition, counteracting the negative consequences of the natural monopoly activities, protection of the interests of energy consumers and minimisation of the energy costs. The Energy Law defines also the principles of the energy company activities and defines the roles of the government institutions in the supervision of the fuels and energy economy.

The Energy Law is compatible with the EU requirements. It creates also conditions for fulfilling of the national and international requirements of the environment protection.

In order to balance between the interests of the energy suppliers and energy consumers, the Energy Regulatory Office was established on the base of the Energy Law. The main activities of this Office are to issue the licenses to the energy companies, to supervise the company activity in the field of their compliance with the Energy Law and the license conditions as well as to approve the energy prices for these market segments for which the Energy Law provides for such procedure.

The Energy Law was amended and modified many times, mainly in the area of the legal regulations which result from Poland's accession to the European Union.

Introduction of the Energy Law, with its subsequent modifications and the establishment of the Energy Regulatory Office, has created conditions for the implementation of the reform policy in the energy sector, implementation of the organisational and ownership transformations as well as the adjustment of the national energy policy to the legal requirements of the European Union.

20

PLACE OF POLISH ENERGY SECTOR IN THE EUROPEAN UNION

The European Union is the economic and political union of democratic countries. It is the only such organisation in the world. Poland, due to its area, population, energy resources and the economic potential, constitutes an important Member State of this organisation. Therefore it is purposeful to present in synthetic way the comparison of basic data, concerning the Polish energy sector and its background, with the appropriate data for the EU-28 and for the individual Member States.

20.1. Main driving forces of the Polish energy sector development at the background of the EU-28 countries

The main driving forces of the energy development of Poland within the European Union are: country size, population, value of GDP and the conditions of energy supply from domestic sources and from imports.

Poland is a country with quite a big surface area and quite a big population, occupying sixth place in the EU-28 according to the values of both these indicators.

The EU countries with the biggest territory are: France – 544.0 th. km^2, Spain – 506.0 th. km^2, Sweden – 438.6 th. km^2, Germany – 357.1 th. km^2, Finland – 338.4 th. km^2, Poland – 312.7 th. km^2 and Italy – 301.3 th. km^2. Total surface area of the listed countries constitutes 64% of total area of the EU-28.

The countries with the highest population are: Germany – 80.5 million, France – 65.6 million, United Kingdom – 63.9 million, Italy – 59.7 million, Spain – 46.7 million, Poland – 38.5 million. Total population of the six listed countries constitutes 70% of the total EU population.

The following countries had in 2012 the highest GDP expressed in EUR in current prices: Germany – 2666.4 billion EUR, France – 2032.3 billion EUR, United Kingdom – 1932.7 billion EUR, Italy – 1566.9 billion EUR, Spain – 1029.0 billion EUR, Netherlands – 599.3 billion EUR, Sweden – 407,8 billion EUR, Poland – 381.5 billion EUR.

It should be underlined that the GDP expressed in current prices and converted to EUR by the exchange rates does not fully reflect the real value of domestic product because it does not take into account the differences in purchasing power between the countries. There exists an alternative method of GDP calculation and comparison, using the purchasing power of the local currency. This better reflects the real levels of GDP in the given countries.

Assuming the average GDP per capita for the whole UE-28 as 100%, the value of this indicator for Poland was 67% in 2012.

Table 20.1 presents the basic data and indicators for the EU-28 countries.

20.2. Production and consumption of primary energy and electricity and the capacity of power plants in the EU-28 countries

In the year 2011 the EU-28 countries have produced 805 Mtoe of primary energy, while the total consumption of primary energy amounted in these countries to 1706 Mtoe. This means that the average energy self-sufficiency was only 47%. All countries of EU-28 – besides only Denmark – were the net importers of primary energy.

In absolute numbers the net imports of primary energy to the EU-28 amounted to 901 Mtoe in 2011. Net imports to the big countries were as follows: Germany – 192 Mtoe, Italy – 141 Mtoe, France – 124 Mtoe, Spain – 97 Mtoe, United Kingdom – 70 Mtoe, Poland – 34 Mtoe.

The relatively low net imports to Poland are a consequence of high production of indigenous hard coal and lignite. Polish reserves of these fuels are the highest in the EU-28 countries.

Gross consumption of electricity in the EU-28 amounted to 3095 TWh in 2011, with the following countries being the largest consumers: Germany – 579 TWh, France – 477 TWh, United Kingdom – 346 TWh, Italy – 328 TWh, Spain – 259 TWh, Poland – 148 TWh, Sweden – 133 TWh, Netherlands – 118 TWh.

The total electric capacity in the EU-28 was 924 GW in 2011. The following countries had the highest capacities: Germany – 172 GW, France – 131 GW, Italy –

Table 20.1. Basic information on EU-28 countries – area, population, population density, GDP in 2012

Country	Country code	Area [1000 km²]	Population [1000]	Population density [inhab./km2]	GDP Total [x] [billion EUR]	GDP Per capita by PPP (EU-28=100[xx])
Belgium	BE	30,5	11 162	366	375,9	120
Bulgaria	BG	110,9	7 285	66	39,9	47
Czech Republic	CZ	78,9	10 516	133	152,9	81
Denmark	DK	42,9	5 603	131	245,3	126
Germany	DE	357,1	80 524	225	2 666,4	123
Estonia	EE	45,2	1 325	29	17,4	71
Ireland	IE	69,8	4 591	66	163,9	129
Greece	EL	132,0	11 063	84	193,3	75
Spain	ES	506,0	46 704	92	1 029,0	95
France	FR	544,0	65 633	121	2 032,3	108
Croatia	HR	87,7	4 262	49	43,7	61
Italy	IT	301,3	59 685	198	1 566,9	100
Cyprus	CY	9,3	866	93	17,7	92
Latvia	LV	64,6	2 024	31	22,3	64
Lithuania	LT	65,3	2 972	46	32,9	72
Luxembourg	LU	2,6	537	207	42,9	263
Hungary	HU	93,0	9 909	107	97,0	67
Malta	MT	0,3	421	1 403	6,9	86
Netherlands	NL	41,5	16 780	404	599,3	127
Austria	AT	83,9	8 452	101	307,0	130
Poland	PL	312,7	38 533	123	381,5	67
Portugal	PT	92,2	10 487	114	165,1	76
Romania	RO	238,4	20 020	84	131,6	50
Slovenia	SI	20,3	2 059	101	35,3	84
Slovakia	SK	49,0	5 411	110	71,1	76
Finland	FI	338,4	5 427	16	192,4	115
Sweden	SE	438,6	9 556	22	407,8	126
United Kingdom	UK	248,5	63 896	257	1 932,7	105
EU-28	-	4 404,9	505 701	115	12 970,2	100

Source: [86]
[x] For the non-Eurozone countries GDP converted to EUR by exchange rate
[xx] Per cent value of GDP per capita for a given country, assuming the average for EU-28 equal to 100%

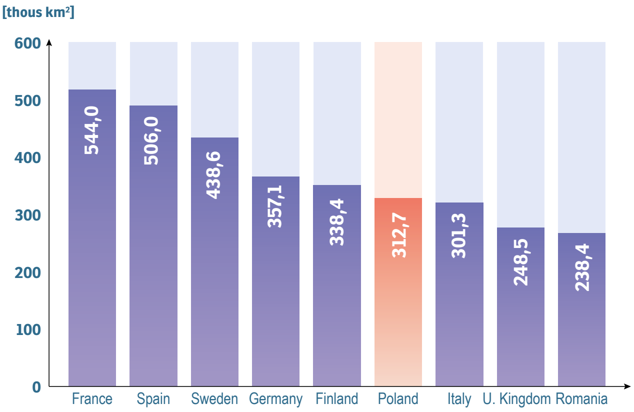

Fig. 25. EU countries with the largest area

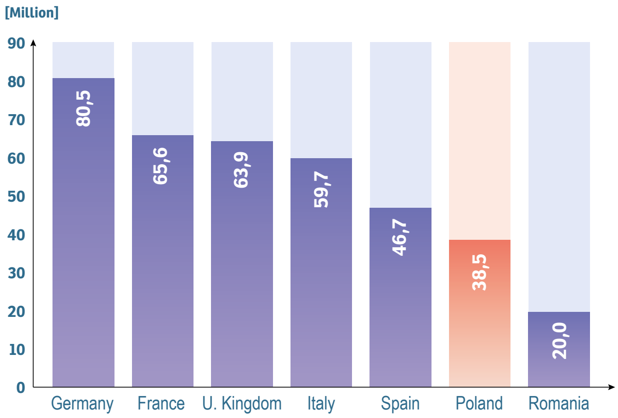

Fig. 26. EU countries with the largest population in 2012

Table 20.2. Production and consumption of primary energy and electricity and installed capacity of power plants in EU-28 countries in 2011

Country	Primary energy [Mtoe]		Electricity [TWh]		Installed capacity of power plants [GW]
	Production	Consumption	Production	Gross consumption [x]	
Belgium	17,6	59,7	88,9	88,6	20,1
Bulgaria	12,3	19,3	50,0	35,7	10,2
Czech Republic	32,0	43,3	86,8	66,0	20,2
Denmark	21,0	19,0	35,2	34,1	13,6
Germany	124,4	316,3	602,6	579,2	171,7
Estonia	5,0	6,2	12,9	8,4	2,8
Ireland	1,8	13,9	27,5	26,1	8,8
Greece	9,6	27,9	59,2	59,9	16,5
Spain	31,6	128,5	290,7	258,5	102,8
France	134,9	259,3	556,4	476,5	131,4
Croatia	3,8	8,5	10,7	16,7	4,2
Italy	31,9	172,9	306,3	327,5	118,4
Cyprus	0,1	2,7	4,9	4,8	1,7
Latvia	2,1	4,2	6,1	6,7	2,6
Lithuania	1,3	7,1	4,2	10,7	3,7
Luxembourg	0,1	4,6	2,6	8,1	1,7
Hungary	10,7	25,2	36,0	38,8	9,7
Malta	0,0	1,1	2,2	2,0	0,6
Netherlands	64,5	81,3	113,0	117,5	28,0
Austria	11,5	34,0	62,2	70,4	22,8
Poland	68,1	102,2	163,1	147,7	37,6
Portugal	5,3	23,9	52,1	51,2	19,9
Romania	27,8	36,3	62,0	53,2	20,5
Slovenia	3,7	7,3	15,9	14,0	3,3
Slovakia	6,2	17,4	28,3	28,9	8,1
Finland	17,0	35,7	73,4	84,8	16,7
Sweden	32,1	49,5	150,3	132,6	35,1
United Kingdom	128,6	198,8	364,9	346,1	93,8
EU-28	805,0	1 706,2	3 268,4	3 094,7	926,5

[x] According to the methodology of IEA, gross consumption of electricity is calculated as: gross production + import – export – network losses
Source: [14, 34]

118 GW, Spain – 103 GW, United Kingdom – 94 GW, Poland – 38 GW, Sweden – 35 GW, Netherlands – 28 GW.

Detailed information on production and consumption of primary energy and electricity as well as on the generating capacities of power plants is presented in Table 20.2.

20.3. Basic energy indicators of the EU-28 countries

Dependency on primary energy imports

In 2011 all countries of the EU-28, besides Denmark, were the net importers of primary energy, though degrees of their import dependency were very different. The average dependency on the primary energy imports was 53,8% in 2011.

Concerning coal, only Poland and Czech Republic were not the net importers. For the whole EU-28, the average dependency on coal imports was 62%. The dependency of the EU-28 on oil imports was very high, reaching 85%. All countries besides Denmark were the net importers of crude oil, and Poland was among the countries which in almost 100% depended on oil imports. The degree of natural gas dependency of the EU-28 was also high and amounted to 67%.

All countries besides Denmark and Netherlands were the net importers of natural gas, through degrees of their import dependency were different. Dependency of Poland on natural gas imports was 75%.

Consumption of primary energy per capita

The European Union has high indicators of primary energy consumption per capita. The average value of this indicator was 3.4 toe/capita in 2011. Poland belongs to the countries which have the relatively low value of this indicator. Its value for Poland was 2.7 toe/capita in 2011 and was by 20% lower than the average indicator for the EU-28.

Consumption of electricity per capita

The average gross consumption of electricity was 6107 kWh per capita in 2011. The countries with the highest indicators of per capita consumption are: Finland – 15742 kWh, Luxembourg – 15511 kWh, Sweden – 14029 kWh, Austria – 8359 kWh, Belgium – 8072 kWh, France – 7318 kWh, Germany – 7083 kWh. Poland is among the countries which have the relatively low value of this indicator. Its value for Poland was 3833 kWh/capita in 2011 and was by 37% lower than the average indicator for the EU-28.

Thermal efficiency of power stations

The average EU-28 value of the indicator of thermal efficiency of power stations was 49,3% in 2011. This value is an average figure calculated jointly for the condensing power stations and the CHP stations. The average value for Polish power stations and CHP stations is very close to the average for the EU-28. It should be however underlined that the thermal efficiency of many condensing power stations in Poland is considerably lower than the efficiency of modern power plants in West Europe.

Coefficients of CO_2 emission

The coefficients of CO_2 emissions per capita are very different in the EU countries. The highest emissions occurred in 2011 in the following countries: Luxembourg – 20.1 Mg/capita, Estonia – 14.4 Mg/capita, Czech Republic – 10.7 Mg/capita, Netherlands – 10.5 Mg/capita, Finland – 10.3 Mg/capita, Belgium – 9.9 Mg/capita, Germany – 9.1 Mg/capita. The coefficient of CO_2 emission for Poland was 7.8 Mg/capita in the year 2011.

Basic energy indicators of the EU-28 countries are presented in Table 20.3. Detailed assessment of these indicators was published in 2009 by R. Nodzyński [43].

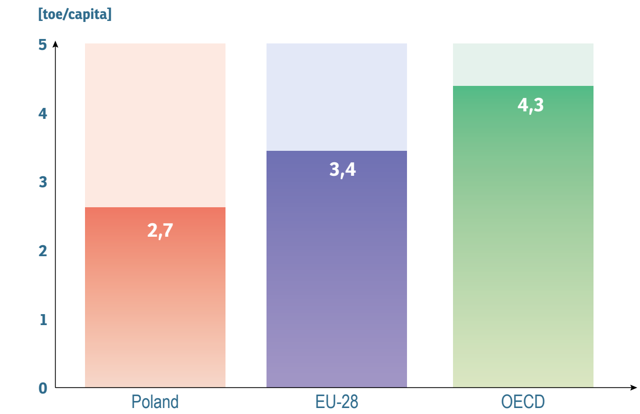

Fig. 27. Primary energy consumption per capita in Poland, EU-28 and OECD in 2011

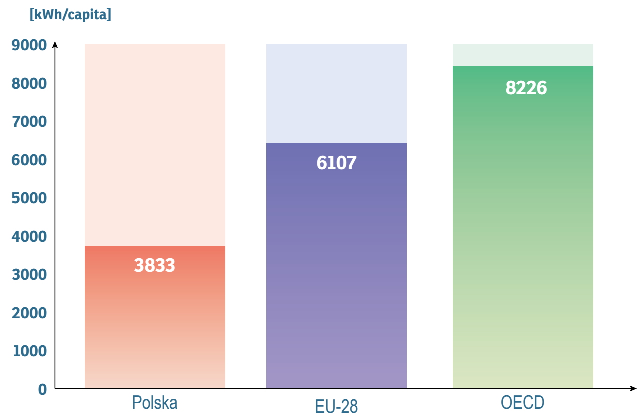

Fig. 28. Electricity consumption per capita in Poland, EU-28 and OECD in 2011

20.4. Place of Polish energy sector in the European Union

Poland belongs in the EU-28 to the group of the six biggest countries which comprises also France, Germany, Italy, Spain, United Kingdom. Combined population of these countries constitutes 70% of the total EU-28 population, and their combined area 52% of the Union.

Polish energy sector is distinguished among the EU-28 countries by the fact that Poland is the largest producer and consumer of hard coal, has the largest central heating subsector and is the country of oil and gas transit between Russian Federation and Germany. On the other hand Poland has no nuclear power and has no substantial resources of hydro energy.

The surface area of Poland is 312.7 th. km^2, and the population 38.5 million. This constitutes 7.1% of the total area and 7.6% of the total population of the EU-28.

Primary energy consumption of Poland accounted in 2011 for 6.0% of the total EU-28 consumption, and the Polish share of gross electricity consumption is 4.8%. The indicators of per capita consumption were in 2011 as follows:

Table 20.3. Selected energy indicators of EU-28 countries in 2011.

Country	Energy import dependency [%]	Primary energy consumption [toe/capita]	Electricity consumption [kWh/capita]	Thermal efficiency of power plants [%]	CO_2 emissions [Mg/capita]
Belgium	72,9	5,4	8 072	56,4	9,89
Bulgaria	36,6	2,6	4 781	42,3	6,58
Czech Republic	27,9	4,1	6 288	45,4	10,73
Denmark	-8,5	3,4	6 124	72,5	7,48
Germany	61,1	3,9	7 083	47,5	9,14
Estonia	11,7	4,6	6 255	39,3	14,40
Ireland	88,9	3,0	5 701	47,0	7,63
Greece	65,3	2,5	5 292	39,3	7,40
Spain	76,4	2,8	5 604	46,5	5,86
France	48,9	4,0	7 318	54,7	5,04
Croatia	54,4	1,9	3 789	54,8	4,26
Italy	81,3	2,9	5 393	46,6	6,47
Cyprus	92,4	3,2	5 939	36,4	8,63
Latvia	59,0	2,1	3 028	83,6	3,41
Lithuania	81,8	2,3	3 337	83,7	4,13
Luxembourg	97,2	9,0	15 511	51,2	20,10
Hungary	52,0	2,5	3 895	50,8	4,75
Malta	100,0	2,7	4 659	31,0	5,90
Netherlands	30,4	4,9	7 036	59,6	10,45
Austria	69,3	4,0	8 359	60,4	8,13
Poland	33,7	2,7	3 833	46,9	7,79
Portugal	77,4	2,3	4 806	49,6	4,51
Romania	21,3	1,7	2 486	48,5	3,82
Slovenia	48,4	3,5	6 806	44,2	7,43
Slovakia	64,2	3,2	5 306	54,9	6,22
Finland	53,8	6,7	15 742	72,9	10,32
Sweden	36,8	5,3	14 029	88,3	4,75
United Kingdom	36,0	3,2	5 518	44,5	7,06
EU-28	53,8	3,4	6 107	49,3	-

Source: [13, 14, 34]

- for primary energy: EU-28 average – 3.4 toe, Poland – 2.7 toe,
- for electricity: EU-28 average – 6107 kWh, Poland – 3833 kWh.

The indicator of per capita CO_2 emission is quite high for Poland (7.8 Mg/capita in 2011) because of the coal-based structure of Polish energy economy. The value of this indicator for the other largest countries of the EU-28 was in 2011: France – 5.0 Mg/capita, Germany – 9.1 Mg/capita, Italy – 6.5 Mg/capita, Spain – 5.9 Mg/capita, United Kingdom – 7.1 Mg/capita.

Against the background of the EU-28, Poland has the relatively low indicator of GDP per capita. Calculated by the Purchasing Power Parity, this indicator amounted to 67% of the EU-28 average in 2011.

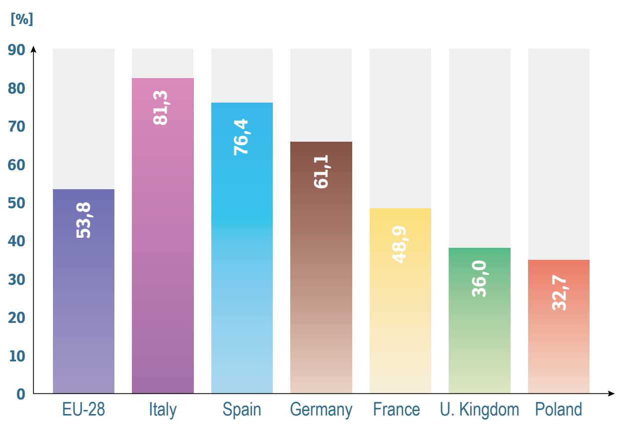

Fig. 29. Energy dependency of the largest EU countries in 2011

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SUMMARY OF PART II OF THE REPORT

Beginnings and development stages of the Polish energy sector

In the old centuries wood was a main source of energy used by the population of Poland, as it was also in the other countries of Europe. At some time wood became also a raw material for the production of charcoal. Gradually an application of hydro energy and wind energy has also developed.

In the middle of 18th century hard coal started to be used as an energy source. Its importance was growing rapidly with the development of industry in 19th century. Later, in the second half of 19th century, after an invention of the oil refining process and an invention of the kerosene lamp by Ignacy Łukasiewicz, an importance of oil started to grow quickly. In the second half of 19th century production of gas from coal was also initiated, mainly for the purpose of street lighting.

The next milestone in the energy use was the initiation of electricity generation at the turn of 19th and 20th century. Electricity was at the beginning applied for lighting and to drive the electric motors.

After the First World War in Poland, as in the other countries, the importance of fossil fuels was growing rapidly, particularly of oil which constituted the basic source of energy for the dynamically developing road transportation.

After the Second War production and consumption of energy started to grow rapidly in Poland. Extraction and consumption of hard coal was growing particularly quickly. Its production reached the maximum 201 million Mg in 1979. Coal was an important export commodity at that time. Production of lignite was also increasing and reached 67 million Mg in 1990. Production and consumption of electricity, natural gas and liquid fuels was on the same trend. Consumption of primary energy and electricity per capita was however in Poland about twice lower in comparison with the developed countries of West Europe.

Many disadvantageous occurrences took place in Polish energy sector during the period 1970-1990. These were particularly:

- high energy intensity of GDP, considerably higher than in the West Europe countries,
- excessive dependence of economy on coal, with a low consumption of hydrocarbon fuels,
- high degradation of the natural environment, caused in the highest degree by the energy sector,
- inadequate system of fuels and energy prices; prices were incompatible with the econo-mically justified costs of production, what resulted in the wastage of fuels and energy.

Energy sector in the conditions of market economy

Social and political transition, which started in the years 1989-1990, enabled the implementation of the economic reform also in the energy sector. Basic results of this reform were as follows:

- fuels and energy prices increase to the realistic levels:
- implementation of the multidirectional activities which rationalised the energy economy,
- improvements in the efficiency of energy use and considerable reduction of primary energy consumption,
- substantial improvement of the environmental conditions due to the reduction of SO_2, NO_x, CO_2 and ash emissions.

After the first difficult years of reform 1990-1993 the production of electricity started to grow slowly and the structure of primary fuel mix has changed in advantageous way, with increasing consumption of hydrocarbon fuels and drop in coal consumption. Close cooperation with the leading international organisations was also initiated.

In 1995 the electric system of Poland was interconnected with the Western European system. In 1996 Poland became a member country of OECD.

In 1997 the Polish Parliament approved the Energy Law which regulates the legal and economic aspects of Polish energy sector operation. On 1 May 2004 Poland became a Member State of the European Union.

Energy resources of Poland

Poland has the relatively large resources of solid fuels, i.e. hard coal and lignite, modest reserves of natural gas, insignificant of crude oil, small hydro energy potential and considerable resources of biomass and geothermal energy. The country has no uranium ores with high concentration of this element.

Recently the information concerning the existence of the substantial resources of unconventional shale gas in Poland was issued by several institutions. The US Energy Information Administration estimates these resources at several trillion m^3. If these estimations were confirmed, it would mean that Poland has the high resources of this fuel.

According to the recent assessments by the Polish Geological Institute, the resources of fossil fuels (excluding shale gas) are as follows:

- hard coal – 51.4 billion Mg,
- lignite – 22.7 billion Mg,
- crude oil – 24.4 million Mg,
- natural gas – 132.1 billion m^3.

The resources of renewable energy are estimated as follows:

- hydro energy – technically exploitable capability amounts to 12-15 TWh/year,
- biomass resources – approx. 750 PJ/year,
- wind energy – substantial resources which under the optimistic assumptions may cover more than a dozen per cent of the electricity requirements of Poland.

Production and consumption of primary energy

After the Second World War, up to the year 1980, due to high production of coal, Poland was self-sufficient in the primary energy supply and the substantial part of produced hard coal was exported.

Since 1980s, in consequence of the fall of hard coal production and the simultaneous growth of hydrocarbon fuels demand, Poland became the net importer of primary energy. In the recent years the primary energy import dependency was growing quickly, reaching 34% in the year 2011. Simultaneously the structure of primary energy consumption has changed substantially. In 1960 coal covered 93% of primary energy demand, and in 2012 the value of this indicator fell to 52%. However, it is still true that the Polish energy economy has the coal-based characteristics.

During the last decades the advantageous occurrence in the energy balance of Poland was the high growth of the hydrocarbon fuels share, from 22% in 1980 to 39% in 2012. Unfortunately, these fuels are mostly imported. Crude oil imports cover about 96% and natural gas imports approx. 75% of its national consumption.

Renewable energy sources still have the relatively low share in the structure of primary energy. This share has however grown from 1.3% in 1990 to 9.3% in 2012.

Production and consumption of electricity

Before the Second World War the electricity production was low in Poland, similarly as in other countries, and in 1938 amounted to 3977 GWh.

Rapid growth of electricity generation took place in the post-war years. Its production has grown from 10.7 TWh in 1950 to 164.4 TWh in 2013.

Power stations in Poland are mostly thermal, hard coal and lignite are the main fuels for electricity generation. The resources of hydro energy are low in Poland, the country has no nuclear plants.

Installed capacity of all power stations has grown in the years 1950-2013 from 2.7 GW to 38.7 GW. Large part of this capacity are however the old units, having more than 40 years of operation. These plants have low thermal efficiency and high emissions. They should be closed down in the forthcoming years.

Gross national consumption of electricity has grown in the years 1950-2013 from 10.4 TWh to 149.7 TWh. Through the majority of this period there was a high share of industrial consumption, mainly in the heavy industry, and low share of electricity consumption by households.

In the last decades, due to the economic reform and the reduction of the heavy industry activity, the electricity consumption in industry was considerably reduced. Consumption has increased gradually in households and in the service sector. The average consumption by a household is however still much lower in Poland than the average consumption by the West European household.

Electricity exchanges with the neighbouring countries were low during the whole post-war period, at a level below 10% of the national consumption. The highest export took place in 2013 – 12.3 TWh and the highest import in 1990 – 10.4 TWh.

Energy and the natural environment

Intensive development of industry, creation of urban and industrial agglomerations, high extraction of hard coal and lignite, growth of electricity production – all these occurrences resulted, particularly in the period 1950-1980, in the large degradation of natural environment in Poland. The environment protection activities were considered unimportant in Poland during this period.

The effects of insufficient protection of environment occurred particularly in the areas of south-western Poland, mainly in the Upper Silesia, and in the region of so-called „black triangle" near Turów in the Lower Silesia.

The country transformation since 1989, the economic reform and the multidirectional activities, particularly in the fuels and energy sector, have led to the advantageous change in the natural environment of Poland. The effects of these activities are as follows: substantial reduction of the emissions of gases, ash and industrial waste, improvement of the air quality, improvement of water purity in the rivers and lakes.

The following reduction of gases and ash emissions was achieved in the years 1988-2012:

	1988	2012	1988=100%
SO_2 [1000 Mg]			
country total	4 180	853	20
public power industry	1 990	334	17
NO_x [1000 Mg]			
country total	1 550	817	53
public power industry	420	217	52
CO_2 [million Mg]			
country total	477	321	67
public power industry	160	147	92
Ash [1000 Mg]			
country total	3 400	428	13
public power industry	770	17	2

The most difficult problem for the future years is the reduction of the CO_2 emissions according to the requirements of the European Union. Reduction of the CO_2 emissions may bring the substantial rise in electricity prices and the negative consequences for the whole national economy.








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Decimal units of measurement

kilo (k) = 10^3 = thousand
mega (M) = 10^6 = million
giga (G) = 10^9 = billion
tera (T) = 10^{12} = trilion
peta (P) = 10^{15} = quadrillion

Units of measure

m – metre
m^3 – cubic metre
km – kilometre
km^2 – sq1uare kilometre
kg – kilogram
Mg – megagram (tonne)
Mtoe – million tonnes of oil equivalent
kJ – kilojoule
MJ – megajoule
GJ – gigajoule
MBtu– million British thermal units
kW – kilowatt
MW – megawatt
GW – gigawatt
kWh – kilowatt-hour
MWh – megawatt-hour
GWh – gigawatt-hour
TWh – terawatt-hour
MVA – megavolt-ampere

Names of the organisations

UNO – United Nations Organisation
OECD – Organisation for the Economic Co-operation and Development
UE – European Union
OPEC – Organisation of the Petroleum Exporting Countries
IEA – International Energy Agency
WEC – World Energy Council
IPCC – Intergovernmental Panel on Climate Change
PAN – Polish Academy of Science
URE – Energy Regulatory Office
CIE – Energy Information Centre
ARE – Energy Market Agency