Report on the Results of the Analysis of National Potential of Combined Electricity and Heat Generation in the Czech Republic

Pursuant to Directive 2004/8/EC

Ministry of Industry and Trade of the Czech Republic
Prague, January 2006

Contents of the Report

1. INTRODUCTION

Directive 2004/8/EC of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market was adopted in order to increase energy efficiency and improve the safety of energy supplies of the EU countries.

Article 6 of Directive 2007/8 EC “Potential for the Application of High-Efficiency Combined Generation of Electricity and Heat in the Member States” includes the following requirements:

- Member States shall perform an analysis of the national potential for the application of high-efficiency cogeneration, including high-efficiency micro-generation.
- The analysis shall be based on well-documented scientific data and identify all potential for useful heating and cooling demands, as well as the availability of fuels and other energy resources to be utilized in cogeneration; it shall also include an analysis of the barriers which may prevent the implementation of the national potential for high-efficiency cogeneration.
- Member States shall evaluate progress towards increasing the share of high-efficiency cogeneration, for the first time not later than by 21 February 2007 and thereafter every four years, upon a request by the Commission at least six months before the due date.

The submitted report, “Analysis of the National Potential for High-Efficiency Cogeneration in the Czech Republic” meets the requirement of Article 6 of the Directive. The report has been prepared on the basis of the study called “Analysis of the National Potential for the Application of High-Efficiency Cogeneration in the Czech Republic” of 2004. This Report complies with the criteria set out in Annex IV to the Directive and

- Considers the types of usable fuels, including the potential for increasing the use of renewable energy sources;
- Considers the types of realistically applicable cogeneration technologies;
- Divides the potential into modernization of existing capacities and construction of new capacities
- Includes appropriate mechanisms to assess the cost effectiveness of construction and operations
- Accepts other national commitments with respect to energy and environmental protection
- Specifies the potentials in relation to the timeframes of 2010, 2015 and 2020.

In terms of its contents and methodology, the Report has been prepared according to the document called “Guidelines for Determining the National Potential for High-Efficiency Cogeneration” drawn up within the tasks of the “Committee on Cogeneration” and approved by the European Commission's DG TREN in January 2006.

The submitted report has been prepared on the basis of the application of assessment criteria consistent with legislative conditions effective in the Czech Republic in 2005 (Decree No. 439/2005 Sb. (Collection of Laws)). The Czech Republic, in accordance with Article 5 of Directive 2004/8/EC, until the harmonized efficiency reference values come into force for all

EU Member States, adopted its own reference values which was accomplished by the issuing of Decree No. 439/2005 Sb. (Collection of Laws).

The reason for application of local assessment criteria and efficiency reference values was the fact that the latest possible deadline for the publication of the report on national potential for cogeneration is 21 February 2006 (under Article 10 of the Directive) and neither the harmonized reference values nor the methodological guidance for the relevant calculations have been officially determined by the European Commission.

In the event that the adopted harmonized reference values and the adopted EU calculation procedures differ considerably from our existing practice, it will be necessary to revise the national potential in the following period, in particular it will be necessary to review the existing level of the share of cogenerated power from sources that meet high-efficiency criteria (achieving 10% savings of the primary energy).

2. SUMMARY OF THE RESULTS

In the energy sector of the Czech Republic the usage of solid and liquid fuels (Czech-produced coal and heating oil) decreases, and on the other hand, the use of nuclear power (for electricity generation), natural gas (for decentralized heat) and renewable energy sources (in particular biomass) increases. There are realistic assumptions that these trends will continue.

In the heating plant industry, the consumption of heat significantly dropped due to the streamlining of the generation, distribution and particularly consumption of heat. Although the potential for heat savings on the consumption side has not been exhausted the decreasing trend has stopped. In the area of electricity consumption we see a gradual increase over the last few years; this trend is likely to continue.

The declared general objectives of the national energy policy include support for cogeneration. More specific objectives foresee utilization of all positive energy and environmental effects of cogeneration.

Approximately 12 TWh of electricity and approximately 156 PJ of heat are currently produced in combined cycle generation, which represents approximately 15% of total electricity generation and approximately 39% of total heat generation. Most of this generation takes place in older coal-fired plants with back-pressure steam turbine generator units and extraction steam turbine generator units. Under the current Czech legislation it is a high-efficiency cogeneration, which achieves at least 10% savings on consumption of the primary power plants relative to the current Czech sources of separated heat and electricity generation.

The growth potential will probably lie in the increase of the number of small and medium-size cogeneration sources based on natural gas, and in the improvement of the quality of utilization of steam turbines (both back-pressure and extraction turbines) in large sources.

The main cogeneration technology in large sources will be extraction steam turbines; in small and medium-size plants gas engines will continue to prevail.

Directive No. 2004/8/EC speaks about the support for cogeneration based on demand for useful heat and cooling in the internal energy market, which is a key basis of the methodology for determining the technical potential of cogeneration. The technical potential therefore represents a theoretical limit, which would be reached if the cogeneration sources were installed wherever there is a need for useful heat.

The technical (theoretical) potential of electricity generation within the cogeneration mode represents approximately 36 TWh of electricity generation as of 2005 and 48 TWh of electricity generation as of 2020, i.e., three times or four times the current real level of generation. The main part of this technical potential lies in medium-size and small plants using gaseous and liquid fuels.

Economic potential for the renewal and construction of cogeneration power plants is based on the technical potential and is affected particularly by the economic conditions existing in the respective timeframe for the respective type of source. A number of non-economic criteria and accruing factors respecting the useful life and gradual implementation of the individual construction projects also have an impact. The economic potential therefore represents a real level which can be achieved if the development of cogeneration is intentionally and specifically supported.

The highest utilization of the technical potential (achievement of the economic potential) will occur within the reconstruction of large power coal-burning and biomass-burning plants where steam condensation extraction and back-pressure turbines can be used.

A comparable economic potential of cogeneration lies in medium-size and small power plants that burn gaseous fuel, although this is a relatively low-percentage utilization of the technical potential. It is particularly combustion piston engines that will be used in such power plants.

Overall increase of electricity generation in cogeneration mode from the current approximately 11.8 TWh (in 2005) to the future 17.4 TWh (in 2020) will be achieved thanks to the increase of demand for useful heating, application of the latest cogeneration technologies in the reconstructed power plants, and installation of new cogeneration equipment in small and medium-size heating plants.

The initial situation of the Czech Republic in the area of utilization and development of combined heat and electricity generation (under the current conditions) is relatively good. Cogeneration power plants and centralized heat supplies have a long tradition in the Czech Republic, the technologies are available, there is enough operational experience and know-how for the preparation and implementation of new cogeneration projects.

Support for cogeneration is provided for in Act No. 458/2000 Sb. (Collection of Laws) (amendment No. 670/2004 Sb. (Collection of Laws)), on business conditions and public administration in energy sectors and on amendment to other laws (the Energy Act). Directive 2004/8/EC is already implemented in this Act. Support for cogeneration is also provided for in Act No. 406/2000 Sb. (Collection of Laws) on energy management. General support for cogeneration is declared in the State Energy Concept as well as the State Environmental Policy.

In order to fulfil the economic potential of cogeneration it is necessary to seek, as a priority, mainly preservation or, if applicable, extension, intensification and refining of the system of support of purchase of the electricity from cogeneration power plants in the form of contributions or guaranteed prices.

It is also necessary to support implementation of a quality system of collection and evaluation of the statistics on the parameters and generation in cogeneration power plants.

In addition to the above-mentioned important measures, it is also important to achieve support of the public opinion in favour of the development of cogeneration.

3. DEVELOPMENT TRENDS AND OBJECTIVES OF THE NATIONAL POLICY

3.1 Trends in the Structure of the Use of Fuels in Energy Sector

The trends in the structure of the use of fuels in energy sector are documented in the comparison of the current (2003) and "historical" (1993) data, as shown numerically in table No. 3.1.1 and graphically on figure No. 3.1.1.

Table No. 3.1.1 Trends in the structure of the use of fuels for the generation of heat and electricity

Total heat consumption in fuel in PJ per year	**Year**	**Centralized heat (CZT)**	**Decentralized heat (DZT)**	**Electricity (El. en)**	**Total energy sector**
Solid fuel	1993	284	188	446	918
	2003	160	73	500	733
Liquid fuel	1993	38	29	3	70
	2003	23	10	3	36
Gaseous fuel	1993	73	93	7	173
	2003	75	106	32	213
Nuclear power	1993	0	0	139	139
	2003	1	0	280	281
Renewable energy sources and other	1993	0	0	0	0
	2003	21	41	5	67
Total energy sector	1993	395	310	595	1300
	2003	280	230	820	1330

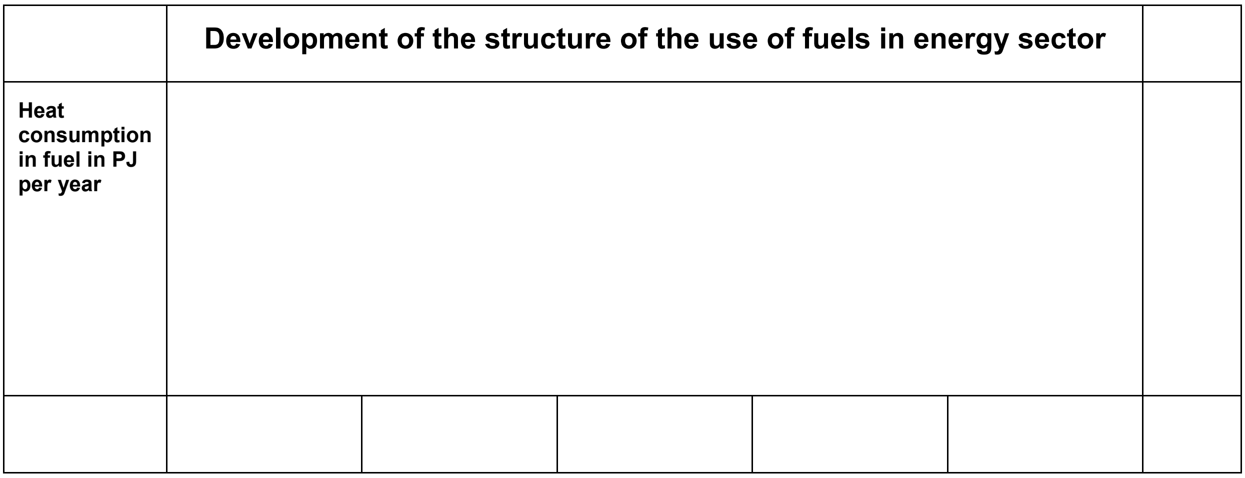

Figure No. 3.1.1 Development of the structure of the use of fuels in energy sector in total

It is apparent, based on the trends shown, that in the energy sector the usage of solid and liquid fuels (Czech-produced coal and heating oil) decreases, and on the other hand the use of nuclear power (for electricity generation), natural gas (for decentralized heat) and renewable energy sources (in particular biomass) increases. There are realistic assumptions that these trends will continue.

3.2 Trends in the Volumes of Energy Generation and Consumption

Trends in the volumes of energy generation and consumption are documented in the comparison of 1993 and 2003 data; see the following table No. 3.2.1 and figure No. 3.2.1

Table No. 3.2.1 Trends in volumes of heat and electricity generation and consumption

Development of basic energy balances in PJ per year	**Year**	**Centralized heat (CZT)**	**Decentralized heat (DZT)**	**Electricity (El. en)**	**Total energy sector**
Consumption of primary sources (of heat in fuel)	1993	395	310	595	1300
	2003	280	230	820	1330
Electricity generation (without process losses)	1993	298	225	212	735
	2003	220	180	300	700
Energy supply (without own consumption)	1993	283	225	196	704
	2003	210	180	217	607
Domestic distribution (without export balance)	1993	283	225	188	696
	2003	210	180	217	607
Domestic consumption (without distribution losses)	1993	230	225	170	625
	2003	180	180	196	556

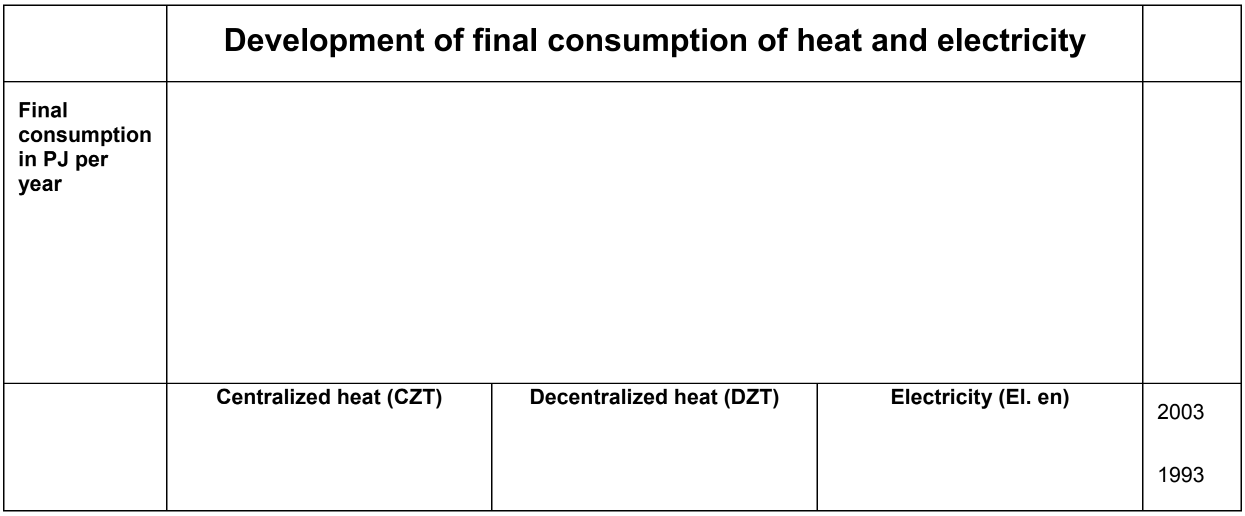

Figure No. 3.2.1 Development of final consumption of heat and electricity

In the area of both centralized and decentralized heat we have recorded a significant decrease of the consumption of primary fuels as well as the final consumption, due to the replacement of the coal sources with gas sources, restructuring of the industry, streamlining measures in generation and distribution of heat, and to a large extent also due to the savings on the consumption side. The decreasing trend of the consumption has stopped and, although the potential has not been exhausted by far, needs of new projects start to be promoted.

3.3 Trends in the Construction and Use of Electricity Generation Technologies

Table No. 3.3.1 and figure No. 3.3.1 documents the change in the use of the technologies (generation facilities) used in electricity generation.

Table No. 3.3.1 Trends in the use of electricity generation technologies

Output and generation of power plants	**Installed capacity of electricity in GW**		**Electricity generation in TWh**	
	1993	**2003**	**1993**	**2003**
Condensation steam turbine generator units	10.0	10.3	46.1	62.1
Extraction steam turbine generator units	1.4	2.5	6.7	12.0
Back-pressure steam turbine generator units	1.5	1.7	4.7	5.7
Gas turbines with generators	0.0	1.8	0.0	1.8
Piston gas engines	0.0	0.1	0.0	0.2
Water turbine generator units	1.4	2.1	1.4	1.5
Total electricity sources	14.3	18.5	58.9	83.3

It is apparent, based on the data shown in table No. 3.3.1 and figure No. 3.3.1 below, that there has been a shift in the past ten years in the area of traditional steam power plants toward the preference to use extraction steam turbine generator units. There are also new technologies, which have virtually not been used in the Czech Republic before 1993, i.e., gas turbines (in larger units in combination with steam turbines – combined cycle gas turbines) and gas engines.

It is likely that the trends in the preferences of extraction steam turbine generator units will continue in connection with the broader use of biomass. There will probably be no new installations of gas turbines for heating plant purposes because large centralized systems based on natural gas are equipped with these devices, and new systems will probably not be built. Natural gas, due to its parameters, is predetermined to be utilized in decentralized manner; it is therefore possible to expect gradual deployment of gas engines. The pace will depend on the price relations between gas and electricity.

	Development of electricity generation in the sources						
Electricity generation in TWh per year							
	Condensation	Extraction	Back-pressure	Gas turbines	Gas engines	Water	

Figure No. 3.3.1 Development of electricity generation in the sources

3.4 General Objectives of the National Policy in Energy Sector

The strategic objective of the national policy of the Czech Republic in energy sector is to create conditions for reliable and long-term safe energy supplies at acceptable prices and to create conditions for the efficient use the energy supplies, which does not pose a risk to the environment and complies with the principles of sustainable development.

This strategic objective is also a basis of the document called "State Energy Concept of the Czech Republic" (SEK), approved by the resolution of the government of the Czech Republic No. 211 of 10 March 2004, which is one of the fundamental components of the economic policy of the Czech Republic.

Basic priorities of the State Energy Concept are:

INDEPENDENCE

- of foreign energy sources
- of energy sources from risky regions
- of reliability of supplies from foreign sources

SAFETY

- of energy sources including nuclear safety
- reliability of supplies of all types of energy
- reasonable decentralization of energy systems

SUSTAINABLE DEVELOPMENT

- protection of the environment
- economic and social development

3.5 General Objectives of the National Policy in the Area of Cogeneration

SEK foresees achievement of the strategic objective (vision) while respecting the basic priorities through gradual compliance with the four main objectives. Each of the four main objectives includes several **specific partial objectives,** of which we present those that are directly related to the application of combined generation of electricity and heat (cogeneration).

MAXIMIZATION OF ENERGY EFFICIENCY

- In the acquisition and transformations of energy sources - an objective with a very high priority aiming at preferring renewable energy sources and energy technologies with high-efficiency energy transformation, utilizing cogeneration and secondary energy sources;
- In the distribution systems - an objective with a medium-high priority aiming at efficient energy distribution systems in terms of centralization and decentralization of energy sources, consumption centre-points, and losses in distribution lines.

ENSURING THE EFFECTIVE AMOUNT AND STRUCTURE OF PRIMARY ENERGY SOURCES CONSUMPTION

- Promotion of electricity and heat produced from renewable energy sources - an objective with a very high priority – all renewable energy sources will be preferred, i.e., including the sources using biomass for electricity and heat generation;
- Optimising the use of indigenous energy sources - an objective with a very high priority - the state will prefer optimal utilisation of all exploitable reserves of lignite and black coal and other fuels that are found in its territory.

MAXIMISING ENVIRONMENTAL FRIENDLINESS

- Minimising environmentally harmful emissions - an objective with a high priority aimed at promotion of the best available environmentally friendly technologies;
- Minimising greenhouse gases emission - An objective with a medium-high priority focusing on minimising emissions of greenhouse gases, especially carbon dioxide.

COMPLETING THE TRANSFORMATION AND LIBERALISATION OF ENERGY SECTOR

- Minimising the prices of all types of energy - an objective with a high priority aimed at creating a highly competitive environment in the generation and distribution of all types of energy;

- Optimising the process of backing-up energy sources - an objective with a high priority aiming at the creation of a regulatory and business environment that will create conditions allowing operative selection of energy suppliers, which will lead to lower dependence on a particular supplier or one group of enterprises.

3.6 Summary of the Main Trends and Objectives

Based on the information provided in the previous chapters, it is possible to summarize that:

- Changes in the use of primary energy sources are legible and stable. The share of Czech-produced coal is decreasing; this fuel is replaced with nuclear energy used for electricity generation and with natural gas used for decentralized heat generation.
- In the area of heat supplies, the consumption decreased significantly, due to the streamlining of the generation, distribution and particularly consumption of heat. Although the potential for heat savings on the consumption side has not been exhausted the decreasing trend has stopped. In the area of electricity consumption we see a gradual increase in the recent years; this trend is likely to continue.
- The traditional and most significant sources of electricity have been steam turbine generator units in coal-fired power plants and heating plants. In the last decades there have been new technologies of gas turbines and gas engines whose share in the market is still relatively low.
- The general objectives of the national energy policy declare support for cogeneration. The specified objectives foresee utilization of all positive energy and environmental effects of cogeneration. The state realizes the importance and benefits of cogeneration, which is shown in the production and adoption of the fundamental economic documents.

4. MAIN ASSUMPTIONS AND BASIS OF THE ANALYSIS

4.1 Situation in the Heat and Electricity Market

Shares of the individual types of sources in the total generation of electricity and heat in the Czech Republic in 2003 are shown on figures No. 4.1.1. (electricity) and No. 4.1.2 (heat).

<table>
<tr><th>Annual electricity generation in:</th><th>TWh per year</th><th>Share of sources in total electricity generation</th></tr>
<tr><td>Coal-fired power plants and heating plants</td><td>53.0</td><td rowspan="5">Nuclear power plants 31 %

Renewable energy sources 2 %

Gas power plants 3 %

Coal-fired power plants 64 %</td></tr>
<tr><td>Gas power plants and heating plants</td><td>2.6</td></tr>
<tr><td>Nuclear power plants</td><td>25.9</td></tr>
<tr><td>Renewable energy sources</td><td>1.5</td></tr>
<tr><td>Total electricity generation</td><td>83.0</td></tr>
</table>

Figure No. 4.1.1 Share of sources in total electricity generation

<table>
<tr><th>Annual useful heat generation in:</th><th>PJ per year</th><th>Share of sources in total heat generation</th></tr>
<tr><td>Power plants and heating plants – centralized</td><td>156</td><td rowspan="4">Local boilers – decentralized 45 %

Heating plants – centralized 16 %

Power plants and heating plants – centralized 39 %</td></tr>
<tr><td>Heating plants – centralized</td><td>64</td></tr>
<tr><td>Local boilers – decentralized</td><td>180</td></tr>
<tr><td>Total useful heat generation</td><td>400</td></tr>
</table>

Figure No. 4.1.2 Share of sources in total heat generation

4.2 Situation in Combined Electricity and Heat Generation (Cogeneration)

The volume of electricity and heat generation in cogeneration power plants is derived from the results of a one-time statistical survey conducted by ČSÚ (the Czech Statistical Office) in 2003 and the summarized values of the reports of the obligatory purchase of electricity from renewable energy sources and cogeneration, as recorded by ERO in 2003. The resulting values are shown in table No. 4.2.1, the graphic representation thereof is shown on figures No. 4.2.1 and No. 4.2.2

Table No. 4.2.1 Structure of electricity and heat generation in cogeneration power plants

Generation technology	Electricity [TWh per year]	Heat [PJ per year]
Condensation extraction turbines	6.3	73
Back-pressure steam turbines	4.5	75
CCGT facilities with heat supplies	0.9	5
Gas turbines with heat recuperation	0.1	1
Combustion piston engines with heat recuperation	0.2	2
Other cogeneration technologies	0	0
Total cogeneration technologies	**12**	**156**

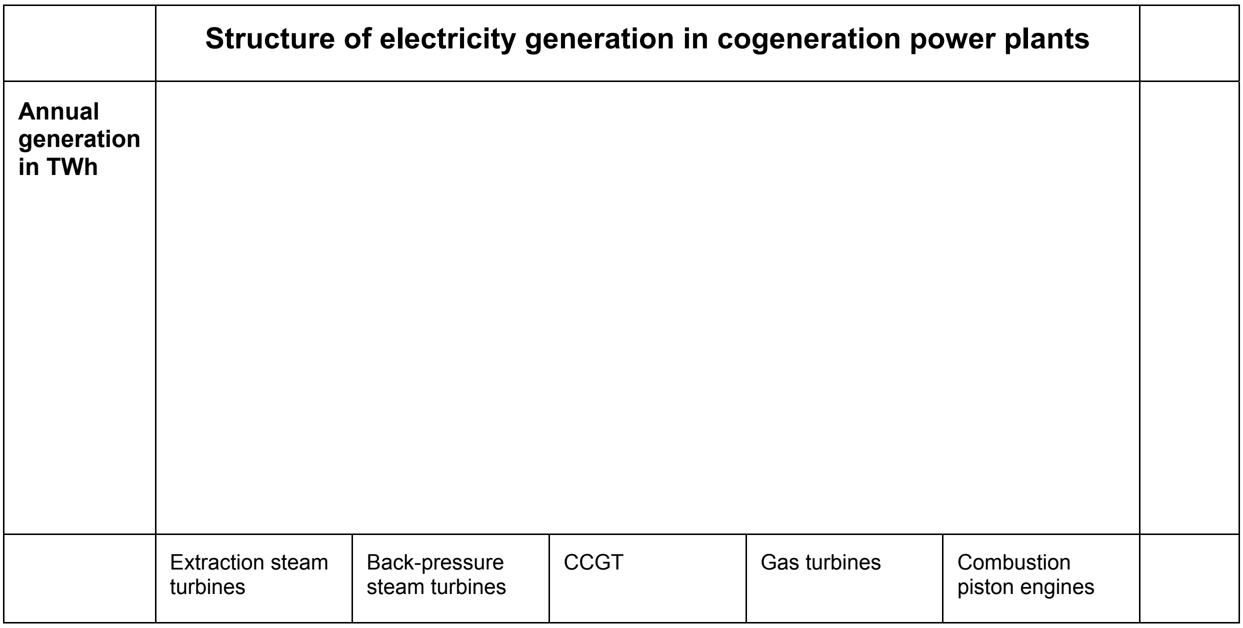

Figure No. 4.2.1 Structure of electricity generation in cogeneration power plants

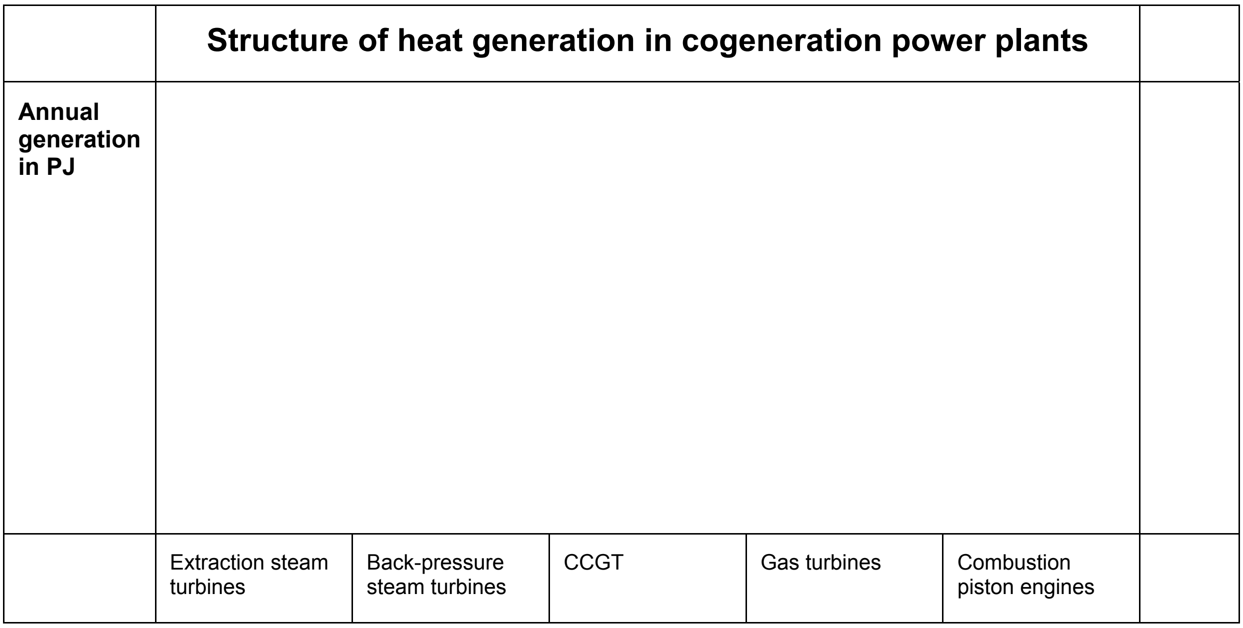

Figure No. 4.2.2 Structure of heat generation in cogeneration power plants

The basic balance of generation, supply and consumption of energies from cogeneration power plants is shown in table No. 4.2.2.

Table No. 4.2.2 Basic balance of generation, supply and consumption of energies from cogeneration power plants

Total cogeneration sources	**Electricity**	**Heat**
Total generation in cogeneration power plants	12.0 TWh	156 PJ
Own consumption of cogeneration power plants	-1.5 TWh	- 8 PJ
Supplies to distribution networks	10.5 TWh	148 PJ
Losses in distribution networks	-1.0 TWh	- 21 PJ
Total supplies to consumers	9.5 TWh	127 PJ

It is apparent, based on the above overview, that the dominant cogeneration sources in the Czech Republic are extraction steam turbines and back-pressure steam turbines installed in coal-fired heating and power plants; relatively significant sources are also combined cycle gas turbine facilities. Combined generation of electricity and heat in gas turbines and gas engines with heat recuperation is still minimal.

4.3 Estimated Development of Demand for Electricity and Heat according to SEK

Development of the demand for electricity and heat is derived from the assumptions of the State Energy Concept. Demand for energy in individual sectors was derived from the GDP growth rates and specific heat consumption.

Overview of the development of the demand for electricity or, more specifically, for the need of electricity generation (taking into account the trade balances, own consumption and distribution losses) is shown in table No. 4.3.1. Overview of the development of the demand for heat is shown in table No. 4.3.2. Graphic representation of the estimated development of generation of electricity and heat is shown on figure No. 4.3.1.

Table No. 4.3.1 Estimated development of electricity generation

Electricity	unit	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Total electricity generation	TWh per year	78.2	82.3	80.9	85.0	87.5	89.2
	PJ per year	282	296	291	306	315	321

Table No. 4.3.2 Estimated development of heat generation

Heat	Unit	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Heat generation in CZT	PJ per year	220	220 **2**	225	228	230	232
Heat generation in DZT	PJ per year	188	213	232	246	254	256
Total heat generation	PJ per year	408	435	457	474	484	488

Note: CZT – Central heat sources; DZT – Decentralized heat sources

	Estimated development of energy generation	
energy generation in PJ		Electricity Heat in CZT Heat in DZT

	2005	2010	2015	2020	2025	2030	

Figure No. 4.3.1 Estimated development of electricity and heat generation in sources

4.4 Future Cogeneration Technologies

Cogeneration technologies in large plants will continue to be based on the use of traditional solid and, where applicable, gaseous fuels, and if the fulfilment of the objectives of the state energy concept wins adequate support the use of biomass will also start increasing.

In large heating plants it will probably be the construction of the so-called “Integrated Multifunctional and Flexible Plants” that will be promoted rather than the construction of special single-purpose high-efficiency sources.

The so-called integrated multifunctional and flexible plants will allow:

- utilization of multiple types of fuel with the possibilities of co-combustion
- a change in the ratio of electricity, heat and, where applicable, other products generated
- use of synergies in the provision of a broad range of services

Utilization of multiple types of fuel with the possibilities of co-combustion will result in reduction of the risks of cogeneration power plants on the input side. Combustion devices (boilers, reactors) used in cogeneration power plants will be those that can burn or gasify different types of coal, and they will also be able to burn or gasify different types of biomass. Other fuels used here will include natural gas, landfill gas, biogas, pit gas, etc.

A change in the ratio of electricity, heat and, where applicable, other products generated will result in reduction of the risks of cogeneration power plants on the output side. Typically, several types of steam and also gas, if applicable, turbine generator units will be installed in cogeneration power plants.

Use of synergies in the provision of a broad range of services will result in reduction of the risks of cogeneration power plants in terms of positions in local markets. It will lead to combination of the operations of electricity and heat generation with other activities such as waste management, generation and supply of cooling and also preparation and distribution of potable water or other services, which we can see in the so-called multi-utility companies.

Small and medium-size plants represent a significant potential for the development of cogeneration. The vast majority of these sources will use natural gas as a fuel, and also, if applicable, other types of gaseous fuels such as landfill gas, biogas, etc.

The cogeneration sources still prevailing in standalone boiler rooms will be primarily gas engines; in heating plants located directly in buildings (on service levels, on roofs), in contrast, we can expect the application of less noisy, vibration-free technologies, i.e. micro-turbines and subsequently also fuel cells. The largest expansion of cogeneration power plants using gaseous fuels can be expected in the services and industry sector.

4.5 Economic Conditions for Application of Cogeneration Power Plants

(according to the currently estimated price development)

Economic conditions for the application of cogeneration power plants will depend particularly on:

- Investment demands of the individual types of cogeneration technology
- Proportion between the prices of fuel, electricity and heat
- Operating parameters, operational usage and operating limitations
- Other related specific costs of individual technologies

The first input for the evaluation of effectiveness of the application of cogeneration power plants is the investment demand of these plants, more specifically, the specific investment demand related to kW of the installed electric output (capacity). Overview of the specific investment demands of the installed capacities within the individual groups and technologies of cogeneration including the estimated development (increase or decrease) in time (in the relevant years of 2005, 2010, 2015 and 2020) is shown in table No. 4.6.1.

Table No. 4.5.1 Overview of the specific investment demands of the individual groups of cogeneration power plants

Specific investment demand related to kW of installed capacity					
Parameter	**Units**	**2005**	**2010**	**2015**	**2020**
Large plants using coal and biomass	CZK/kWe	30000	30000	30000	30000
New large plants using gas and oil	CZK/kWe	28000	28000	28000	28000
New medium-size plants using natural gas	CZK/kWe	28000	28000	28000	28000
New medium-size plants using biomass	CZK/kWe	60000	60000	60000	60000
New small plants using gas and oil	CZK/kWe	35000	35000	35000	35000
New other cogeneration plants	CZK/kWe	40000	40000	40000	40000

The second important input information for economic evaluation of the effectiveness of the installation and operation of different cogeneration technologies is the price of the fuel used. Overview of the development of specific prices of the individual types (or groups) of fuel used in combined electricity and heat generation is shown in the following table No. 4.4.2. Specific prices of fuel shown in the table are related to GJ of caloric value (not total heat value) of the respective fuel. The values are average.

Table No. 4.5.2 Overview of specific prices of fuels used in cogeneration power plants

Specific prices of fuels					
Parameter	**Units**	**2005**	**2010**	**2015**	**2020**
Lignite	CZK/GJ	50	55	60	65
Biomass	CZK/GJ	90	100	110	120
Natural gas and oil – large customers	CZK/GJ	180	200	215	230

Natural gas – medium-size customers	CZK/GJ	185	210	225	245
Natural gas and oil – small customers	CZK/GJ	215	240	260	280
Nuclear fuel and other waste fuel	CZK/GJ	35	38	41	45

Other important inputs for economic evaluation of the effectiveness are the purchase prices of the energies generated in cogeneration power plants, i.e., electricity and heat. Specific purchase prices of electricity related to kWh supplied are shown in the following table No. 4.5.3, specific purchase prices of heat related to GJ supplied are shown in table No. 4.5.4.

Table No. 4.5.3 Overview of specific prices of electricity from cogeneration power plants

Specific prices of electricity supplied					
Parameter	**Units**	**2005**	**2010**	**2015**	**2020**
Supply to v.h.v. – with small share of services	CZK/MWh	940	1050	1150	1250
Supply to v.h.v. – with big share of services	CZK/MWh	1250	1400	1500	1600
Subsidized from cogeneration – VT zone	CZK/MWh	2200	2400	2600	2800
Small consumption from network – low v.	CZK/MWh	3200	3600	3900	4200
Subsidized from ren. en. sources – biomass	CZK/MWh	2520	2750	3000	3200
Bonus for cogeneration – large sources	CZK/MWh	40	44	48	52
Bonus for cogeneration – medium-size sources	CZK/MWh	250	270	290	300

Table No. 4.5.4 Overview of specific prices of heat from cogeneration power plants

Specific prices of heat					
Parameter	**Units**	**2005**	**2010**	**2015**	**2020**
From large plants using coal and biomass	CZK/GJ	142	150	160	170
From large plants using natural gas and oil	CZK/GJ	245	265	280	295
From medium-size plants using biomass	CZK/GJ	220	230	250	265
From medium-size plants using natural gas	CZK/GJ	265	285	305	320
From small plants using gas and oil	CZK/GJ	300	320	340	360
From other plants (Nuclear)	CZK/GJ	142	150	160	170
Bonus for the use of renewable energy sources	CZK/GJ	0	10	20	30

In addition to the capital and fuel component of the costs and in addition to the revenues from the heat and electricity supplies the overall economy of operation will also be affected by other operating costs including the costs of repairs and maintenance, storage of ashes, inspections, emission charges, wages of the operating staff, overhead costs, etc. Although it is difficult to express these on lump-sum basis, table No. 4.5.5 shows gross estimates of the average values based on practical knowledge and experience. These costs are related to GJ of the heat in fuel consumed.

Table No. 4.5.5 Specific other operating costs related to GJ of heat in fuel

Specific other operating costs related to GJ of heat in fuel					
Parameter	**Units**	**2005**	**2010**	**2015**	**2020**
Large plants using coal and biomass	CZK/GJ	17	18	20	22
New large plants using gas and oil	CZK/GJ	24	26	28	30

Medium-size plants using natural gas	CZK/GJ	45	47	49	51
Medium-size plants using biomass	CZK/GJ	31	34	37	40
Small plants using gas and oil	CZK/GJ	39	42	45	48
Other cogeneration plants	CZK/GJ	10	11	12	13

Comparison of the individual price relations of the investments, fuel, heat and electricity in the period 2005 and 2020 is graphically shown on figure No. 4.5.1.

Specific investment demand of cogeneration power plants

Specific investment in CZK /kWe

2020
2005

Large plants using coal and biomass	New large plants using gas and oil	New medium-size plants using natural gas	New medium-size plants using biomass	New small plants using gas and oil	New other cogeneration plants

Comparison of specific prices of fuel

Specific prices of fuel in CZK/GJ

2020
2005

Lignite	Biomass	Natural gas and oil – large customers	Natural gas – medium-size customers	Natural gas and oil – small customers	Nuclear fuel and other waste fuel

Comparison of specific prices of electricity

Specific prices of electricity in CZK/MWh

2020
2005

Supply to v.h.v. – with small share of services	Supply to v.h.v. – with big share of services	Subsidized from cogeneration – VT zone	Small consumption from network – low v.	Subsidized from ren. en. sources – biomass

Comparison of specific prices of heat

Specific prices of heat in CZK /GJ

2020
2005

Large plants using coal and biomass	Large plants using gas and oil	Medium-size plants using biomass	Medium-size plants using natural gas	Small plants using gas and oil	Other plants (nuclear)

Figure No. 4.5.1 Comparison and development of the main economic inputs for cogeneration power plants

The information provided in tables No. 4.5.1 through 4.5.5 and figure No. 4.5.1 shows that while growth of specific investments in years is not envisaged in the development of the specific investment demand, the development of specific prices of fuel and energy takes into account a certain year-on-year growth, which, however, envisages significant proportionality and linearity in the period until 2020.

4.6 Summary of the Main Assumptions and Basis of the Analysis

The main assumptions and basis of the analysis of the potential of cogeneration in the Czech Republic include:

- Almost all electricity in the Czech Republic is generated in steam cycles of nuclear and coal-fired power plants or heating plants; the share of gas plants and renewable energy sources is relatively low.
- 55 % of the total consumption of heat is generated in central plants, of which more than 2/3 in combined cycles together with electricity and almost 1/3 only on heat-generation basis.
- Approximately 12 TWh of electricity and approximately 156 PJ of heat is generated in combined cycle, which represents approximately 15 % of the total electricity generation and approximately 39 % of total heat generation.
- Dominating cogeneration technologies in the Czech Republic are extraction steam turbines and back-pressure steam turbines. The share of combined cycle gas turbines is low; the share of gas engines is almost negligible.
- The state energy concept foresees an increase in the use of biomass in central sources of heat, nuclear energy in power plants, and natural gas for local decentralized heating. The consumption of Czech-produced coal is supposed to continue decreasing, although it will still be the most important fuel use in our energy sector.
- It is estimated that on long-term basis, there is will be stable demand for district heating (CZT), gradual increase of demand for electricity, and relatively most rapid increase of demand for heat from decentralized sources.
- Technologies for combustion of several types of fuel with flexible energy production will be preferred in large central sources; piston engines with internal combustion will be preferred in medium-size sources; modern micro-cogeneration technologies will be preferred in small local sources.

5. TECHNICAL POTENTIAL FOR THE DEVELOPMENT OF COGENERATION IN THE CZECH REPUBLIC

5.1 Methodology of Determination of the Technical Potential of Cogeneration

Directive No. 2004/8/EC speaks about the support for cogeneration based on **demand for useful heat and cooling** in the internal energy market, which is a key basis of the methodology for determining the technical potential of cogeneration. Directive No. 2004/8/EC also mentions that the potential of cogeneration should be divided into two groups: modernization of the existing capacities and construction of new capacities.

In addition to the development of the demand for heating and cooling, the technical potential will also be influenced by the development, or a change of the structure of the primary energy sources used, degree of centralization or decentralization of heat supplies, cogeneration technologies used, etc.

With respect to the above, the technical potential will be calculated for six characteristic groups of sources, namely:

- Modernization of the existing capacities of large power plants using coal and biomass
- Construction of new capacities of large power plants using gaseous and liquid fuels
- Construction of new capacities of medium-size power plants using natural gas
- Construction of new capacities of medium-size power plants burning biomass
- Construction of new capacities of small power plants using gaseous and liquid fuels
- Construction and reconstruction of capacities in other cogeneration sources

It makes no sense to consider modernization of the existing cogeneration capacities based on natural gas in large, medium-size and small power plants because these are usually not older than 10 years, and in the next 15 years of operation their modernization will not be necessary due to their still low utilization.

Construction of new cogeneration capacities in large and medium-size power plants burning coal is practically also not considered because the implementation of new heating plants using coal and more extensive CZT systems under the current circumstances is unlikely.

Start of the massive use of new types of fuel (e.g., oil products, hydrogen, etc.) is unlikely in the timeframe until 2020.

All the calculations will be based on the situation in the period 2003 - 2005 (base line) and will be made for the periods of 2010, 2015 and 2020.

The initial balances of needs (of generation) of heat for the individual groups in question are shown in table No. 5.1.1.

Table No. 5.1.1 Initial balances of heat generation in the individual groups in question

Basic group	Parameter	Units	2005	2010	2015	2020
Modernization of the existing capacities of large power plants using coal and biomass	Heat in fuel	PJ per year	168.2	169.0	167.2	166.0
	Efficiency	%	84.0	84.8	85.2	85.5
	Heat generation	PJ per year	141.3	143.3	142.5	141.9
Construction of new capacities of large power plants using gaseous and liquid fuels	Heat in fuel	PJ per year	53.4	43.5	40.2	38.5
	Efficiency	%	90.0	90.5	90.8	90.9
	Heat generation	PJ per year	48.0	39.3	36.5	35.0
Construction of new capacities of medium-size power plants using natural gas	Heat in fuel	PJ per year	43.7	35.6	32.9	31.5
	Efficiency	%	89.0	89.6	89.9	90.2
	Heat generation	PJ per year	38.8	31.9	29.5	28.4
Construction of new capacities of medium-size power plants burning biomass	Heat in fuel	PJ per year	8.8	24.0	30.8	36.0
	Efficiency	%	81.0	83.0	83.2	84.0
	Heat generation	PJ per year	7.1	19.9	25.6	30.2
Construction of new capacities of small power plants using gaseous and liquid fuel	Heat in fuel	PJ per year	106.0	117.0	133.0	143.0
	Efficiency	%	88.0	89.7	90.2	91.0
	Heat generation	PJ per year	93.3	104.9	120.0	130.1
Construction and reconstruction of capacities in other cogeneration sources	Heat in fuel	PJ per year	4.7	6.5	9.5	10.4
	Efficiency	%	85.0	87.0	87.5	88.0
	Heat generation	PJ per year	4.0	5.7	8.3	9.2
Total modernization and construction of all types of cogeneration power plants	**Heat in fuel**	**PJ per**	**384.7**	**395.5**	**413.5**	**425.4**
	Efficiency	**%**	**86.4**	**87.2**	**87.6**	**88.1**
	Heat	**PJ per**	**332.6**	**345.0**	**362.3**	**374.9**
Total of other power plants generating only heat	Heat in fuel	PJ per year	100.3	114.5	118.5	122.6
	Efficiency	%	75.5	78.7	80.0	81.0
	Heat generation	PJ per year	75.7	90.1	94.8	99.3

The category "Modernization of the existing capacities of large power plants using coal and biomass" includes power plants with heat extraction, coal-fired heating plants and large district heating plants which will use coal after modernization and increasingly also biomass, in the form of co-combustion, parallel or even separate combustion.

The category "Construction of new capacities of large power plants using gaseous and liquid fuels" includes combined cycle gas turbine facilities with heating applications and large steam heating plants using natural gas or oil.

The category of other cogeneration power plants includes heat extraction from nuclear power plants, small gasification biomass units with gas engines, etc.

The category "Other power plants generating only heat" includes local heating based on solid fuels (coal and wood), where the installation of cogeneration sources is out of question; it includes also local electrical heating.

5.2 Calculation of the Technical Potential of Cogeneration

Technical potential of cogeneration is calculated separately for each of the above-mentioned categories, but it uses a uniform procedure. This calculation procedure is based on:

- Demand for useful heat corresponding to the respective category and fuel
- Increase in demand for useful heat by the demand for heat for the purpose of generating cooling
- Annual heating plant module (ratio between heat from cogeneration and total heat)
- Characteristic target value of the proportion of electricity generation and the heat supplied
- Coefficient of other operating effects (outage rate, scheduled shutdowns, etc.)
- Time of utilization of the maximum (to determine the maximum achievable outputs)
- Output reserve coefficient (to determine installed capacities)

Demand for useful heat is shown for each of the categories in question in the previous table No. 5.1.1.

Increase in demand for useful heat by the demand for heat for the purpose of generating cooling is determined by the multiplication coefficient which determines the likely increase in total demand for heat for the purpose of generating cooling in absorption cooling units in the summer period.

Annual heating plant module also represents a multiplication coefficient which determines the ratio between the heat generated in cogeneration facilities (supplied from back-pressure or extraction turbines) and the heat generated in the power plant in total (in cogeneration + heating plant boilers + heat via reductions).

Characteristic target value of cogeneration represents the ratio of the generated electricity and the useful heat generated in a cogeneration source. This number corresponds with the type of technology and its operation mode; it is actually a conversion coefficient between the volume of heat and electricity generated in cogeneration cycle.

Coefficient of other effects – This is a multiplication coefficient which takes into account accidental (failure), regular (inspection), scheduled (overhaul) or other shutdowns of boilers or turbine generator units, i.e., the time during which cogeneration sources cannot be operated for technical reasons.

Period of peak use – the time during which the facility would have to be operated at nominal output in order to generate the same amount of energy as it generates in normal operation in one year. These values are in indirect proportion (although far from linear) to the annual heating plant module and in direct proportion (again non-linear) to the total number of operating hours of the facility in question.

Output reserve coefficient characterizes the normal output reserves (stand-by or pre-investments), degree of overrating of cogeneration power plants or the share of installed capacities that are not operated for technical, sales or economic reasons.

5.3 Results of the Calculation of the Technical Potential of Cogeneration

Specific values of the coefficients of the increase of the demand for heat for the purpose of cooling, annual heating plant modules, characteristic target value of cogeneration, and other coefficients used for the calculations have been selected according to the actual values achieved in the individual types of sources in real life or, if applicable, according to the latest and expected development trends.

Comparison of the existing level of electricity generation in the individual categories of cogeneration power plants with the technical potential calculated as of 2020 is shown numerically in table No. 5.3.1 and graphically on figure No. 5.3.1.

Table No. 5.3.1 Technical potential of electricity generation until 2020 in the categories of cogeneration power plants

Technical potential of cogeneration Summary of results by source categories	**Units**	**Large plants using coal and biomass**	**New large plants using gas and oil**	**Medium-size plants using natural gas**	**Medium-size plants using biomass**	**Small plants using gas and oil**	**Other cogeneration plants**	**Total cogeneration sources**
Actual level as of 2005	GWh	10688	867	153	0	66	15	11788
Potential of increase until 2020	GWh	2659	-70	5878	833	26106	673	36080
Technical potential as of 2020	GWh	13347	797	6031	833	26172	688	47868

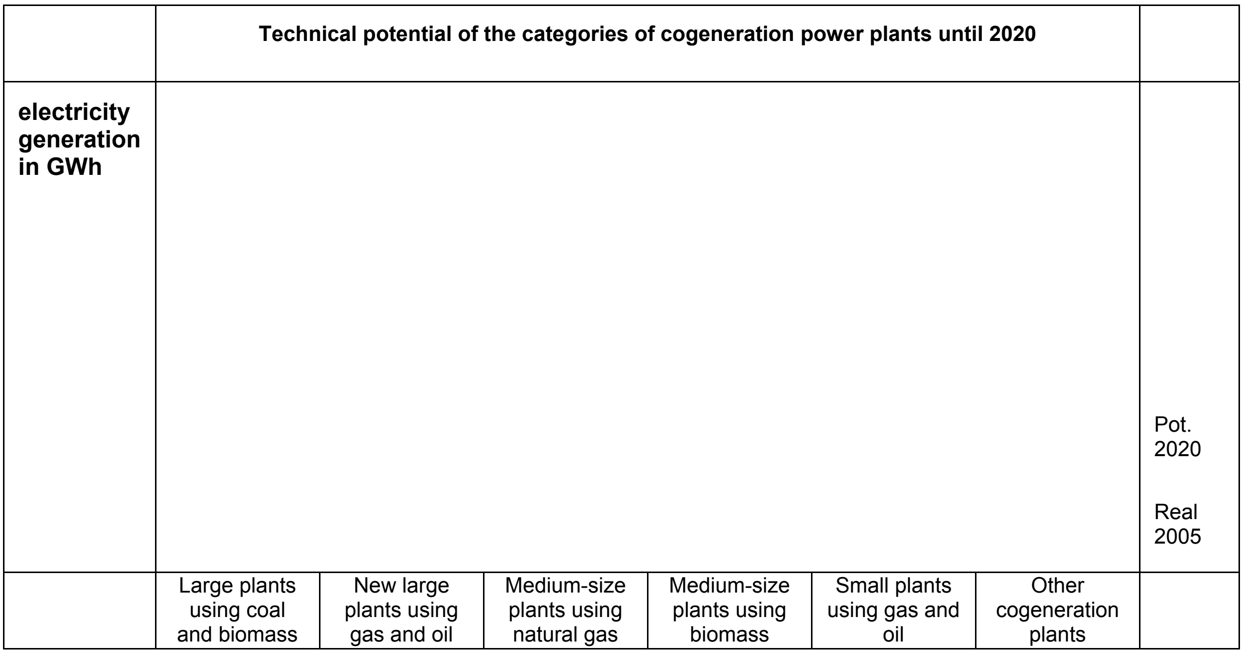

Figure No. 5.3.1 Technical potential of the categories of cogeneration power plants until 2020

As the above-information implies, the highest technical potential of cogeneration power plants lies in small power plants using gaseous and liquid fuels (instead of household and building boilers), and in medium-size power plants using natural gas (in building block gas boiler rooms). A relatively significant potential lies also in large power plants burning coal and biomass or, more specifically, in reconstruction of these power plants.

We find a minimum technical potential of growth of electricity generation until 2020 in medium-size power plants burning biomass and in other cogeneration plants; zero potential is found in large power plants using natural gas.

Development of the total technical potential of electricity generation in cogeneration power plants in the period 2005 through 2020, divided into the existing sources, reconstructed sources and new sources is summarized numerically in table No. 5.3.2; graphic representation of selected values is shown on figure No. 5.3.2.

Table No. 5.3.2 Development of the technical potential of electricity generation in cogeneration power plants

Total technical potential of cogeneration	**Units**	**2005**	**2010**	**2015**	**2020**
Total electricity generation in cogeneration	**GWh**	**33767**	**37237**	**42535**	**47868**
Installed capacity of cogeneration power plants	**MWe**	**21726**	**23865**	**27266**	**30634**
of which in the existing facilities	GWh	11788	10661	9053	6927
	MWe	5273	4947	4342	3643
of which in reconstructed facilities	**GWh**	**0**	**1879**	**4239**	**7469**
	MWe	**0**	**586**	**1435**	**2533**
of which in new facilities	**GWh**	**21978**	**24696**	**29242**	**33472**
	MWe	**16453**	**18331**	**21489**	**24458**
Reference value (actual situation in 2005)	GWh	11788	11788	11788	11788
	MWe	5273	5273	5273	5273
Technical potential of growth	**GWh**	**21978**	**25448**	**30746**	**36080**
	MWe	**16453**	**18591**	**21992**	**25361**

Growth of the technical potential of electricity generation in cogeneration power plants

Electricity generation in cogeneration power plants in GWh

2005 **2010** **2015** **2020**

existing facilities | reconstructed facilities | new facilities

Figure No. 5.3.2 Growth of the technical potential of electricity generation in cogeneration power plants

Technical potential of growth characterizes by how much it would be possible theoretically (not practically - economically) to increase the total electricity generation in cogeneration power plants if these were immediately installed wherever there is a need for useful heat.

6. ECONOMIC POTENTIAL FOR THE DEVELOPMENT OF COGENERATION IN THE CZECH REPUBLIC

6.1 Methodology of the Calculation of the Economic Potential of Cogeneration

Economic potential for the modernization and construction of cogeneration power plants will be based on the technical potential (see the results presented in chapter 5.3) and it will be affected in particular by:

- Economic conditions for the application of cogeneration power plants represented by the "Coefficient of economic effectiveness of implementation".
- Non-economic criteria of installation of cogeneration power plants represented by the "Coefficient of non-economic feasibility".
- Criteria of accruing factors of the construction of cogeneration power plants represented by the "Coefficient of accruing factors".

Economic conditions for the application of cogeneration power plants or the particular calculations of the **Coefficients of economic effectiveness of implementation** are based on the evaluation of economic effectiveness of the operation of cogeneration power plants. These evaluations were made separately for each category of sources.

The basic calculation input information was the specific investment costs, specific prices of fuels, heat and electricity (see the information in chapter 4.6), and in addition to specific other operating costs the calculation algorithms work also with a number of technical parameters such as the time of use of the installed capacity (see the technical potential), the characteristic target value of the proportion of electricity and heat generation (see the technical potential), coefficients of own consumption of heat and electricity, etc.

The result of the type calculations for the model cases always of one installed kWe in a cogeneration source within the respective category will be determination of the total annual revenues and total annual costs, or, as the case may be, difference between these two items. This difference should determine whether the operation (taking into account also the capital component of the costs) will be profitable (when the difference between revenues - costs is positive), or loss-making (when the difference is negative).

If the difference "total revenues – total costs" is positive it can be assumed that the respective types (characteristic categories) of cogeneration power plants will be attractive for investors and the investors will invest in the construction thereof; on the other hand, if the difference "total revenues – total costs" is negative these types will not be attractive for investors, and the investment funds will probably be used otherwise.

The criterion of "either, or" based on the results of the calculation of total revenues and total costs, however, must be "loosened" a little, mainly because the calculations were made for "average" conditions and for "average prices" within each category of cogeneration power plants, which means that some particular implementations may have conditions that are significantly better than "average" and, on the other hand, some implementations may have worse conditions.

For the above-mentioned reasons, also the so-called "limit price of electricity" will be quantified when evaluating the economic effectiveness of the operation of the different categories of cogeneration power plants; it is a price at which there was zero difference between total revenues and total costs. The ratio between the average purchase price of electricity (used in the original evaluation) and the additionally calculated limit price of electricity becomes the main factor for determination of the Coefficient of economic effectiveness of implementation – "Ke".

If the ratio between the purchase price of electricity and the limit (calculated) price is less than 0.75, the estimated value of "Ke" will always be 0.05 (in such source it will be possible to implement, e.g., only a cogeneration source up to the level of own consumption of electricity).

If the ratio between the purchase price of electricity and the limit price is greater than 1.10, the estimated value of "Ke" will always be 1.0 (in such source it will be possible to implement cogeneration at any rate).

Non-economic criteria of the installation of cogeneration power plants or, as the case may be, calculations of the **"Coefficients of non-economic feasibility"** are based on subjective evaluation of the willingness and capabilities of individual investors to install cogeneration systems in their plants.

The first prerequisite of the implementation of any new project in every industry is the effort to find modern solutions, to gain independence, to help protect the environment, etc. Such partial criterion is called "Criterion of the desire for independence and modern technology".

The second prerequisite of the project implementation will be the investor's willingness to bear the business risk in terms of indebtedness, future uncertainties in price relations, possibilities of accidents and failures, etc. Such partial criterion will therefore be called "Criterion of the willingness to bear business risk".

The third prerequisite is space and structural preparedness for the installation of cogeneration power plants, i.e., so that the installation of a new additional unit would not require process-intensive purchase or long-term lease of new areas, land, or construction of new buildings. Such partial criterion will be called "Criterion of structural and technical preparedness".

One of the very important conditions for the installation of cogeneration power plants is management of the process of the administrative (building) permit, approval and occupancy permit of new facilities. This partial criterion will be called "Criterion of administrative process intensity".

Finally, one of the last aspects, which will certainly affect the decisions of some investors, is the aspect of operational intensity, not only in terms of the necessary actions in the operation of the facility but also in terms of the authorization to carry out these actions. This last criterion will be called "Criterion of service and operational intensity".

To evaluate the effects of the individual partial criteria within the respective categories of sources we will use the rating: complies “YES", “NO”, or “YES/NO”. Should the respective category of cogeneration power plants receive the “YES” rating in any of the five above-mentioned partial criteria, the value included in the resulting coefficient of non-economic feasibility, “Km”, will be “0.2”; should it receive the “YES/NO” rating the value included will be “0.1”; should it receive the “NO” rating the respective category of sources will get the value “0” included in “Km”. “Km” can therefore take the value ranging from 0.0 (in the event that the rating of the respective category of cogeneration power plants in all five criteria is negative, i.e., “NO”) up to 1.0 (in the event that the rating of the respective category of cogeneration power plants in all five criteria is positive, i.e., “YES”).

The criterion of accruing factors of the construction of cogeneration power plants or, more specifically, the resulting **“Coefficient of accruing factors”** attempts to cover the simple fact that not all investors will decide to build a new plant in one year or just in the following decade and that the time from the decision on implementation to commissioning will vary.

In this respect it will probably be most realistic to build on the average twenty-year life cycle of new energy facilities (in large plants this is of course more, in small plants it is less), i.e., from the moment of “now”, 25 % of all new opportunities will be used in 5 years, 50 % of all new opportunities will be used in 10 years, 75 % of all new opportunities will be used in 15 years, and finally 100 % of all new opportunities will be used in 20 years.

A somewhat different situation is in the case of reconstruction of the existing capacities (category of large power plants using coal and biomass) where the installation of a new cogeneration source usually takes place in the year of shutdown of the original source, which is already taken into account in the quantification of the technical potential. For this reason, it will be assumed that in terms of time, 100 % of replacements (reconstruction) of the original sources will take place in each relevant year.

The above-mentioned percentage values will define the resulting coefficients of accruing factors, “Kt”, which will range between “0” to “1” according to the timeframes and categories of cogeneration power plants.

Economic potential for each relevant year and for each category of cogeneration power plants shall be calculated as follows:

$$\mathbf{EP = TP * Ke * Km * Kt}$$

Where: EP - economic potential

TP - technical potential

Ke - coefficient of economic effectiveness of implementation

Km - coefficient of non-economic feasibility

Kt - coefficient of accruing factors

6.2 Resulting Values of the Multiplication Coefficients

Comparison of the resulting **coefficients of economic effectiveness of implementation, "Ke"** for the individual categories of cogeneration power plants in question is shown in table No. 6.2.1.

Table No. 6.2.1 Comparison of the resulting coefficients of economic effectiveness of implementation

Coefficients of economic effectiveness of implementation Ke	**Units**	**Large plants using coal and biomass**	**New large plants using gas and oil**	**Medium-size plants using natural gas**	**Medium-size plants using biomass**	**Small plants using gas and oil**	**Other cogeneration plants**
Coefficient **Ke** for the year 2005	-	0.90	0.05	0.05	0.55	0.05	0.05
Coefficient **Ke** for the year 2010	-	0.90	0.05	0.10	0.80	0.10	0.10
Coefficient **Ke** for the year 2015	-	0.90	0.05	0.35	1.00	0.20	0.50
Coefficient **Ke** for the year 2020	-	0.90	0.05	0.55	1.00	0.35	0.80

The resulting ratings of the different categories of power plants according to non-economic criteria and the corresponding **coefficients of non-economic feasibility, "Km"** are shown in table No. 6.2.2.

Table No. 6.2.2 Results of rating according to non-economic criteria

Compliance with non-economic criteria and the amount of the coefficient of non-economic feasibility Km	**Large plants using coal and biomass**	**New large plants using gas and oil**	**Medium-size plants using natural gas**	**Medium-size plants using biomass**	**Small plants using gas and oil**	**Other cogeneration plants**
Desire for independence and modern technology	**YES**	**YES**	YES	**YES**	YES/NE	YES
Willingness to bear business risk	**YES**	**YES**	YES/NE	**YES**	NE	YES/NE
Structural and technical preparedness	**YES**	**YES**	YES/NE	**YES**	YES/NE	YES/NE
Administrative process intensity	**YES**	**YES**	YES/NE	**YES**	NE	YES
Service and operational intensity	**YES**	**YES**	YES/NE	**YES**	NE	YES
Coefficients of non-economic feasibility **Km**	1.0	1.0	0.6	1.0	0.2	0.8

The resulting values of the **coefficients of accruing factors, "Kt"** are shown in table No. 6.2.3.

Table No. 6.2.3 Resulting values of the coefficients of accruing factors

Coefficient of accruing factors Kt	**Large plants using coal and biomass**	**New large plants using gas and oil**	**Medium-size plants using natural gas**	**Medium-size plants using biomass**	**Small plants using gas and oil**	**Other cogeneration plants**
Kt for the year 2005	1.0	0.0	0.0	0.0	0.0	0.00
Kt for the year 2010	1.0	0.25	0.25	0.25	0.25	0.25
Kt for the year 2015	1.0	0.50	0.50	0.50	0.50	0.50
Kt for the year 2020	1.0	0.75	0.75	0.75	0.75	0.75

6.3 Results of the Calculations of the Economic Potential of Cogeneration

Comparison of the current level of electricity generation in the different categories of cogeneration power plants with economic potential of generation in these categories as of 2020 is shown numerically in table No. 6.3.1 and graphically on figure No. 6.3.1

Table No. 6.3.1 Economic potential of electricity generation until 2020 in the categories of cogeneration power plants

Economic potential cogeneration Summary of results by source categories	Units	Large plants using coal and biomass	New large plants using gas and oil	Medium-size plants using natural gas	Medium-size plants using biomass	Small plants using gas and oil	Other cogeneration plants	Total cogeneration sources
Actual level as of 2005	GWh	10688	867	153	0	66	15	11788
Potential of increase until 2020	GWh	1912	-70	1464	625	1376	323	5630
Economic potential as of 2020	GWh	12600	797	1617	625	1442	338	17419

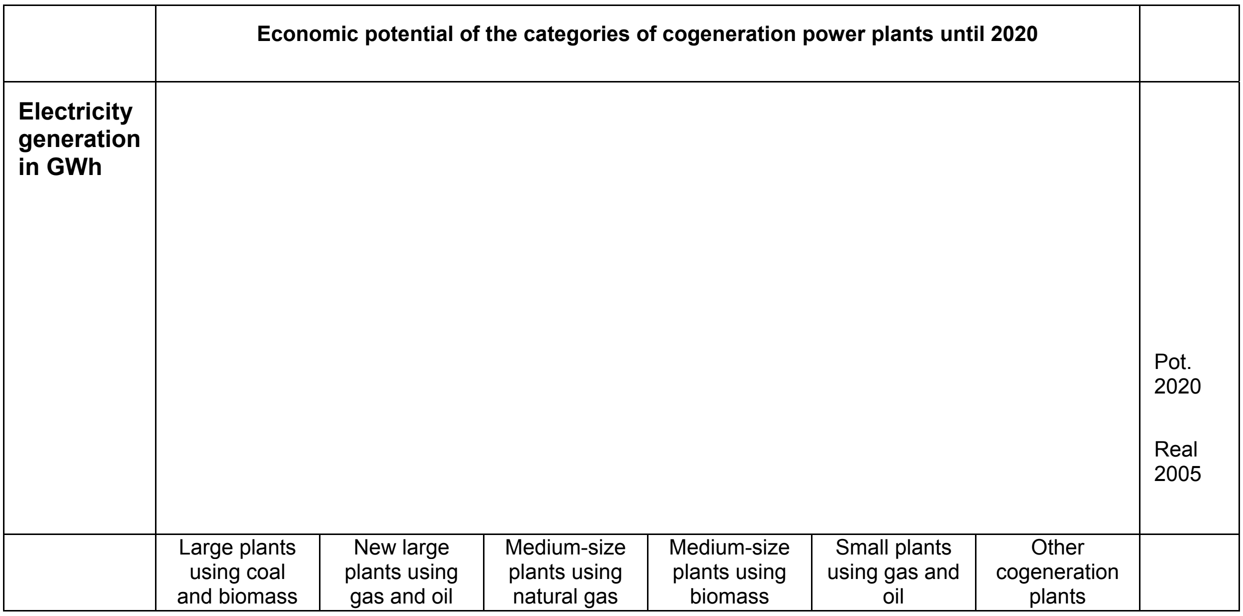

Figure No. 6.3.1 Economic potential of the categories of cogeneration power plants until 2020

As the information shown in table No. 6.3.1 and on figure No. 6.3.1, the highest economic potential of cogeneration power plants lies in reconstructions of large cogeneration power plants using coal and biomass, and also in medium-size and small power plants using natural gas. A certain although not so significant economic potential lies in medium-size power plants using biomass and other cogeneration power plants; zero economic potential is in large power plants using natural gas and heating oil.

Development of the total economic potential of electricity generation in cogeneration power plants in the period from 2005 to 2020, divided into the existing sources, reconstructed sources and new sources is summarized numerically in table No. 6.3.2, graphic representation of selected values is shown on figure No. 6.3.2.

Table No. 6.3.2 Development of the economic potential of electricity generation in cogeneration power plants

Total economic potential of cogeneration	**Units**	**2005**	**2010**	**2015**	**2020**
Total electricity generation in cogeneration	**GWh**	**11788**	**12636**	**14365**	**17419**
Installed capacity of cogeneration power	**MWe**	**5273**	**5635**	**6473**	**8110**
of which in the existing facilities	GWh	11788	10661	9053	6927
	MWe	5273	4947	4342	3643
of which in reconstructed facilities	**GWh**	**0**	**1691**	**3815**	**6722**
	MWe	**0**	**527**	**1291**	**2280**
of which in new facilities	**GWh**	**0**	**283**	**1496**	**3770**
	MWe	**0**	**160**	**840**	**2188**
Reference value (actual situation in 2005)	GWh	11788	11788	11788	11788
	MWe	5273	5273	5273	5273
Economic potential of growth	**GWh**	**0**	**847**	**2576**	**5630**
	MWe	**0**	**361**	**1200**	**2837**

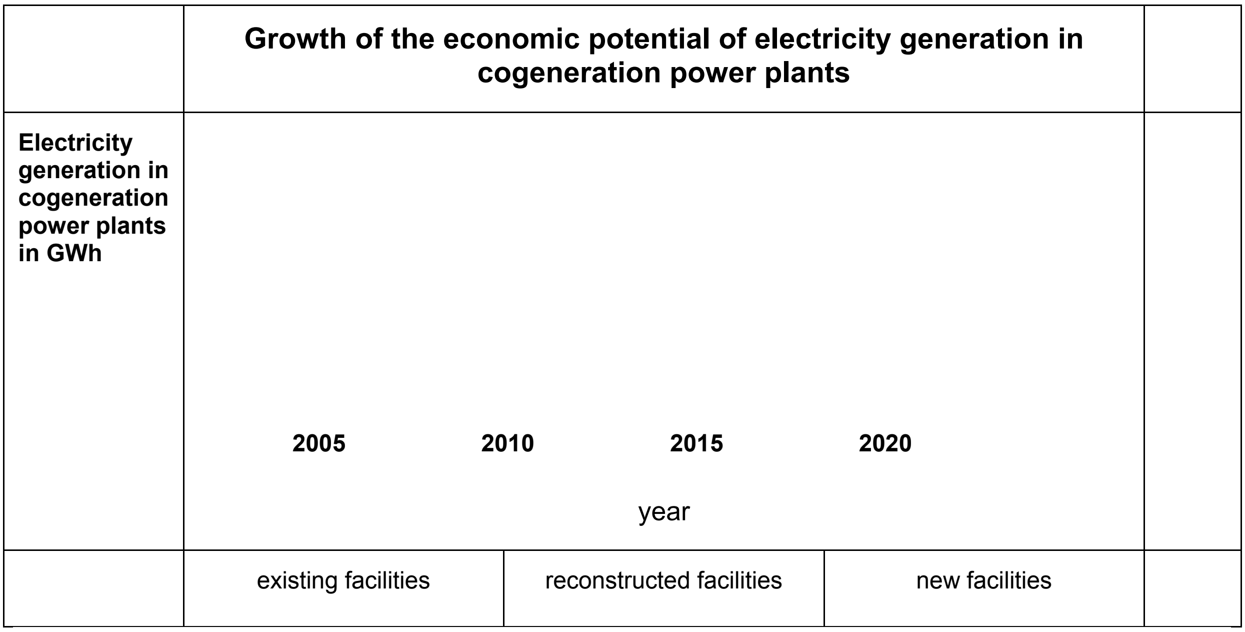

Figure No. 6.3.2 Growth of the technical potential of electricity generation in cogeneration power plants

6.4 Overall Evaluation of the Economic Potential of Cogeneration

Economic (actual) potential represents partial use of the technical (theoretical) potential, as shown in table No. 6.4.1 and on figure No. 6.4.1.

Table No. 6.4.1 Technical and economic potential of electricity generation until 2020

Economic and technical potential cogeneration - Summary of results by source categories	**Units**	**Large plants using coal and biomass**	**New large plants using gas and oil**	**Medium-size plants using natural gas**	**Medium-size plants using biomass**	**Small plants using gas and oil**	**Other cogeneration plants**	**Total cogeneration sources**
Actual level as of 2005	GWh	10688	867	153	**0**	66	**15**	11788
Economic potential of increase until 2020	GWh	1912	**-70**	1464	625	1376	323	5630
Economic potential as of 2020	GWh	12600	797	1617	625	1442	338	17419
Technical potential of increase until 2020	GWh	2659	**-70**	5878	833	26106	673	36080
Technical potential as of 2020	GWh	13347	797	6031	833	26172	688	47868

Total potential of the categories of cogeneration power plants until 2020

Electricity generation in GWh

Tech. pot. 2020

Econ. pot. 2020

Real 2005

Large plants using coal and biomass | New large plants using gas and oil | Medium-size plants using natural gas | Medium-size plants using biomass | Small plants using gas and oil | Other cogeneration plants

Figure No. 6.4.1 Comparison of the current reality, technical and economic potential of cogeneration

It is apparent, based on the above-mentioned information, that the technical potential will be mostly used in the reconstructions of large power plants burning coal and biomass where the following technologies will be applied:

- Condensation extraction steam turbines
- Back-pressure steam turbines

A comparable economic potential of cogeneration is in medium-size and small power plants burning gaseous fuel, although it is a relatively small percentage of utilization of the technical potential. The following technologies will be applied in these power plants:

- Combustion piston engines over 100 kWe (in larger and medium-size power plants)
- Combustion piston engines up to 100 kWe (in small and medium-size power plants)
- Stirling engines and micro-turbines (in small power plants)

A relatively low economic potential, in terms of the absolute volumes of electricity generation, is in medium-size power plants using biomass and in other cogeneration power plants (although here the technical potential is used to a relatively high degree). The following technologies will be applied in these power plants:

- Steam engines (reduction piston or rotation engines)
- Organic Rankine Cycles
- Fuel cells

Zero economic potential is represented by large power plants burning natural gas and heating oil (CCGT and steam turbines with boilers burning noble fuels).

The total increase of electricity generation in cogeneration from the current approximately 11.8 TWh (in 2005) to the future 17.4 TWh (in 2020) will be achieved thanks to three comparably significant phenomena. These phenomena are total increase of demand for useful heat, application of more modern technologies in the reconstructed plants, and installation of new systems in small and medium-size heating plants.

Comparison of the current and future use of the opportunities of electricity generation in cogeneration systems is shown on figure No. 6.4.2.

<table>
<tr><th colspan="3">Use of the potential of reconstruction and construction of new capacities as of 2005</th><th colspan="3">Use of the potential of reconstruction and construction of new capacities as of 2020

Existing generation in cogeneration plants 14 %</th></tr>
<tr><td>Unusable potential 65 %</td><td></td><td>Existing generation in cogeneration plants 35 %</td><td>Unusable potential 62 %</td><td>Generation in new cogeneration plants 10 %</td><td>Generation in modernized cogeneration plants 14 %</td></tr>
</table>

Figure No. 6.4.2 Use of the potential of cogeneration power plants in the period 2005 and 2020

7. BARRIERS, RISKS, UNCERTAINTIES AND OPPORTUNITIES

7. 1 Fuel Availability

One of the conditions for the development of generation of heat and electricity in combined cycle in the Czech Republic is availability of the fuels used for this purpose. In future we expect further development of the use of natural gas; the share of renewable energy sources, in our conditions of biomass, should increase rapidly; consumption of coal should gradually decrease.

The factor decisive for the investors' decisions on the construction of new energy sources using coal will be whether the relatively cheap coal of certain quality is available only for a limited period of time.

Imported **noble fuels** include oil products (heating oil) and natural gas. While no major use of heating oil in the energy sector in the Czech Republic is envisaged, the situation of natural gas is quite opposite.

Vast majority of natural gas consumed in the Czech Republic is covered by imports, mainly from Russia and Norway. The Czech Republic currently has sufficient and modern network of gas pipelines; gas supplies are secured by long-term contracts.

Large part of **biomass** (currently mainly in wooden waste) started to be used in the Czech Republic recently for combustion in dozens of smaller heating plants and particularly for co-combustion together with coal in large power and heating plant boilers.

7. 2 Development of Technologies, Equipment and Services in the Area of Cogeneration

Further development of the technology and equipment will also contribute to the development of cogeneration systems. It will include operator-free, high-efficiency systems with modular structure, which will minimize the requirements for structural preparedness, the delivery and installation times will decrease, and repair and periodic maintenance requirements will also be reduced (see developments in a technologically similar sector (the automotive industry)). An important role will also be played by the rapid development of automation, control and communication technology. It will be possible to control the operation automatically and monitor the parameters of up to thousands of facilities (cogeneration power plants) from one location; it will be possible to operate these sources in terms of administrative, commercial and financial management (see the development in the sector of telecommunications, cable TV, etc.)

Development of technology and equipment will probably also encourage development of business in the so-called "small energy sector". There will probably be new companies specializing in energy services not only for large complexes of buildings but later also for whole areas consisting of hundreds of small operations, service providers and maybe also residential buildings. These companies will specialize either in construction and subsequent sale of energy centres (source of heat, cooling, ventilation and air-conditioning system, source of electricity), or also in the operation thereof and the sale of the final energy services.

All these phenomena will of course be accompanied by the development of financial and commercial services, starting with leasing of new systems up to commercial offers with lump-sum payments for entire "service packages" (water, electricity, heat, telecommunications, etc.).

7. 3 Economic Conditions, Charges and Taxes

Development of combined generation of electricity and heat will be influenced by the necessary amount and availability of investment resources, development of fuel and energy prices, taxes, and other charges related to the production of waste or CO_2 emission trading, if applicable.

Modernization of the existing sources and construction of new sources will represent gradual spending of significant **investment resources,** as shown numerically in table No. 7.3.1 and graphically on figure No. 7.3.1.

Table No. 7.3.1 Overview of the process of investing in cogeneration power plants

Overview of investments in the modernization of existing cogeneration power plants and construction of new cogeneration power plants	2005 - 2010 [CZK billion]	2010 - 2015 [CZK billion]	2015 - 2020 [CZK billion]	**Total 2005 -2020 [CZK billion]**
Investment in modernization	6	30	78	**114**
Investment in new construction projects	16	39	68	**123**
Total investment	**22**	**69**	**146**	**237**

Process of investing in reconstructions and constructions of cogeneration power plants

Investments in CZK million

Investment in reconstruction of cogeneration plants

Investment in the construction of new cogeneration plants

Figure No. 7.3.4 Process of investing in reconstructions and constructions of new cogeneration power plants

A specific feature is the proportion between the **prices of fuel** used for mono-generation of electricity and prices of fuel used for mono-generation of heat, or for combined generation of electricity and heat. A vast majority of condensation power plants are located in the vicinity of open-cast coal mines where the prices of coal are not burdened with transport and distribution costs, or they use the relatively inexpensive nuclear fuel.

This situation implies an obvious disadvantage for cogeneration power plants – relatively smaller coal customers scattered throughout the Czech Republic with higher demands for the quality of coal – who burn a fuel that is up to two times more expensive – also Czech-produced coal, after having taken into account the transport costs.

The result of this situation is relatively lower price of power electricity and relatively higher price of system services for the power grid, which can be offered and provided – due to technical reasons – only by a small group of the largest cogeneration power plants.

Prices of natural gas are related to prices of oil products in global markets. The risk for cogeneration may lie in rapid fluctuations of crude oil price.

The current advantage for cogeneration is the reduced **VAT rate** for heat. This reduced rate supports the purchase of heat from centralized sources.

Other factors, which may have positive or negative impact on the development of cogeneration, are the **consumer taxes,** the introduction of which is expected. The costs of energy generation include of course also the **charges for emissions** of pollutants to the atmosphere and, if applicable, the costs of the purchase or revenues from the sale of **CO_2 emission allowances.**

The dramatic increase of charges for some types of emissions or, as the case may be, charges for waste depositing or disposal may influence the proportion between the costs of producers of energy generated by cogeneration technologies and the costs of mono-producers of the individual types of energy. The impact of the CO_2 emission allowance trading, consumer taxes or environmental taxes may be positive or negative on the development of cogeneration.

7.4 Legislative Support

An amendment of Act No. 458/2000 Sb. (Collection of Laws), on business conditions and public administration in energy sectors and on amendment of other laws **(the Energy Act)** came into force in the beginning of 2005. The principles of EU Directive 2004/8/EC on the support for cogeneration are implemented in this amendment.

A change could result only from the implementation of **new directives of the** EU, if any, i.e., in particular adoption of the action plan for the support for the use of biomass and adoption of a directive on the support for heat generation from renewable resources.

Amendment (extension) of the existing act on the support for the use of renewable energy sources for electricity generation and on the support for the use of renewable energy sources for heat generation, together with the adoption of the action plan for the support for the use of biomass, would probably result in an increase of the share of cogeneration based on biomass in the Czech Republic.

7. 5 Summary of the Main Barriers, Risks, Uncertainties and Opportunities of the Development of Cogeneration

Availability and utilization of fuels

- An advantage is the availability of Czech resources.
- Imported noble fuels – natural gas and heating oil – the risks are posed by the unstable countries of origin.
- Biomass – still non-stabilized market – future need of artificially grown energy crops – availability risk.
- Some uncertainty lies in the prediction of the development of the fuel prices.

Development of technologies, equipment and services

- Availability of modern technologies in the market (including domestic producers) – quality distribution and service network.
- Good business environment for the establishment of companies such as ESCO – risk of excessive monopolization of the energy market.

Economic conditions, charges and taxes

- The necessary investment volumes correspond with the capacities of investors and capital resources, but they may be influenced by the price development in the area of inputs.
- Electricity prices determined by one dominant producer – there is a system of contributions toward the prices of electricity from cogeneration.
- Development of VAT, results of the CO_2 emission trading, amount of air pollution charges, effect of the energy consumer taxes, environmental taxes, etc. – risk posed by the poorly set up systems.
- All the economic support, however, is borne by the final consumers.

Legislative support

- The principles of the EU Directive 2004/8/EC on support for cogeneration are already implemented in the Czech legislation, although the interpretation of the directive is not completely unambiguous.
- There is an act on support for electricity generation from renewable energy sources – it prefers the use of biomass for electricity generation; there is a risk of shortage of biomass for heat generation and for combined generation of both products.

8. NATIONAL STRATEGY OF DEVELOPMENT OF COGENERATION

8.1 Current Situation

The current situation in the Czech Republic is quite good in the area of the opportunities of use and development of cogeneration. It can be characterized by the following attributes:

- There is a long tradition of cogeneration power plants and centralized heat supplies in the Czech Republic. In particular the application of condensation extraction steam turbines and back-pressure steam turbines has been supported and developed also during the central planning period.
- Modern technologies are available, there is a functioning network of financial services, there is sufficient operational experience and know-how for the preparation and implementation of new cogeneration projects.
- Support for cogeneration is provided in Act No. 458/2000 Sb. (Collection of Laws) (amendment No. 670/2004 Sb. (Collection of Laws)) on business conditions and public administration in energy sectors and on amendment of other laws (the Energy Act). This act also implements Directive 2004/8/EC.
- Support for cogeneration is provided in Act No. 406/2000 Sb. (Collection of Laws) on energy management or, more specifically, in its amendment which is under preparation.
- Support for cogeneration is stated in the State Energy Concept as well as in the State Environmental Policy.
- There is a law-regulated procedure for the process of issuing the certificate of origin of electricity from cogeneration and stipulated method of determination of the amount of electricity from combined generation of electricity and heat – Decree of the Ministry of Industry and Trade of the Czech Republic No. 439/2005 Sb. (Collection of Laws).
- There is a system of support of purchase of electricity from cogeneration in the form of contributions to the market prices of electricity (price decisions of ERO) in place.
- Projects of investment support for cogeneration are present in the grant programmes of ČEA and SFŽP, although only to a limited extent.

The list of the above-mentioned facts is a good basis for the operation of power plants using cogeneration technologies. Future development and achievement of the set objectives determined by the economic potential, however, will require a number of additional measures, of which we mention the most important ones.

8.2 Important Measures

To fulfil the economic potential of cogeneration it is necessary to seek, as a priority:

- At least preservation or, as the case may be, expansion, intensification and refinement of the system of support of purchase of electricity from cogeneration in the form of surcharges or guaranteed prices.
- Increase of the contributions for cogeneration and utilization of the EA (Early Action) reserve for increased generation electricity in cogeneration systems (with the connection of small and medium-size power plants to the central source) within the preparation of the national allocation plan of CO_2 emission allowances.
- Reflect the benefits of cogeneration in the harmonization (environmentalisation) of the tax system of the Czech Republic with Directive No. 2003/96/ES on taxes from energy products and electricity.
- Extension of the application of Act No. 72/2000 Sb. (Collection of Laws) and its amendment No. 453/2001 Sb. (Collection of Laws) on investment incentives also to cogeneration projects.
- Preparation of projects and obtaining support for cogeneration projects from foreign sources, particularly from EU structural funds.

9. GUARANTEE OF ORIGIN OF ELECTRICITY FROM COGENERATION

Section 32, subsection 7 of Act No. 458/2000 Sb. (Collection of Laws), on business conditions and public administration in energy sectors and on amendment of other laws (the Energy Act), as amended, states that the certificate of origin of electricity from cogeneration is issued by the Ministry of Industry and Trade based on an application, the contents of which are specified in the Act. An example of the application for the certificate is provided in Decree No. 939/2005 Sb. (Collection of Laws), which stipulates the details of determination of the amount of electricity from combined generation of heat and electricity and determination of the amount of electricity from secondary energy sources. The decree also includes an example of the statement of the actual amount of electricity generated from high-efficiency combined generation of heat and electricity, which is examined by the electricity distributor authorized to pay the contribution to the price of electricity. The amount of the contribution is set by the Energy Regulatory Office by its price decisions. Supervision is provided by the State Energy Inspection within its scope of powers and responsibilities.