REPUBLIC OF BULGARIA

MINISTRY OF ECONOMY AND ENERGY

Analysis of the national potential for high-efficiency cogeneration of heat and electricity in the Republic of Bulgaria and evaluation of the progress towards implementation of Art. 6 and Art. 10 of Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market

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List of acronyms

CPP	-	Condensing power plant
NPP	-	Nuclear power plant
HPP	-	Hydropower plant
HEP	-	Heat and electricity plant
HoP	-	Heat-only plant
DHP	-	District heating plant
HSS	-	Heat supply system
CHEG	-	Combined heat and electricity generation
CAB	-	Co-owned apartment building
RES	-	Renewable energy sources
EA	-	The Energy Act
NSSI	-	National Social Security Institute
GFA	-	Gross floor area
DHW	-	Domestic hot water supply
PB/WB	-	Peak boiler/water boiler
ACM	-	Absorption chilling machine
ICE	-	Internal combustion engine
MPHAT	-	Multi-profile hospital for acute treatment
EU	-	European Union
SCEWR	-	State Commission of Energy and Water Regulation
MEE	-	Ministry of Economy and Energy
RFB	-	Regional Forestry Board
MoEW	-	Ministry of Environment and Waters
EEA	-	Energy Efficiency Agency
AEUB	-	Association for Energy Utilization of Biomass
RDF	-	Fuel of high calorific value derived from urban waste (Refuse Derived Fuel)

1. METHODOLOGY FOR ANALYSING THE EXISTING POTENTIAL TO MEET THE DEMAND FOR HEAT AND CHILLING ENERGY FOR AIR-CONDITIONING SUITABLE FOR IMPLEMENTATION OF HIGH-EFFICIENCY COGENERATION

1.1. Introduction

The present project "Analysis of the national potential for implementation of high-efficiency cogeneration of heat and electricity, and evaluation of the progress towards increasing the share of high-efficiency generation in the gross electricity consumption in the Republic of Bulgaria" has been developed on the basis of a contract between the Ministry of Economy and Energy and the Technical University.

The objective of the project is to ensure implementation of Art. 6 of Directive 2004/8/• • of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market.

The scope of the project includes:

- The energy generation in Bulgaria
- The different types of technologies used for combined generation of electrical, heating and chilling energy;
- Centralized heat supply;
- Residential and public buildings;
- Industrial enterprises;
- Renewable energy sources.

1.2. Methodology for achieving the project objective

To achieve the project objective, the project team undertook a technical and economic analysis based on well-substantiated and documented statistical, bibliographic, scientific and prognosticated data related with the sectors covered by the project and the research methodology.

Two approaches have been used to address the issues: top-down and bottom-up. The top-down approach has been used for analysing the energy production in Bulgaria, including cogeneration and its fuel base.

The bottom-up approach has been used for analysing and prognosticating the cogeneration of electricity and heat in the following sectors: centralized heat supply; residential and public buildings; industrial enterprises; renewable energy sources.

In regional aspect, an analysis has been made of the various heat and electricity cogeneration technologies from the perspective of the climatic and geographical circumstances of the various regions of Bulgaria, always in accordance with the requirements for high-efficiency generation as well as with reference to the fuel base and economic/environmental sustainability expectations.

In accordance with Directive 2004/8/• • of the European Parliament and the Council of 11 February 2004 and the MEE Ordinance on the determination of the electricity output from heat and electricity cogeneration plants, for plants with capacity greater than 1 MW_{el} the criterion for high-efficiency generation is saving of primary energy sources greater than 10% compared to separate generation. Small cogeneration plants of maximum capacity up to 1 MW_{el} and micro-cogeneration plants of maximum capacity up to 50 kW_{el}, even if their savings of primary energy are lesser than 10% compared to separate generation, can still be considered to be highly efficient.

All projects for new plants must meet the abovementioned criteria for primary energy savings, while the existing plants have been analysed to establish the extent, to which they meet these criteria. The results obtained are important for the retrofitting of existing plants.
The useful cold generation potential is seen as complementary to the useful heat potential insofar as it improves the economic efficiency of the plants by increasing their use throughout the year.Cooling in Bulgaria has a secondary role at this stage and applies only to special circumstances in certain production processes, hospitals, theatres and museums. In principle, the heat load is the determinant factor for dimensioning of cogeneration plants. The efficiency of including cold generation to the cogeneration process has been considered in some specific cases such as hospitals.

The technical potentials of the various application fields have been evaluated from methodological perspective. After identification of the consumption profiles as estimated for the period 2007-2020, the analysis went on to evaluate the economic potentials and thence to estimate primary energy savings, reductions of • •$_2$ emissions, heat and electricity cogeneration volumes and the required investments. This was followed by investment analysis and evaluation of sensitivity to the following financial parameters: prices of primary energy sources, electricity prices, investment costs and revenue from reduction of CO_2 emissions.

The technical potentials covered by the analysis have been classed as follows:

- The potential of the centralized and local heat supply sector is substantial because of the existing central and local heat supply systems. Two options for enlarging the potential of these facilities have been considered:

1. Increase heat load density levels by connecting new buildings to the existing heat distribution networks, installation of pipelines and heat substations in the yards of residential properties;
2. Modify the technological structure of the heat source with a view to:

1.1.1. switch from heat generation to high-efficiency cogeneration of heat and electricity;

1.1.2. intensify the existing cogeneration by maximising the ratio between electricity output and useful heat.

The potential of the smallest cogeneration systems in the residential sector, which have not been connected to the heat distribution network, is a function of the specific barriers in this sector. Thus for example, the low heat load density of a populated settlement can be a reason for the absence of centralized heat supply. However, this does not mean that separate buildings or groups of buildings are not suitable for construction of low-capacity cogeneration systems. In this respect, it has been analysed how competitive the cogeneration is for single buildings or groups of buildings versus direct gas supply. Where a heat/electricity cogeneration plant is found to be more efficient than direct gas supply, the potential of the residential areas with existing gas distribution networks is evaluated for the various types of buildings and is then interpolated to the whole sector with the help of suitable characteristics. The database of various building structures in Bulgaria is crucial to the evaluation of this potential. Since there are no energy plans for the populated settlements in Bulgaria, the evaluation of the potential for cogeneration of heat and electricity in residential and public buildings is of an informative nature at this stage.

A separate area of research into the low-capacity cogeneration plants is the heat supply of non-residential buildings such as small workshops, public buildings, schools, hospitals and buildings for special purposes such as museums, theatres, etc. Due to the heterogeneous structure of heat consumption and cold generation in some of these buildings, and to the incompleteness of the database, the potential has been estimated on the basis of typical examples and then interpolated to the whole sector. The examples used in this case are hospitals, because they are representative in terms of heat and cold consumption.

The existing industrial plants for cogeneration of heat and electricity have been evaluated in terms of their residual service life and energy efficiency. The results obtained are essential for the retrofitting of these installations and for evaluation of their technical and economic potential. As concerns the industrial enterprises, which do not have heat and energy cogeneration facilities and in respect of which there are not sufficient databases with information about the structure of their consumption, the description of final energy-consuming equipment needs to be analysed with reference to the particular industrial sector. A preliminary evaluation of the relevant cogeneration potential can be obtained by examining the heat and electricity requirements of typical enterprises, while taking into account the development trends of the various industrial sectors.

Heat and electricity cogeneration from renewable energy sources has been examined separately due to their preferential terms of use. This potential relates to the economic and environmental efficiency of the energy plant rather than to meeting certain demand for heat energy. The largest share of renewable energy sources belongs to biomass and therefore the analysis of the potential for heat and electricity cogeneration is focused on biomass, in particular its potential for being a primary energy source in the various regions and in the country as a whole. Consideration has been given to the economic viability of using biomass for heat and electricity cogeneration in some centralized heat supply systems. Consideration has also been given to the possible use of urban residential waste for centralized heat supply by combusting such waste in heat and electricity cogeneration plants. The technical, economic and investment analysis is based on data about Sofia's urban residential waste provided by FICHTNER – a consortium performing a feasibility study for the project "Management of the residential waste of Sofia municipality" [11].

1.3. Framework conditions

1.3.1. Reference prices of primary energy sources

The analysis of the primary energy sources in terms of mobility, ease of use, economic and environmental efficiency demonstrated that the development and retrofitting of heat and electricity cogeneration plants relates mainly to the use of natural gas and, to a lesser extent, biomass. For this reason, the price analysis relates mainly to these two types of primary energy sources.

Natural gas prices in Bulgaria during 2008 arepected to stand at BGN 400/1000m^3, and reach BGN 450/1000m^3 (w/o VAT) from 2009 onwards.

After analysis of publications on natural gas prices and their trends until 2020, it was chosen to use values based on the estimates of the National Technical University of Athens [32], Fig. 1.1. - natural gas prices and trends by 2030 in EUR per MT oil equivalent (toe). Plotted on the same chart is the 2008 price in Bulgaria, which has been converted from BGN/1000m^3 into EUR/toe using the following dependency:

1 GJ = 34 kg. conditional (comparison) fuel = 0.239 Gcal = 278 kWh = 0.0239 toe,

where the calorific value of natural gas is 8 000 kcal/m^3.

The converted values are:

BGN 400/1000m^3 = 255,7 EUR/toe

BGN 450/1000m^3 = 287,7 EUR/toe

Since the estimations of natural gas price trends by 2020 are quite controversial, for the purposes of the investment analysis it has been assumed that the expected fluctuations of natural gas prices will be in the 450 ± 30 % BGN/1000m^3 range.

Fig. 1.1. shows the values corresponding to this assumption:

287,7 ± 86.3 EUR/toe

With the prices of natural gas supplied by Bulgargaz being BGN 400/1000m^3 and BGN 450/1000m^3, the estimated final price for residential consumers will be: BGN 635/1000m^3 and accordingly BGN 685/1000m^3 (w/o VAT).

The price of timber waste is taken to be BGN 75/MT and is expected to increase by 3% per annum.

For the purposes of the investment analysis, the referential price of timber waste is taken to be BGN 75/MT - a value obtained from the heat plants fired by this type of fuel. This price can not be precisely regulated, since it is largely commercial and subject to negotiations between suppliers and buyers.

1.3.2. Referential price of electrical energy

The referential sales price of the electricity generated by heat and electricity cogeneration plants has been determined on the basis of the following factors:

- current levels of electricity prices in Bulgarian;
- increased demand for electricity in the region;
- expected increase of producers' prices during the next years of the period under examination (by 2020) due to the commissioning of newly-built generation capacities (NPP Belene, the new TPP at Maritsa East 1, which is currently built by AES, probably another plant using local coal in the Maritsa East basin, for which there is serious interest from investors, etc.);
- possible reductions in the costs of transmission and access to the transmission system due to the better positioning of power generation capacities vis-à-vis consumer loads.

Thus, for the purposes of the investment analysis, the referential price of electricity output is taken to be BGN 90/MWh_{el}, which in our view is a relatively conservative estimate in comparison with the reference paper on expected prices in Europe [33] which shows much higher price levels. Furthermore, this referential price is much lower than the current preferential prices determined by SCEWR.

For the purposes of the investment analysis it has been assumed that electricity output prices will fluctuate in the range of BGN 90 ± 30 % /MWh_{el}.

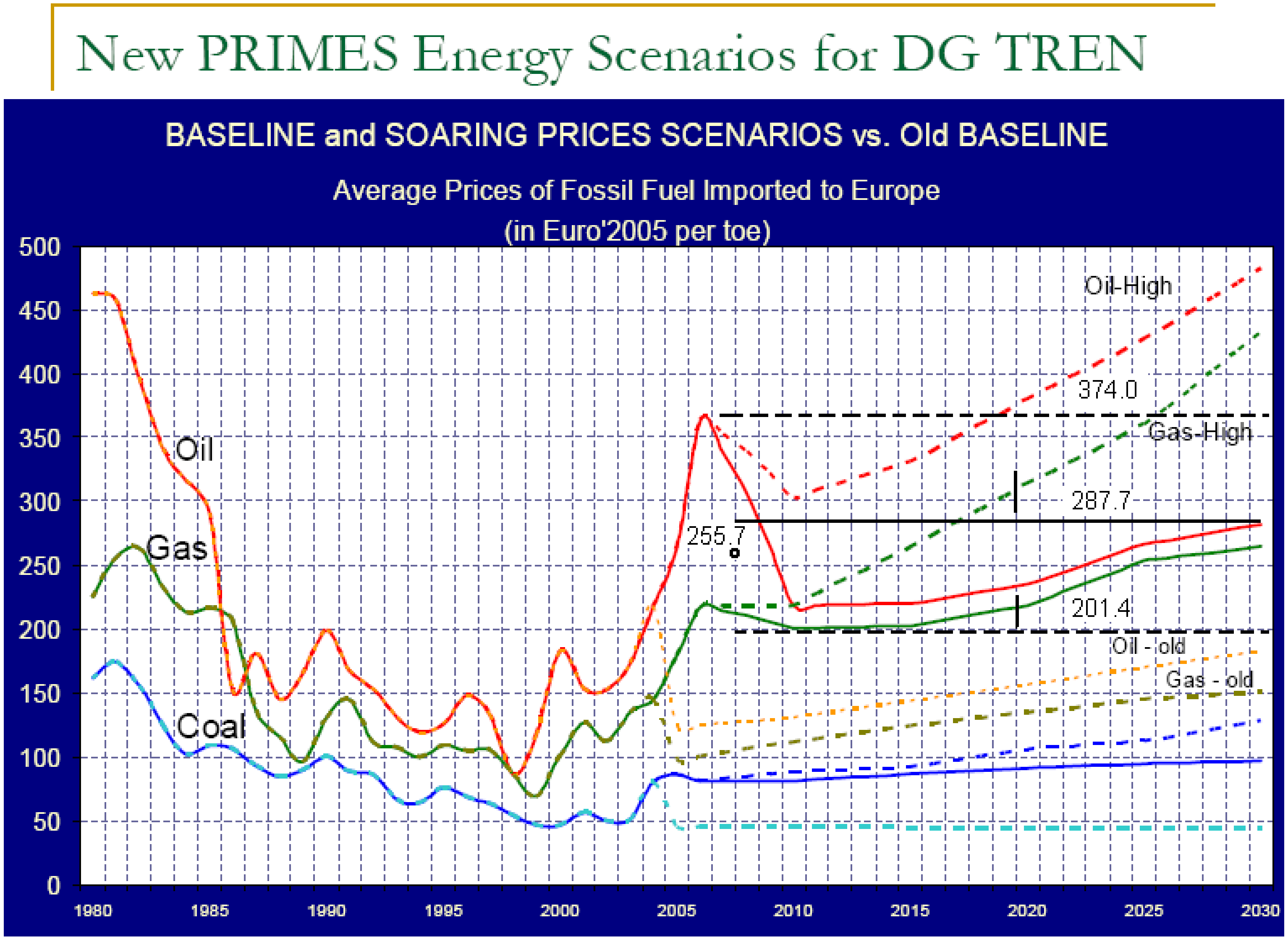


Fig. 1.1. Natural gas prices estimated by the Technical University of Athens

1.3.3. Referential price of heat energy

The heat energy referential price applied for the purposes of the investment analysis is BGN 63,43 /MWh_{th}. This price is definitely lower than the calculated price of the heat generated by local heating systems using condensing gas boilers and fired by natural gas from residential gas distribution networks. Furthermore, the comparison takes into account the costs for transmission and distribution of heat supplied by centralized heating systems.

1.3.4. Economic lifecycle

Insofar as this analysis extends to the year 2020, the economic lifecycle of the projects should accordingly be 13 years meaning that within this timeframe the investor should reach the desired return on his project. We believe that this timeframe is acceptable from investment risk perspective, moreover similar timelines (ca. 15 years) are frequently used for evaluation of investment projects relating to construction of energy generation plants. As concerns the normal technical life of complex facilities such as cogeneration systems, the generally accepted practice worldwide points to a technical service life of 20 years.

1.3.5. Discount rate

The discount rate used for calculating the net present value of the projects is taken to be 8%. This rate reflects the value of money over time and is close to the rates usually used for this purpose (between 8 and 10%).

1.3.6. Investment and operational costs

Investment and operational costs are determined on a case by case basis for each heat and electricity cogeneration plant. Use has been made of specific investment and operational costs statistics from Germany after adaptation to the specific circumstances in Bulgaria for each synthesized scheme of high-efficiency cogeneration plants.

The specific investment and operational costs of the various types of cogeneration plants, taken from a similar study for Germany published by the Bremen Energy Institute [31] are presented in table 1.1. for gas as a primary energy source and table 1.2. for biofuel as a primary energy source (1 EURO = 1,9558 BGN).

Negotiations with manufacturers or importers of cogeneration plants can lead to lower investment costs, however the investment analysis uses the prices shown on table 1.1 after adaptation to the particular heat and energy cogeneration plants.

The impact of investment costs on the internal rate of return has been estimated by varying these costs with the ± 30 % range.

1.3.7. Revenue from reduction of CO_2

Revenues from • •$_2$ reduction are based on the cost balance of cogeneration schemes at a price of EUR 10/tCO_2.

1.3.8. Operational time per year

Two annual operational scenarios have been considered:

- Baseline scenario – 8 400 h;
- Technical potential, which includes the cogeneration plant from the baseline scenario operated for 8,400 h and a new cogeneration plant to be operated only for 4 200 h/y during the heating season.

The operational time of centralized heat supply systems operated only during the heating season is 4 200 h/y.

Table 1.1. Basic details of heat and electricity cogeneration plants according to the study of the Bremen Energy Institute [31]

Parameters	**Unit of measure**	**Internal combustion unit**						**Gas turbine**	**Steam turbine**	
									Counter-pressure	**Steam extraction, condensing**
Electric capacity	MW_{el}	0.0055	0.018	0.054	0.31	1.080	5.4	10.0	20.0	80.0
Specific investment costs	EUR/kW_{el}	2458	1680	1400	1300	1000	800	700	820	644
Specific fixed investment costs	EUR/kW_{el}	60.0	-{}-39.0	16.0	13.0	11.0	10.0	8.0	12.25	14.50
Annual electric efficiency	%	27.7	27.6	31.0	35.4	38.1	41.5	31.0	42.5	55.5
Annual heat efficiency	%	60.3	58.4	58.0	53.6	47.9	43.5	49.0	43.5	39.9
Peak boiler										
Heat capacity including reserve		0.04	0.127	0.29	1.18	3.4	14	40	50	200
Specific investment costs	EUR/kW_{el}	170	120	80	70	65	60	60	50	50
Specific fixed investment costs	% of investments	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0
Annual efficiency	%	90	90	90	90	90	90	90	90	90

Table 1.2. Basic investment/operational costs and energy efficiency values of plants fired by biofuels [31]

Plants	**Capacity**	**Installation costs**	**Operational costs**	**Efficiency**		
				Total	**Electric**	**Heat**
-	kW_{el}	EUR/kW_{el}	% of investments	%	%	%
Wood-fired TPP	5 000	3 850	6.4	81	14	67
TPP with gas-generator units	155	5 540	6.5	83	31	52
Stirling engine	9	5 989	4.5	78	20	58
Straw-fired TPP	5 000	6 707	6.4	82	14	67
Combined combustion	7 000	370	6.5	80	35	45
Small biogas-fired plant	30	4 500	9.9	83	30	53
Large biogas-fired plant	350	3 170	8.5	78	34	44

2. CURRENT STATUS OF THE BULGARIAN ENERGY GENERATION SECTOR

2.1. Electricity generation

An analysis of electric power production in Bulgaria during the years 2002 - 2005 is provided in Table 2.1 and Fig. 2.1. Electricity output from Condensing Power Plants (CPP) exhibited a downward tendency during the period, decreasing by 7% in 2005. Output from the Nuclear Power Plant (NPP) decreased by 7.8%. In 2005 there was a strong rise in electricity output from Hydropower Plants (HPP) due to the abundant rainfalls during that year. In the industrial sector, after a period of restructuring and closing of inefficient production processes, industrial activities came to a stable level and electricity output from mill-owned power plants saw a strong increase by 83.7% in 2005. Electricity output from Heat and Electricity Plants (HEPs) grew by 23.7% in 2005. Bulgaria's total electricity cogeneration from HEPs including mill-owned HEPs in 2005 reached 5,96 • 10^6 kWh against a level of 3,81 • 10^6 kWh in 2002. During the period, the overall increase in cogenerated electricity output from HEPs and mill-owned HEPs was 56.4%. Total electricity output in Bulgaria increased by 3.9% in 2005.

The share of Condensing Power Plants (CPPs) in the gross electricity output in Bulgaria dropped from 37,4% in 2002 •. to 33,5 % in 2005. NPP contribution to the gross electricity output dropped to 42,1%. The share of HPPs in the gross electricity output of Bulgaria increased significantly - from 6,3 % in 2002 to 11 % in 2005. Mill-owned HEPs increased their contribution to the country's gross electricity output to 8,6 %. The share of other HEPs is 5 %. In 2005, the total share of the electricity cogenerated by HEPs and mill-owned HEPs increased to 13,4% compared to 8,9 % in 2002.

Table 2. 1. Gross electricity output in Bulgaria

Gross electricity output	***2002***		***2003***		***2004***		***2005***	
	10^6 kWh	***%***	***10^6 kWh***	***%***	***10^6 kWh***	***%***	***10^6 kWh***	***%***
HEPs in total	15 959.7	37,4	17 195,7	40,4	16 650,7	40,0	14 875,3	33,5
NPP	20 221,7	47,4	17 278,4	40,6	16 814,8	40,4	18 653,1	42,1
HPP in total: - turbines	2 687,7	6,3	3 284,8	7,7	3 363,4	8,1	4 878,8	11,0
Mill-owned HEPs	2 078,8	4,9	2 497,0	5,9	2 525,4	6,1	3 818,1	8,6
HEPs in total	1 730,7	4,0	2 297,6	5,4	2 266,0	5,4	2 140,8	4,8
Bulgaria total	**42 678,7**	**100,0**	**42 553,6**	**100,0**	**41 620,3**	**100,0**	**44 366,0**	**100,0**

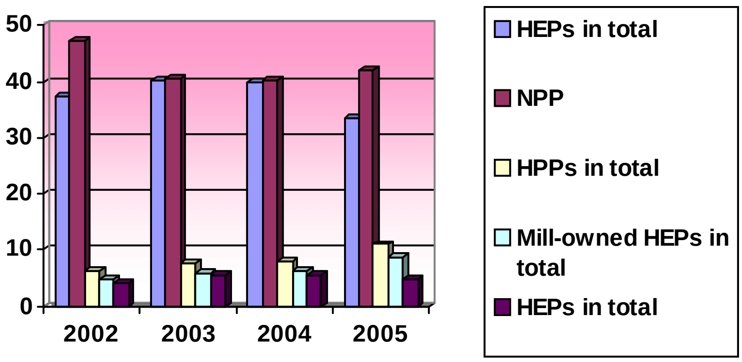


Fig. 2. 1. Gross electricity output structure, %

2.2. Energy resources used for electricity generation

The structure of the fuels and energies used for generation of electricity, as derived from official statistics, is presented in table 2. and Fig 2. 2. During the period under review, the relative weight of nuclear fuels in the structure of the fuels used for generation of electricity decreased from 47 % to 43%, while the absolute decrease for the year 2005 is 11,2 %. The relative weight of coal increased from 43% to 46%, with an absolute increase in 2005 of 5.4%. Petroleum products and natural gas maintained their weight during the period at constant levels of 2% and 6% respectively. The relative weight of other energy sources increased from 2,5% to 4,3% with an absolute increase of 71.3% in 2005.

Table 2.2. Energy resources used for conversion in power plants

	2002		**2003**		**2004**		**2005**	
	10^3 toe	***%***	***10^3 toe***	***%***	***10^3 toe***	***%***	***10^3 toe***	***%***
Total:	***11 596***	***100,0***	***11 345***	***100,0***	***10 975***	***100,0***	***11 379***	***100,0***
Nuclear energy	5 463	47.1	4 594	40.5	4 444	40.5	4 851	42.6
Coal	4 950	42.7	5 511	48.6	5 361	48.8	5 216	45.8
Petroleum products	199	1.7	220	1.9	197	1.8	175	1.6
Natural gas	698	6.0	727	6.4	670	6.1	647	5.7
Other energy sources	286	2.5	293	2.6	303	2.8	490	4.3

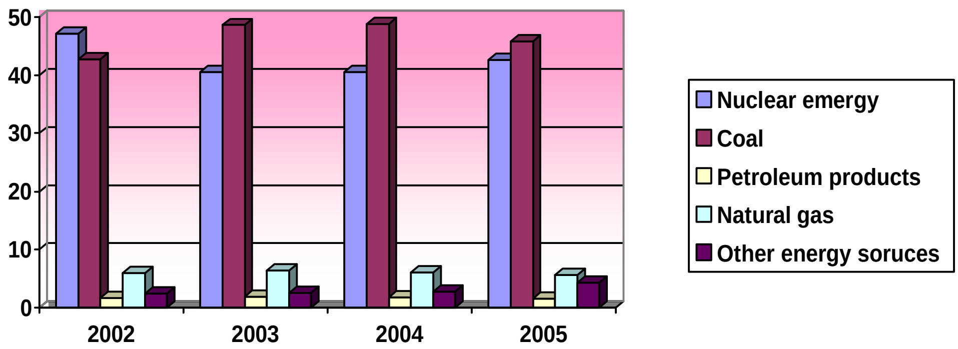


Fig. 2. 2. Structure of the energy resources used for conversion in power plants,%

The total amounts of energy sources used for conversion in electricity and heat plants are presented in table 2.3. The prevailing fuel in 2005 was coal of calorific value lower than 24 MJ/kg (5700 kcal/kg) – more than 32%, and this percentage was maintained during the whole period under consideration. The relative weight of coal with calorific value higher that 24 MJ/kg is more than 13%. In absolute terms usage of this type of coal increased by 20%.

Table 2.3. Total amount of energy resources used for conversion in electricity and heat plants

	2002		**2003**		**2004**		**2005**	
	10^3 toe	***%***	***10^3 toe***	***%***	***10^3 toe***	***%***	***10^3 toe***	***%***
Total:	***11 596***	***100,0***	***11 345***	***100,0***	***10 975***	***100,0***	***11 379***	***100,0***
Coal of calorific value higher than 24 MJ/kg	1 265	10,9	1 452	12,8	1 392	12,7	1 515	13,3
Coal of calorific value lower than 24 MJ/kg	3 685	31,8	4 059	35,8	3 969	36,2	3 701	32,5
Other solid fuels	251	2,2	252	2,2	264	2,4	456	4,0
Petroleum products	199	1,7	220	1,9	197	1,8	175	1,6
Natural gas	698	6,0	727	6,4	670	6,1	647	5,7
Other gases	35	0,3	41	0,4	39	0,4	34	0,3
Nuclear energy	5 463	47,1	4 594	40,5	4 444	40,5	4 851	42,6

Source: *Statistical Yearbook, National Statistical Institute (NSI)*

The nuclear energy has a dominant weight in the overall structure of energy resources used for conversion in electric and heat plants, reaching more than 42% at the end of the period. Natural gas has a stable contribution to the conversion in electrical and heat plants - about 6% of all sources used in 2005. Petroleum products are minor part of the fuels used for electricity and heat generation - 1.6% to the end of the period. The relative weight of other fuels is about 4%.

Table 2. 4 presents the structure of the fuels converted in electric power plants. Nuclear energy prevails with 54%, followed by coal of calorific value lower than 24 • J/kg with 36 % in 2005 •. Coal of calorific value higher than 24 • J/kg accounts for 8% during the final year and scores an increase of about 25% during the period. Petroleum products have a symbolic share of 0.4 %. Other solid fuels account for 1.4% of the fuels used for conversion in electric power plants in the final year of the period.

Fig. 2.3 presents the structure of the energy resources used for conversion in electric power plants in 2005.

Table 2.4. Energy resources used for conversion in public electric power plants

	2002		***2003***		***2004***		***2005***	
	10^3 toe	***%***	***10^3 toe***	***%***	***10^3 toe***	***%***	***10^3 toe***	***%***
Total:	***9 311***	***100.0***	***8 928***	***100,0***	***8 642***	***100,0***	***9 011***	***100,0***
Coal of calorific value higher than 24 MJ/kg	608	6.5	715	8.0	627	7.3	759	8.4
Coal of calorific value lower than 24 MJ/kg	3 185	34.2	3 599	40.3	3 534	40,9	3 243	36.0
Other solid fuels	-	-	-	-	18	0.2	124	1.4
Petroleum products	33	0,4	20	0,2	19	0.2	32	0.4
Natural gas	22	0,2	-	-	-	-	2	0.0
Other gases	-	-	-	-	-	-	-	-
Nuclear energy	5 463	58.7	4 594	51.5	4 444	51.4	4 851	53,8

Source: *Statistical Yearbook, National Statistical Institute (NSI)*

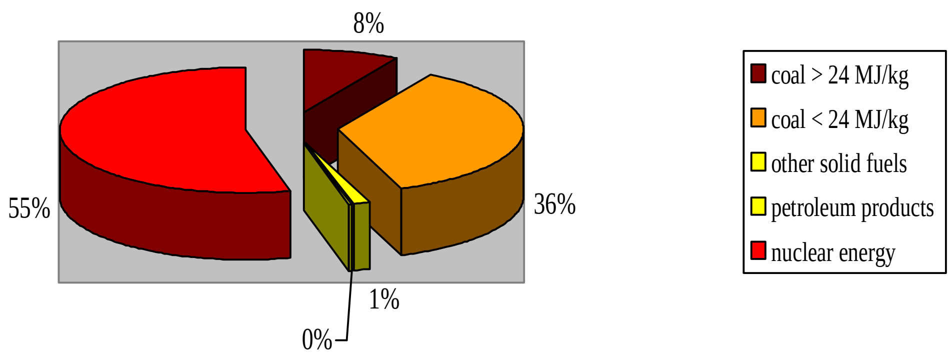


Fig. 2. 3. Structure of the energy resources used for conversion in electric power plants in 2005,%

Table 2. 5 presents the structure of the fuels converted in cogeneration plants. Coal of calorific value higher than 24 MJ/kg had a dominant share of about 33 % in 2005. The relative weight of coal with calorific value less that 24 MJ/kg is about 23 %. The weight of other solid fuels in the structure of converted fuels is about 16 %. Petroleum products have a relatively low weight in the structure of converted fuels – 1,8 %. Natural gas has a strong share in the structure of converted fuels – 26 %. Fig. 3. 4 presents the fuel mix of heat and electricity cogeneration plants in 2005.

Table 2. 5. Energy resources used for conversion in cogeneration plants

	2002		2003		2004		2005	
	10^3 toe	%	10^3 toe	%	10^3 toe	%	10^3 toe	%
Total:	***1 915***	***100,0***	***1 872***	***100,0***	***1 934***	***100,.0***	***1 975***	***100,0***
Coal of calorific value higher than 24 MJ/kg	563	29,4	501	26,8	662	34,2	647	32,8
Coal of calorific value lower than 24 MJ/kg	500	26,1	460	24,6	435	22,5	458	23,2
Other solid fuels	237	12,4	240	12,8	234	12,1	320	16,2
Petroleum products	12	0,6	27	1,4	18	0,9	36	1,8
Natural gas	603	31,5	644	34,4	585	30,2	514	26,0
Other gases	-	-	-	-	-	-	-	-
Nuclear energy	-	-	-	-	-	-	-	-

Source: *Statistical Yearbook, National Statistical Institute (NSI)*

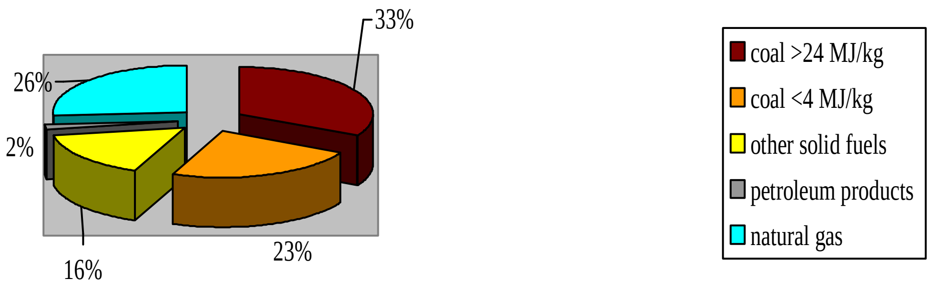


Fig. 2. 4. Structure of the energy resources used for conversion in cogeneration plants in 2005,%

Fig. 2.5 presents the structure of the energy resources used for conversion in mill-owned plants in 2005.

Table 2. 6 presents the structure of the fuels converted in mill-owned plants. Coal of calorific values higher than 24 MJ/kg accounted for ca. 28 % in 2005 and tended to increase by around 16% throughout the period. Other solid fuels were 3 % of the fuels used for conversion in mill-owned plants in the final year of the period. Natural gas dominates the structure of fuels converted in mill-owned plants with a share of more than 33% and 81% absolute increase during the period. Petroleum products also have a strong share in the fuel mix of mill-owned plants - more than 27% during the final year, however they decreased by 30% during the period. The weight of other gases in the structure of fuels converted in mill-owned plants is a the constant level of ca. 9 %.

Table 2. 6. Energy resources used for conversion in mill-owned plants

	2002		2003		2004		2005	
	10^3 toe	%	10^3 toe	%	10^3 toe	%	10^3 toe	%
Total:	***370***	***100,.0***	***545***	***100,0***	***400***	***100,0***	***394***	***100,0***
Coal of calorific value higher than 24 MJ/kg	94	25,4	236	43,3	103	25,8	109	27,7
Coal of calorific value lower than 24 MJ/kg	-	-	-	-	-	-	-	-
Other solid fuels	14	3,8	12	2,2	12	3,0	12	3,0
Petroleum products	154	41,6	173	31,7	161	40,3	107	27,2

Natural gas	73	19,7	83	15,2	85	21,3	132	33,5
Other gases	35	9,5	41	7,5	39	9,8	34	8,6
Nuclear energy	-	-	-	-	-	-	-	-

Source: *Statistical Yearbook, National Statistical Institute (NSI)*

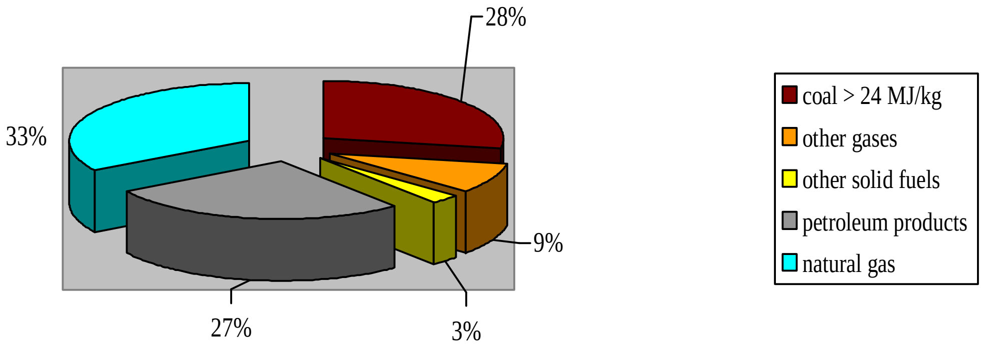


Fig. 2. 5. Structure of the energy resources used for conversion in mill-owned plants in 2005,%

Table 2. 7 presents the structure of the fuels converted in district heating plants. Natural gas prevails in the structure of the fuels used for conversion in district heating plants with a share of 92% in 2005. Petroleum products also have some weight in the fuel mix - 7% in the final year of the period.

Fig. 2. 6 presents the structure of the energy resources used for conversion in district heating plants in 2005.

Table 2. 7. Energy resources used for conversion in district heating plants

	2002		**2003**		**2004**		**2005**	
	10^3 toe	**%**	**10^3 toe**	**%**	**10^3 toe**	**%**	**10^3 toe**	**%**
Total:	**275**	**100,0**	**305**	**100,0**	**273**	**100,0**	**359**	**100,0**
Coal of calorific value higher than 24 MJ/kg	-	-	-	-	-	-	-	-
Coal of calorific value lower than 24 MJ/kg	-	-	-	-	-	-	-	-
Other solid fuels	-	-	-	-	-	-	-	-
Petroleum products	29	10,5	37	12,1	37	13,6	27	7,5
Natural gas	246	89,5	268	87,9	236	86,4	332	92,5
Other gases	-	-	-	-	-	-	-	-
Nuclear energy	-	-	-	-	-	-	-	-

Source: *Statistical Yearbook, National Statistical Institute (NSI)*

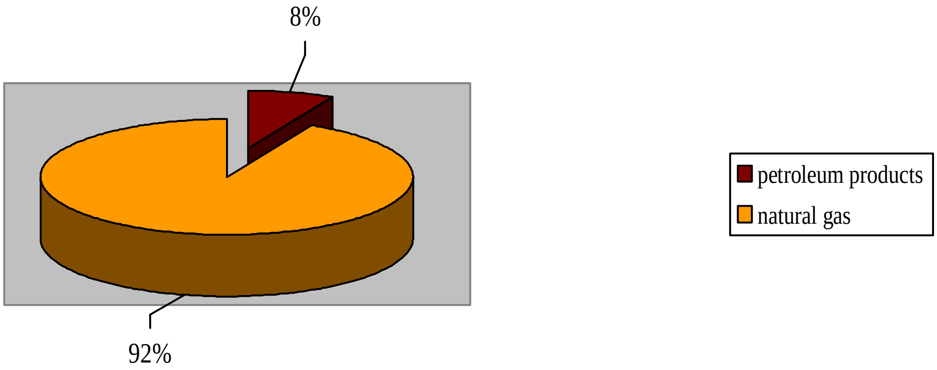


Fig. 6.Structure of the energy resources used for conversion in district heating plants in 2005,%

2.3. Generation and consumption of heat

Gross heat output in Bulgaria grew from 21 018 GWh in 2002 to 21 736 GWh in 2005, which is an increase of 3,4 %. From 5 688 GWh in 2002, gross heat output from HEPs became 5 593 GWh in 2005, which is a minor decrease of ca. 2% for the whole period. The relative weight of HEPs in the gross heat output of Bulgaria decreased from 27,1% in 2002 to 25,7% in 2005 •. Gross heat output from Heat-only Plants (HoPs) increased from 2 727 GWh in 2002 to 2 916 GWh in 2005, which is an increase of about 7% for the whole period. During the period under examination, HoPs had a constant relative weight of ca. 13% in the gross heat output. From 8,329 GWh in 2002, gross heat output from mill-owned HEPs became 9,359 GWh in 2005, which is an increase of 12.4 % for the whole period. The relative weight of mill-owned HEPs in the gross heat output of Bulgaria increased from 39.6 % in 2002 to 43.1 % in 2005 •. Gross heat output from industrial boilers changed from 4,274 GWh in 2002 to 3,868 GWh in 2005, which is an decrease of 9.5 % for the whole period. The relative weight of industrial boilers in the gross heat output in Bulgaria decreased from 20,3 % in 2002 to 17,8 % in 2005.

Table 2.8 and Fig. 2. 7 present the structure of gross heat output in Bulgaria.

Table 2. 8. Gross heat output in Bulgaria

Heat output	***2002***		***2003***		***2004***		***2005***	
	GWh	***%***	***GWh***	***%***	***GWh***	***%***	***GWh***	***%***
HEPs in total	5 688	27,1	6 117	27,2	5 546	25,9	5 593	25,7
HoPs in total:	2 727	13,0	3 009	13,4	2 712	12,6	2 916	13,4
Mill-owned HEPs in total:	8 329	39,6	8 971	39,9	8 984	41,9	9 359	43,1
Industrial boilers:	4 274	20,3	4 376	19,5	4 213	19,6	3 868	17,8
Total:	**21 018**	**100,0**	**22 473**	**100,0**	**21 455**	**100,0**	**21 736**	**100,0**

Source: *Statistical Yearbook, National Statistical Institute (NSI)*

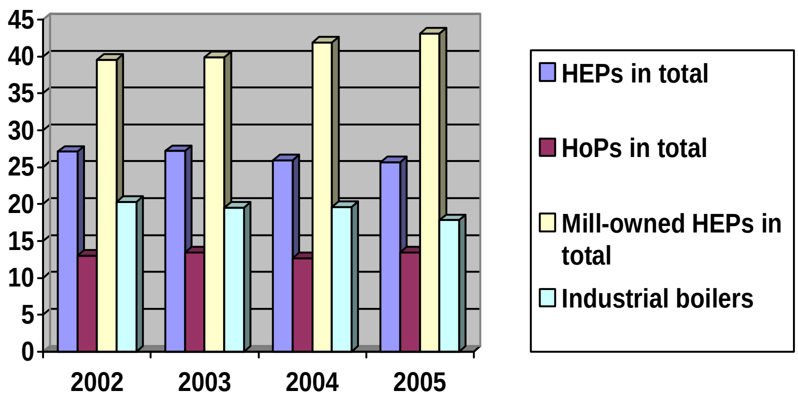


Fig. 2. 7. Gross heat output in Bulgaria, %

Table 2. 9. presents the heat balance of the country. Final heat consumption increased by 4.2% during the period 2002-2005. Losses in heat transmission and distribution systems are ca. 8%. An insignificant statistical difference is observed.

Table 2. 9. National heat balance

• • • • • • • • •:	***2002***		***2003***		***2004***		***2005***	
	GWh	***%***	***GWh***	***%***	***GWh***	***%***	***GWh***	***%***
Output	***21 018***	***100,0***	***22 473***	***100,0***	***21 455***	***100,0***	***21 736***	***100,0***
Final consumption	19 271	91,7	20 463	91,1	19 711	91,9	20 076	92,4
Transmission/distribution losses	1 761	8,4	1 980	8,8	1 644	7,7	1 631	7,5
Statistical difference	-14	-0,1	30	0,1	100	0,4	29	0,1

Source: *Statistical Yearbook, National Statistical Institute (NSI)*

Table 2.10 presents the structure of heat consumption in Bulgaria during the period 2002-2005.

Table 2. 10. The structure of heat consumption in Bulgaria

	2002		***2003***		***2004***		***2005***	
	GWh	***%***	***GWh***	***%***	***GWh***	***%***	***GWh***	***%***
Consumption:	***19 271***	***100,0***	***20 463***	***100,0***	***19 711***	***100,0***	***20 076***	***100,0***
Agriculture and forestry	182	1,0	207	1,0	341	1,7	387	1,9
Mining industry	136	0,7	105	0,5	108	0,6	115	0,6
Processing industry	10 516	54,6	10 702	52,3	10 608	53,8	10 660	53,1
Electricity, gas and water production and distribution	1 906	9,9	2 351	11,5	2 279	11,6	2 264	11,3
Construction	7	0,0	13	0,0	5	0,0	10	0,0
Trade	14	0,0	12	0,0	17	0,0	25	0,1
Transport and communications	33	0,2	58	0,3	71	0,4	29	0,1
Others	1 364	7,1	1 519	7,5	1 354	6,9	1 496	7,5
Households	5 112	26,5	5 496	26,9	4 930	25,0	5 091	25,4

Source: *Statistical Yearbook, National Statistical Institute (NSI)*

The biggest heat consumer in Bulgaria is the processing industry with ca. 53% during the period 2002-2005. The second biggest consumer is the residential sector (households) with ca. 25% during the final year of the period. The electricity, gas and water production and distribution sector accounts for 11 % of the total consumption. The weight of other consumers in total heat consumption in Bulgaria is ca. 7%.

3. POTENTIAL FOR HEAT AND ELECTRICITY COGENERATION BY CENTRALIZED HEAT SUPPLY SYSTEMS IN BULGARIA

3.1. Evaluation of the state of cogeneration plants used for centralized heat supply systems

Of the 16 centralized heat supply utilities operating in Bulgaria in the end of 2006, two do not have heat and electricity cogeneration plants. The rated electric capacity of the cogeneration plants is 774,7 MW_{el}.

Almost 95% of the cogeneration facilities are based on the Rankin cycle and are between 20 and 36 years of age. The most recently installed energy boilers and steam turbines have been in operation since 1988. 12 turbine generators rated from 6 to 12 MW_{el}, mainly counter-pressurized, 11 turbine generators rated from 25 to 30 MW_{el} and 6 turbine generators rated from 50 to 66 MW_{el} are in operation.

The new cogeneration systems installed during the past 2-3 years have an aggregate capacity of 32 MW_{el} and use gas piston engines of limited capacity (from 0,4 to 3,3 MW_{el}). They are mainly acquired second-hand and have an electrical efficiency of 38 %.

Four heating plants with aggregate capacity 333 MW_{el} are fired by local and imported solid fuels, such as the plant in Pernik, rated 105 MW_{el}, which burns fossil fuels with high ballast levels (ash content up to 65%). The remaining plants are fired by natural gas.

In 2006, heating plants produced a total of 2 144 GWh_{el} electricity, of which 1 585,5 GWh_{el} were recognized as cogenerated electricity by the National Electric Company. The useful heat produced by district heating utilities is 7 990 GWh_{th} (23 040 TJ).

The data for 2006 (see table 3.1) concerning the currently operated cogeneration plants in Bulgaria provide grounds for making the following findings:

1. As little as 53.2 % of the useful heat comes from electricity and heat cogeneration plants. 38% of the useful heat produced and sold in Sofia comes from plants, which do not have cogeneration systems, but just Heat-only Boilers (HoPS). This provides an opportunity to consider increasing the electricity and heat cogeneration capacities of plants with significant useful heat volumes.
2. The heat supplied to final consumers is 80% of the released useful heat, i.e. technical losses in heat distribution systems are ca. 20% (in Sofia these losses are 16.8% due to the extensive investments in the system).
3. The ratio between electricity output and useful heat released by cogeneration plants is 0.379 country average and 0.32 in Sofia. This suggests that there is large technical potential for modernization of cogeneration plants with the aim increasing the output of electricity at the existing heat output levels.
4. The overall energy efficiency of the cogeneration systems operated by all heat supply utilities is 67.23 %. The plants fired by natural gas and using Rankin cycle equipment report an overall energy efficiency of 75 %, while the efficiency of coal fired plants is between 33 and 58 %. The electricity and heat cogeneration plants, which use gas piston engines, have a guaranteed overall energy efficiency of more than 80 %.
5. All plants fired by natural gas achieve more than 10 % savings of primary energy, but those fired by solid fuels are unable to reach the primary energy savings required by Directive 2004/8. Against the regulatory efficiency reference values of separate production, these plants report higher fuel consumption compared to separated production. Moreover these plants present environmental concerns, therefore the issue of their future operation should be solved in the nearest future.

3.2 Evaluation of the economic and environmental efficiency, expressed in terms of primary energy savings and reduced CO_2 emissions, which would be achieved through increasing the share of high-efficiency cogeneration by centralized heat supply systems in Bulgaria

Two annual operational scenarios have been considered:

- Baseline scenario – 8 400 h;
- Technical potential, which includes the cogeneration plant from the baseline scenario operated for 8,400h and a cogeneration plant to be operated only for 4 200 h/y during the heating season.

The results of the detailed technical, economic, investment and environmental assessments of the existing centralized heat supply systems in Bulgaria have been summarised. The scenarios of using biomass as a primary energy source have been evaluated. From an investment perspective these are not profitable, since their internal rate of return is low and their net present value is negative. Realization of these scenarios should rely on appropriate support schemes such as partial grants from European Union programmes or preferential electricity purchase prices throughout the economic life of the project on account of the fact that these plants are using RES.

The evaluation of the potential for heat and electricity cogeneration takes into account the key factors, which have an impact on centralized heat supply systems - intensification of technological processes, extension of heat loads and increasing their density.

Table 3. 2. Aggregated indicators of the potential of centralized heat supply systems in Bulgaria

Scenario	***Indicators***					
	Electric capacity	***Cogenerated electricity***	***Cogenerated heat***	***• • $_2$ reduction***	***Primary energy savings***	***Investments***
	MW_{el}	GWh_{el}	GWh_{th}	MT '000	GWh_f	BGN '000
Existing	728.6	1 469.3	4 594.3	980	-	-
Baseline	646	5 086.4	4 492	2 652.6	3 509	722 460
Technical potential	870.2	6 686	6 284	3 504	4 670	995 700

Realization of the potential for heat and electricity cogeneration by 2020 will depend on the owners of the respective utilities, the actual heat energy market, heat, electricity and fuel prices as well as on CO_2 allocations.

Table 3.1. Operational performance of cogeneration plants in 2006

No.	Indicators		Cogeneration plants														
			Sofia 1	***Sofia 2***	***Plovdiv***	***Ruse***	***Pernik***	***Pleven***	***Vratsa***	***Tege***	***Varna***	***Burgas***	***Shumen***	***Sliven***	***Gabrovo***	***Kazanlak***	***Pravets***	***TOTA***
1	Rated electrical capacity	MW	75	186	85	180	105	36	6.6	0.4	4.4	17.8	18	30	18	12	0.5	774.7
1	Electrical output	GWh	131	668	137	471	400	60	41.8	0.8	32.7	5.1	11.5	176	7	0	1.64	2143.5
2	Cogenerated electricity	GWh	131	668	137	310	128	60	41.8	0.8	32.7	5.1	11.5	51	7	0	1.64	1585.5
3	Electricity sales	GWh	55	536	120	397	294	45	39.4	0.77	30	4.6	7.3	148	4.3	0	1.44	1682.8
4	Useful heat	GWH	1444	2087	409	405	312	407	64	1.7	113	272	91	106	46.3	0	5	5763
5	Cogenerated useful heat	GWh	711	1797	392	349	312	407	44	1.2	41	6	58	87	46.3	0	2.7	4254.
6	Heat sales	GWh	1812*	2838*	358	308	234	294	110	1.0	75	215	51	66	35	0	3	6400
7	Fuel consumption	GWh	1784	3477	663	1931	1916	573	141	3.4	161.6	290	122	828	94	0	8	11992
8	Fuels used for cogeneration	GWh	984	3165	660	1517	613	558	102.5	2.2	81.6	13	94	798	93	0	5.3	8686.
9	Total referential efficiency	%	80	80	75	75	75	75	80	80	80	80	80	75	75	0	80	-
10	Total calculated efficiency	%	85.53	77.9	80.12	42.47	36.23	83.79	84.14	92.5	90.56	84.5	73.54	32.98	57.55	0	82.03	57.5
11	ELECTRICITY/HEAT ratio		0.184	0.372	0.5	0.89	0.41	0.148	0.942	0.71	0.796	0.86	0.2	0.6	0.154	0	0.61	0.373
12	Referential electrical efficiency	%	32.3	32.3	32.3	32	32.3	32.3	55	55	55	55	32	32.3	32	0	55	-
13	Referential heat efficiency	%	84	84	84	84	84	84	91	91	91	91	84	84	84	0	91	-
14	Referential fuel savings	%	5	5	5	5	5	5	10	10	10	10	10	5	5	0	10	-
15	Fuel savings	%	21.3	24.8	25.9	-	-	16.9	17.9	22.7	22.11	17,29	9,77	-	-	0	11,11	-
	Total useful heat	GWh	2287*	3305*	499	405	312	407	139	3	113	272	91	106	46	0	5	7990

*) *total heat output and heat sales figures for Sofia include the heat output of heat plants without cogeneration systems.*

4. POTENTIAL FOR HEAT AND ELECTRICITY COGENERATION IN RESIDENTIAL AND PUBLIC BUILDINGS

4.1. THE RESIDENTIAL BUILDINGS

4.1.1. Classification of residential stock as presented in the National programme for renovation of residential buildings [13]

Table 4.1 presents the total number of buildings in Bulgaria, their useful floor space and gross floor areas and the average area of one home.

Table 4.1.

	Buildings	***Homes/ apartments***	***Useful floor space***		***GFA, m²***	***Average GFA per home m²***
			Total:	***Incl. living space***		
Country total						
Total:	2124533	3678441	233344110	150141127	283873613	77.2
Habitable buildings	1509819	3056707	200123541	126976376	243459296	79.6
Cities/towns						
Total:	740450	2291364	146957155	91519098	178779994	78.0
Habitable buildings	586814	2132940	138861084	85723353	168930759	79.2

Breakdown of residential stock by year of construction (Table 4.2):

Table 4.2. Breakdown per year of construction, %

	Before 1929	1930-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1984	1985-1989	1990-1994	1995-2001
Country total	4	4	5	12	20	24	12	10	5	4
Towns/cities	3	2	3	8	19	28	15	12	6	5

Breakdown of residential stock by number of floors (Table 4.3):

Table 4.3. Breakdown of residential stock by number of floors, %

	1	2	3	4	5	6	7	8	9	10 or more
Country total	28	22	5	6	6	5	4	15	3	5
Towns/cities	15	16	7	8	9	8	6	21	4	8

Table 4.4 presents a data set, which is of important relevance for assessing the potential for heat and electricity cogeneration, namely buildings, apartments, number of floors and number of inhabitants.

Table 4.4. Breakdown of residential stock by number of floors and number of inhabitants

Types	***Number of buildings***	***Number of apartments***	***Number of inhabitants***
All buildings	1 794 989	3 348 565	7 820 168
Buildings 1 and 2 floors	1 703 438	1 829 165	4 174 154
Buildings 3 to 10+ floors	91 551	1 519 400	3 646 014

4.1.2. Statistics the National Statistical Institute (NSI)

As little as 15.8% of all heated homes receive their heat from district heating utilities. Adding to these the homes, which use electricity as a second heat source (water heating from a central source + electricity), the above figure becomes 16.6 %. 100% of the homes heated in this way are in the towns and cities [14].

Insofar as CHEG plants are more efficient with greater heat loads, table 4.5 shows a breakdown of buildings having 3 to 10+ floors (structurally, these are building made only of prefabricated panels, ferroconcrete buildings, buildings of concrete slabs and brickwork, buildings of timber joists and brickwork).

Table 4.5. Breakdown of buildings by number of floors

	Total:	3	4	5	6	7	8	9	10+
All buildings	91 551	49 444	16 428	9 257	4 913	2 673	5 655	1 006	2 175
%	100	54	18,0	10,1	5,4	2,9	6,2	1,1	2,4

4.2. Economic efficiency thresholds as a function of the residential buildings

The potential of the smallest cogeneration systems in the residential sector, which have not been connected to the heat distribution network, is a function of the specific barriers in this sector. Thus for example, the low heat load density of a populated settlement can be a reason for the absence of centralized heat supply. However, this does not mean that separate buildings or groups of buildings are not suitable for construction of low-capacity cogeneration systems. In this respect, an analysis has been completed on how competitive the cogeneration for single buildings or groups of buildings is versus direct gas supply. Where a heat/electricity cogeneration plant is found to be more efficient than direct gas supply, the potential of the residential areas with existing gas distribution networks is evaluated for the various types of buildings and is then interpolated to the whole sector with the help of suitable characteristics. The database of various building structures in Bulgaria is crucial to the evaluation of this potential. Since there are no energy plans of the populated settlements in Bulgaria, the evaluation of the potential for cogeneration of heat and electricity in residential and public buildings is of informative nature at this stage.

Since climatic conditions in Bulgaria vary from region to region, a data set of special interest for assessing the economic benefit of putting into operation Combined Heat and Electricity Generation (CHEG) plants is the breakdown of residential buildings by regions and by number of floors [15]. Table 4. 6 presents aggregated baseline values of the climatic factors by climatic regions, which form the basis for calculating the referential heat requirements of the various types of buildings taken from "ORDINANCES UNDER THE ENERGY EFFICIENCY ACT" [16].

Table 4.6. Climate-related values of the various climate zones of Bulgaria

Climate zone 1	Northern Black Sea Coast		
Heating season	Start: 21.10	Referential outdoor temperature	-11,0 º•
	End: 20.04	Day-degrees at mean indoor temperature 19 º•	2400
Climate zone 2	Dobrudzha		
Heating season	Start: 21.10	Referential outdoor temperature	-15.0 º•
	End: 25.04	Day-degrees at mean indoor temperature 19 º•	2800
Climate zone 3	North Bulgaria along the Danube river		
Heating season	Start: 23.10	Referential outdoor temperature	-17.0 º•
	End: 15.04	Day-degrees at mean indoor temperature 19 º•	2600
Climate zone 4	North Bulgaria – central part		

Heating season	Start: 16.10	Referential outdoor temperature	-17.0 º•
	End: 23.04	Day-degrees at mean indoor temperature 19 º•	2700
Climate zone 5	Southern Black Sea Coast		
Heating season	Start: 25.10	Referential outdoor temperature	-10.0 º•
	End: 19.04	Day-degrees at mean indoor temperature 19 º•	2300
Climate zone 6	South Bulgaria – central part		
Heating season	Start: 24.10	Referential outdoor temperature	-15.0 º•
	End: 06.04	Day-degrees at mean indoor temperature 19 º•	2400
Climate zone 7	Sofia and the Sub-Balkan Valley		
Heating season	Start: 15.10	Referential outdoor temperature	-16.0 º•
	End: 23.04	Day-degrees at mean indoor temperature 19 º•	2900
Climate zone 8	South Bulgaria		
Heating season	Start: 28.10	Referential outdoor temperature	-14.0 º•
	End: 06.04	Day-degrees at mean indoor temperature 19 º•	2300
Climate zone 9	Southwest Bulgaria		
Heating season	Start: 28.10	Referential outdoor temperature	-10.0 º•
	End: 05.04	Day-degrees at mean indoor temperature 19 º•	2100

Table 4.7 presents a summary of residential buildings/number of floors, now distributed by climate zones.

Table 4.7. Breakdown of buildings/number of floors by climate zones

	Number of floors							
Climate zone	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10+***
1	2366	884	759	391	218	357	191	147
2	2517	1009	643	284	208	454	29	102
3	1298	711	517	234	171	434	46	116
4	6336	2790	1472	733	349	613	94	223
5	3691	1235	675	373	97	314	22	114
6	10596	3567	1920	849	462	1257	107	471
7	16866	4390	2430	1739	997	1860	479	903
8	2840	866	561	179	55	265	33	74
9	3101	1081	340	144	122	104	11	27
Total:	**49611**	**16533**	**9317**	**4926**	**2679**	**5658**	**1012**	**2177**

The specific reference values for the heat requirements of the various types of buildings in the various climate zones [16] have been used to determine the required heat load of the typical buildings by number of floors and climate zones. Scope of the evaluation:

- Buildings with up to 4 floors are excluded from the evaluation because of their low heat load levels;
- Buildings of 4 to 8 floors inclusive are evaluated on the basis of the reference values for a 5-floor building;
- Buildings of 9 floors or more are evaluated on the basis of the reference values for a 14-floor building. This distribution pattern is taken from the evaluation methodology used for the National Energy Efficiency Plan 2008-2015. Account has also been taken of the specifities

related with the installation of heating systems in these buildings and the form (layout) of these buildings, which varies depending on the number of floors.

The methodology for evaluating the economic efficiency of CHEG plants has been applied to the following scenarios: heat only, domestic hot water (DHW) supply and combined heat/DHW supply.

The calculations of the economic efficiency of CHEG plants, taken together with statistical profiles of the buildings in terms of number of floors, number of inhabitants, form factor, year of construction and heat supply methods, lead to the following conclusions:

1. Based on the heat load for heating and domestic hot water supply, use of CHEG plants is economically viable for buildings of 7 to 9 floors, where the specific price of heat energy from CHEG plants satisfies the $\bullet_q < C_f$ criterion as follows:

   - low price of natural gas - $\bullet_q < C_f$ BGN/MWh;

   - high price of natural gas - $\bullet_q < C_f$ BGN/MWh;

Applying these results to the residential stock in Bulgaria, and taking into account that 16.6% of these buildings use centralized heat supply, leads to the following technical potential of CHEG in respect to residential buildings:

- annual cogenerated electricity output – 2 452 GWh_e;
- annual cogenerated heat output – 4,612 GWh_t;
- annual consumption of primary fuel (natural gas) – 8 193 GWh_f.

2. In addition to the number of floors and inhabitants, the form of the buildings is also important for assessing the economic viability of CHEG in the case of residential buildings. Therefore this methodology is applicable for assessing the global CHEG potential, however each technical implementation requires a separate investment analysis to be undertaken for each particular building.

3. The economic efficiency of using CHEG plants is to a large extent insensitive to the age of the buildings.

4. 3. Potential for application of CHEG in non-residential buildings

Non-residential buildings such as hospitals, schools, hotels, etc. are also of interest for assessing the economic efficiency and potential of combined heat and electricity generation. Based on NSI statistics, in Bulgaria there are 1348 hotels with ca. 170 000 beds following a 12.1% growth during the recent years. Most of these are concentrated in the Black Sea and winter resorts. Heat and gas supply infrastructure is underdeveloped. Heat requirements are largely met by electricity (air conditioners and heating boilers), firewood, liquid/solid fuels and timber waste. These sites are characterized by seasonal use, which makes CHEG inefficient due to the low number of operational hours. The hotels that are of interest from the perspective of CHEG application belong to the 4 and 5 stars category - these are required to maintain high level of comfort throughout the year, including amenities such as airconditioning, swimming pools, spa centres, etc. – the number of these hotels is about 200, half of them are in the large cities and are already connected to the centralized heating systems.

The National strategy for development of the Bulgarian tourist sector 2008-2013 prioritises the introduction of efficiently functioning innovative systems - energy-saving technologies and use of renewable energy sources.

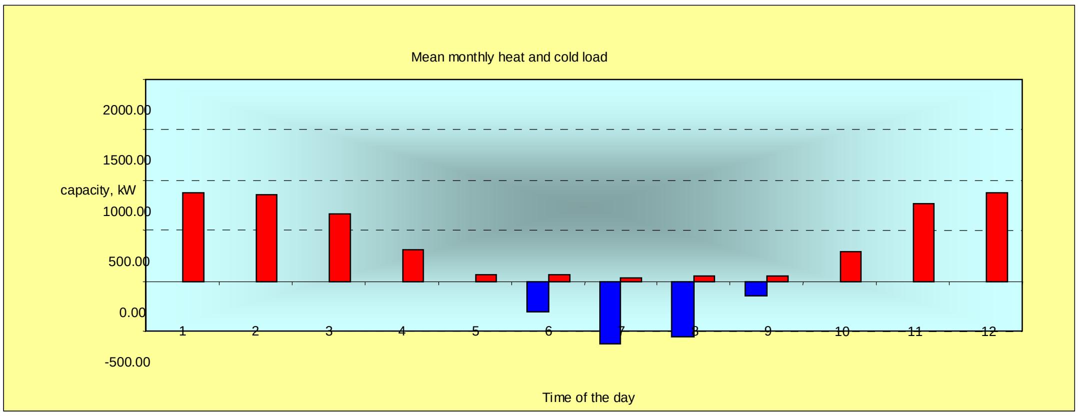
Schools are not included in the study because of the limited number of operational hours - they are open one or two shifts during working days only, there is no DHW load, very few schools have swimming pools, etc.

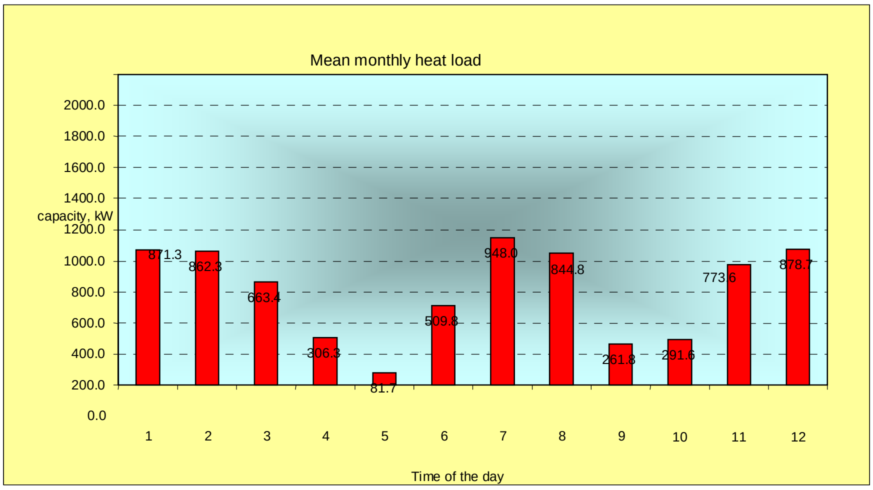
An analysis has been made of the potential for CHEG application in the hospital sector, more specifically in the existing multiprofile hospitals. The evaluation is based on statistical information about number of beds, annual number of bed-days and ambience requirements. Heating, DHW and airconditioning chilling requirements have been calculated. Data sets for several hospitals have been used and the situation is illustrated with a case study based on the Multiprofile hospital for acute treatment (MPHAT) in the town of Dobrich. The results have been multiplied to the multiprofile hospitals with similar requirements in the country and the annual number of bed-days - a typical indicator of hospital operations. The evaluation includes both cogeneration schemes for covering the specific heat and electricity requirements and trigeneration schemes for covering the specific heat, cold and electricity requirements.

4.3.1. *Determining the economic efficiency of CHEG introduction at MPHAT Dobrich*

The economic efficiency of introducing a CHEG system to cover the hospital's heat and cold requirements with accompanying electricity generation has been evaluated for two scenarios: (i) only heat load requirements are covered without using an Absorption Chilling Machine (ACM) and (ii) both heat and cold requirements are covered using an ACM.

Figures 4.1 and 4.2





Figures 4.1 and 4.2 present the hospital's mean monthly heat and cold requirements and the mean monthly heat requirements with an ACM for airconditioning purposes.

CHEG covering heat and DHW requirements

The heat load is distributed between CHEG and the peak boiler to cover the hospital's requirements without the chilling load. The economic efficiency of using a CHEG plant is presented in tables 4. 10 and 4.11.

A CHEG plant of 500 kW capacity has been selected – during the summer months of May, June, July, August and September this capacity it too high for the limited DHW load, while in April and November the plant will be operated at half capacity.

Table 4. 9. Heat loads of the CHEG and Peak Boiler (PB)

Month	Number of days in the month	Hours/mo.	Qh+DHW	•(CHEG)	•(CHEG)	Q(CHEG)	Q_{PB}	$•_{PB}$
			•Wh/•m	kW	hrs/mo.	•Wh	•Wh/m	kW
1	31	744	649	500	744	372	277	372
2	28	672	580	500	672	336	244	363
3	31	744	494	500	744	372	122	164
4	30	720	221	250	720	180	41	57
5	31	744	47	0	0	0	47	63
6	30	720	42	0	0	0	42	58
7	31	744	25	0	0	0	25	33
8	31	744	33	0	0	0	33	44
9	30	720	29	0	0	0	29	40
10	31	744	217	250	744	186	31	42
11	30	720	557	500	720	360	197	274
12	31	744	654	500	744	372	282	379
Total		8760	3547	3000	5088	2178	1369	156

••••.4. 10. Economic efficiency of the CHEG plant

Qcogen	Ecogen	Icogen	Q cogen,y	Qpb,y	Fcogen,y	F_{PB},•	F,•	Ia	Q	Q f
MW	MW•	BGN	MWhth	MWhth	MWhf	MWhf	MWhf	BGN	MW	MW
0,429	0,289	685006	2178	1369	4196	1522	5717	685006	0.428	0.825
Fuel price – Cf					Electricity price – Ce					
*low price scenario			61,06	BGN/MWhf	*Mean price – 2 tariffs				140	BGN/MWhel
*high price scenario			73,28	BGN/MWhf	*daytime 157, nighttime 101BGN/MWhel					
Heat price for low and high price scenarios with:										
1. CHEG-only operation				52.05	75.58	BGN/MWhth				
2. CHEG+PB operation				55.53	74.69	BGN/MWhtj				
3. Boiler-only operation				61.06	73.28	BGN/MWhth				

Using the CHEG plant only for heating and DHW purposes depends mainly on the price of natural gas. The baseline scenario meets the economic efficiency criterion, but with high gas prices application of the scheme is economically unviable.

CHEG covers heat, DHW and chilling requirements with trigeneration scheme using an ACM

Table 4. 11. demonstrates the distribution of the heat load between CHEG and the peak boiler to cover the hospital's requirements including the chilling load. A CHEG plant of 500 kW capacity is selected, which covers nearly all the heat load during the summer period.

Table 4. 11.

Mo.	Days	h/mo.	•ttl	•(CHEG)	CHEG	Q(CHEG)	Qttl	Q_{PB}	Q(•••)

			kW	kW	h	• Wh	• Wh/h	• Wh/h	• Wh
1	31	744	871	500	744	372	648	276	0
2	28	672	862	500	672	336	579	243	0
3	31	744	663	500	744	372	494	122	0
4	30	720	306	250	720	180	221	41	0
5	31	744	82	250	209	52	52	0	5
6	30	720	510	250	720	180	191	11	149
7	31	744	948	500	744	372	450	78	425
8	31	744	845	500	744	372	405	33	372
9	30	720	262	250	275	69	69	0	40
10	31	744	292	250	744	186	217	31	0
11	30	720	774	500	720	360	557	197	0
12	31	744	879	500	744	372	654	282	0
Total					7780	3223	4537	1314	992
						ACM electricity consumption			331
						ACM mean electrical capacity			0.04

Table 4. 11. Economic efficiency of CHEG trigeneration plant at MPHAT Dobrich

Qcogeh	Ecogen	Icogen	Q ACM	Q cogen,y	Q pb,y	cogen,y	Fpb,y	F,y	I(ACM)	Ia	Q	Q f
MW	MW •	BGN	MWth	MWhth	MWhth	MWhf	MWhf	MWhf	BGNk	BGN	MW	MW
0,40	0,264	634998	1,15	3223	1314	6182	1460	7642	600	1234998	0,41	0,79
Fuel price - Cf						Electricity price – Ce						
* high price scenario				61,06	BGN/MWhf	* Mean price – 2 tariffs				140	BGN/MWhel	
* low price scenario				73,28	BGN/MWhf	* daytime 157, nighttime 101 BGN/MWhel						
Heat price for low and high price scenarios with:												
1. CHEG-only operation					48,70	72.13	BGN/MWhth					
2. CHEG+PB operation					52,28	72.46	BGN/MWhth					
3. Boiler-only operation					61,06	73.28	BGN/MWhth					

A trigeneration scheme makes CHEG use economically viable even at high natural gas prices.

It should be noted that neither scenarios include investment costs for a peak water-heating boiler, while the second scenario takes into account the significant investment in an ACM system.

4.3.1 Determining the economic efficiency of introducing CHEG in the multi-profile hospitals in Bulgaria

Calculation of the economic benefits derived from CHEG implementation at MPHAT Dobrich lead to the finding that such implementation would be advantageous if a trigeneration technology is used to cover both heat and chill requirements.

The results were proliferated to the multi-profile hospitals in Bulgaria based on the available beds and the bed usage rate (bed-days) as established for MPHAT Dobrich. It has been assumed that the heat load depends on the number of beds and their occupancy rate expressed in bed-days/year, thus the estimated heat load is taken to be proportional to the estimated number of bed-days and to the results obtained from the MPHAT Dobrich case study. Operation of CHEG systems in the Bulgarian multi-profile hospitals will be economically efficient if they implement a trigeneration scheme for production of heat, cold and electricity using CHEG and ACM plants. Introduction of such plants at MPHATs must be preceded by detailed investment analysis for each site. This study uses only one criterion, that is price of the heat energy.

4.3.3 Assessment of CHEG potential and the possibilities for reduction of CO_2 emissions by MPHATs

This assessment looks at a baseline and project scenario as follows:

- ***Baseline scenario*** – covers the hospitals, where CHEG is expected to be economically viable. The baseline scenario calculates their actual heat and DHW requirements, and the related consumption of natural gas for covering such heat and DHW using water heating boilers, on this basis the scenario estimates the greenhouse gas emissions ($\bullet\bullet_2$) from burning the necessary amount of fuel assuming that the efficiency of the water heating boilers in 90%.
  - $\bullet\bullet_2$ emissions from the combustion processes in the water heating boilers ($C\bullet_{2BASE}$) are calculated by the following equation:
    - $\bullet\bullet_{2BASE} = F_{fuel,\ sum} * f_e$, t CO_2/year

    Where: f_e = 247 gCO_2/kWh – emission factor of the natural gas [16]

    $F_{fuel,\ sum}$ = 313 243 MWh/year – total amount of fuel energy in one year;

    Thus $\bullet\bullet_2$ emissions in the baseline scenario are:

    $\bullet\bullet_{2BASE}$ = 77 371 t CO_2/year

- ***Project scenario*** – the multi-profile hospitals are equipped with CHEG plants using a trigeneration scheme.
  - The total amount of heat produced by the CHEG plant, including the heat used for generation of cold is Qcogen,sum.

CHEG operational time is assumed to be 7780 hours in accordance with the calculations for MPHAT Dobrich - T, h/year.

$\bullet\bullet_2$ emissions in the project scenario, i.e. the emissions from CHEG plants and peak boilers ($\bullet\bullet_{2PROJECT}$) are calculated using the dependency:

$\bullet\bullet_{2PROJECT} = F_{fuel,\ sum} * f_e - \bullet_{sum} * f_{el,}$ t CO_2/year,

Where f_{el} = 683 gCO_2/kWh is the emission factor for the electricity produced by the Bulgarian energy system, which will be replaced by the CHEG plant [16];

$F_{fuel,\ sum}$ = 501 746 MWh/year – the total amount of fuel energy in one year;

$\bullet_{sum}$ = 118 419 MWh/year – the total amount of electricity output in one year.

Thus $\bullet\bullet_2$ emissions in the project scenario are:

$\bullet\bullet_{2PROJECT}$ = 123 933 – 101 390 = 22 543 t CO_2/year.

Conclusion:

Theoretically possible, the CHEG potential of residential buildings in Bulgaria has been calculated using the methodology explained above and the existing data about residential buildings. Evaluation of the technical and economical feasibility of CHEG plants in residential buildings relates to technical, economic and investment analysis of the technological schemes for the particular areas and sites - at this point of time this analysis is based on experts' estimates since it is related with town and country planning schemes, which do not include detailed energy masterplans yet.

Development of gas supply infrastructures within the populated settlements largely predetermines the forecasts for installation of cogeneration plants in the public and business sector. The market analysis demonstrates that until 2010 the number of newly-installed cogeneration plants fired by natural gas will not be increasing significantly.

Analysis of the heat consumed in 2007 by non-residential buildings, including businesses and government agencies connected to the centralized heat supply systems, demonstrates that the non-residential sector accounts for 25% of the total heat consumption. On this basis, the market of heat energy for non-residential buildings not connected to centralized heat supply has been estimated to be 865 GWh/year. Taking into account the fact that these buildings have up to 7 floors and that most of them do not have domestic hot water systems, this market can be economically viable for CHEG only in combination with generation of cold for airconditioning purposes during the summer period.

Implementation of energy efficiency measures is likely to lead to a gradual increase of heat demand for heating and domestic hot water supply. The large investment costs, which households would incur, do not create a favourable investment environment for introduction of trigeneration schemes for heat, electricity and cold at locations where cogeneration systems do exist.

5. POTENTIAL FOR COMBINED HEAT AND ELECTRICITY GENERATION IN THE INDUSTRIAL SECTOR

5.1. Potential for using CHEG

When determining the upper limit of the theoretical potential for usage of CHEG plants in the industrial sector, it should be borne in mind that CHEG is appropriate where the heat demand is in the low mean temperature range (heat for hot water, heating and production purposes within the 100-400 ^{0}• temperature range). The value of 82143 TJ/year can be regarded as the upper limit of the theoretical potential for usage of CHEG plants in the industrial sector, however, having regard to the required number of operational hours at full load as shown in Table 5. 1, it would be more credible to set the upper limit at **61607 TJ**. The cost efficiency of a plant largely depends on the extent, to which the required number of operational hours at full load is reached, which in turn depends on the size (capacity) of the plant and the related load pattern. The production cycle has a decisive influence on the technical heat load pattern. Thus, load patterns are more even in enterprises with continuous production cycles and three-shift operations.

In assessing the potential it should be borne in mind that part of the theoretical potential is already covered by existing CHEG plants in some industrial enterprises (table 5.1).

Table 5.1. Heat load coverage by existing Thermal Power Plants (TPPs) in the industrial sector

Industrial sector	Number	Heat consumption	Heat produced by mill-owned TPPs in 2006.	Coverage
				%
Food and beverage	46	4317.5	467.0	10.8
Textile	33	1520.9	-	-
Wood processing	7	1467.7	-	-
Paper and cellulose	7	781.2	591.5	75.7
Chemicals	22	29924.8	13372.2	44.7
Rubber and plastics	7	1304.7	1028.0	78.8
Non-metal minerals	16	5426.7	-	-
Ferrous metals	6	5800.2	4391.1	75.7
Non-ferrous metals	5	2313.7	-	-
Metal products and equipment	44	1248.5	-	-
Coke and refineries	3	7501.6	6031.0	80.4
Total	196	61607.5	25880.8	42.0

During the period under examination, the available heat potential has decreased to **35727 TJ.**

As a next step, the residual potential has been determined for each enterprise included in the database of the Energy Efficiency Agency (EEA) first by calculating the ratio between annual electricity consumption and the annual heat consumption (E/T) and then by classifying the enterprises in the following three groups:

- **• /• < 0.4** – these enterprises have high heat loads and a CHEG plant can be an option either for covering the heat requirement and exporting electricity or for full coverage of the electric load and partial coverage of the heat load. The appropriate option for these enterprises is to cover the full heat load;
- **0.4 < E/• < 1.5** – the option chosen for these enterprises is full coverage of the heat load and partial coverage of the electrical load;

- **•/• >1.5** – these enterprises are excluded from the CHEG potential due to their limited heat load compared to the electrical one.

The classification of these enterprises is presented in table 5.2, which demonstrates that exclusion of the •/• >1.5 group from the total potential reduces the available potential by a further 324557 MWh (1168 TJ) down to **34559 TJ**. This value can be regarded as the economically available potential in the industrial sector. Using the same table, one can also gauge the available electricity production potential – **5434,6 GWh** (19564 TJ).

To determine which configuration is the most suitable to use, the capacity factor of each enterprise was determined and then compared against the minimum capacity factor of each configuration. The enterprises included in the analysis are allocated to the groups of higher heat (electrical) capacity.

Table 5.2. Technically feasible potential

Industrial sector	**Plant, MW, el**				**Total**	
	0,3	**1**	**5**	**20**		
	MWh,el				**GWh,el**	**TJ,el**
Food and beverage	10500	116000	210000	720000	1056.5	3803.4
Textile	7500	112000	105000	180000	404.5	1456.2
Wood processing	0	16000	17500	600000	633.5	2280.6
Paper and cellulose	1500	12000	0	180000	193.5	696.6
Chemicals	0	20000	70000	240000	330	1188
Rubber and plastics	0	0	17500	60000	77.5	279
Non-metal minerals	3000	8000	140000	540000	691	2487.6
Ferrous metals	0	0	0	180000	180	648
Non-ferrous metals	0	0	0	180000	180	648
Metal products and equipment	7500	24000	87500	180000	299	1076.4
Coke and refineries	1500	0	0	0	1.5	5.4
Total	**31500**	**308000**	**647500**	**3060000**	**4047**	**14569.2**

Reduction of the potential for production of electricity to **4047 GWh** is due only to the potential of several chemical, cement and steel enterprises, which have extremely low E/T values and can not be allocated to any of the above groups. A specific feature of these enterprises is that due to their very high absolute consumption of electricity, they should be allocated to a group with capacity greater than 100 MW. This in turn renders them inappropriate for CHEG implementation due to the high level of investments. The above potential is based on the upper limit of the full operational hours required for each configuration.

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Table 5.3. Allocation of enterprises to groups based on the E/T ratio

Industrial sector	Total number	E/T<0,4			0,4<E/T<1,5			E/T>1,5		
		Number	Consumption, MWh		Number	Consumption, MWh		Number	Consumption, MWh	
			• •	• •		• •	• •		• •	• •
Food and beverage	46	24	218190.2	1080206.3	14	73668.6	108435.6	8	29518.0	10660.0
Textile	33	14	44419.5	212882.4	13	110500.3	206887.8	6	45614.7	2712.2
Wood processing	7	4	69100.0	387314.0	2	13170.0	19907.0	1	2600.0	550.0
Paper and cellulose	7	2	2494.0	12830.0	3	94424.6	200329.0	2	46692.6	3840.2
Chemicals	22	11	601513.4	7828201.3	7	362166.0	468173.0	4	56692.2	16075.4
Rubber and plastics	7	3	67661.7	356632.8	0	0.0	0.0	4	23693.5	5791.3
Non-metal minerals	16	14	250072.1	1487313.0	0	0.0	0.0	2	219585.8	20113.0
Ferrous metals	6	1	45706.0	162348.0	2	1743003.0	1438727.0	3	37582.8	10086.0
Non-ferrous metals	5	0	0.0	0.0	3	468607.6	455537.0	2	684000.0	187150.0
Metal products and equipment	44	1	2450.0	7650.0	15	180879.7	271572.8	28	267543.7	67578.6
Coke and refineries	3	0	0.0	0.0	3	1086546.0	2083774.0	0	0.0	0.0
Total	**196**	**74**	**1301606.9**	**11535377.8**	**62**	**4132965.8**	**5253343.2**	**60**	**1413523.3**	**324556.7**

5.2. Investments for development of the retrofitting potential

Seen from the age breakdown table, more than 75% of the CHEG plants in the industrial sector are older than 25 years.

Table 5.4. Age structure of HEPs and TPPs in the industrial sector in 2005

	> 35 years	31-35 years	26-30 years	21-25 years	16-20 years	< 15 years
HEPs, %	59,0	0,7	19,2	6,0	15,2	0
Industrial TPPs, %	41,2	33,0	1,0	12,4	5,0	7,4

Despite the advantages offered by CHEG plants (lower $\bullet\bullet_2$ emissions and primary energy savings), in respect to each industrial site the decision to invest in CHEG largely depends on whether the annual energy costs of the enterprise will be reduced or otherwise. A new CHEG plant would be installed only when the investment buyback period is short enough and the project risk is manageable. A technically acceptable and feasible project can also be advantageous only if the economic terms are favourable. Such projects often do not come to fruition because they are less advantageous than other projects of the enterprises, which are aimed at development and growth of the core business, promise higher profit, contain less inherent risks and can be readily implemented without having to overcome various administrative and market barriers. An investor would venture a CHEG plant only if the rate of return of such investment is high enough and the risk is acceptable compared to the alternative option of investing in a heat-only boiler and outsourcing all electricity required. For this reason CHEG investors demand higher return on the invested capital than enterprises, whose main business is the production of electricity.

The main advantages of a CHEG plant compared to a heat-only boiler and outsourcing the electricity needed are:

- lower energy costs;
- generation of income from sales of electricity and/or heat;
- control on the production of electricity.

On the other side, the risks are:

- volatile fuel prices (especially natural gas prices);
- uncertain market developments and electricity sales prices.

The industrial potential can develop in two directions:

1. Commissioning of new plants;
2. Rehabilitation of existing plants by:

- Integration of additional gas turbines - upstream gas turbine, economizing boiler with make-up (additional) combustion; parallel steam feed to the steam turbine from the main steam generator and from the economizer of the gas turbine; if the equipment is beyond its service life it is possible to replace the main steam generator with economizers;
- Retrofitting of the steam turbines in order to increase their electrical efficiency.

Retrofitting and renovation of industrial TPPs is indispensable, because during the next 5 to 10 years up to 50% of the equipment will have exceeded its service life or will be much more inefficient compared to the new technologies. Many studies demonstrate that investing in a CHEG plant is a profitable venture if electricity prices are high. At the present levels of fuel prices, a plant fired by natural gas is the preferred option.

Potential development barriers can be:

- barriers of investment nature – lack of capital and market liquidity due to identified risk of making strong investments in the sector;
- capital-related barriers – insufficient working capital of the investor, the requirement for 40-50 percent of own contribution; generally a CHEG investment is off the mainstream of the company's core business;
- technological barriers – non-availability of own infrastructure and staff for implementing such a project;
- administrative barriers.

To determine the investments required for realization of this potential, it is first of all necessary to define the capacity of each configuration. Table 5. 5 demonstrates that industry as whole can realize an additional potential of ca. **1,2 GW_{el}**.

Table 5.5. Potential for implementation of new CHEG plants

Industrial sector	***Plant capacity, MWel***				***Total***
	0.3	***1***	***5***	***20***	
Food and beverage	2.1	29	60	240	**331.1**
Textile	1.5	28	30	40	**99.5**
Wood processing	0	4	5	180	**189**
Paper and cellulose	0.3	3	0	40	**43.3**
Chemicals	0	5	20	80	**105**
Rubber and plastics	0	0	5	20	**25**
Non-metal minerals	0.6	2	40	180	**222.6**
Ferrous metals	0	0	0	60	**60**
Non-ferrous metals	0	0	25	40	**65**
Metal products and equipment	1.5	6	15	20	**42.5**
Coke and refineries	0.3	0	0	0	**0.3**
Total	**6.3**	**77**	**200**	**900**	**1183.3**

Taking into account the specific investment costs for each plant, the overall investment requirement for new CHEG plants in the industrial sector comes to ca. EUR 1 billion (see table 5.6). This estimate can be regarded as an approximate one since the specific circumstances vary between enterprises even in the same industrial branch and investments can vary substantially from the baseline values. At this point it should be added that according to our own estimates retrofitting of the existing plants will require additional investments in the range of EUR 0.3bn.

Table 5.6. Size of the investments in new CHEG plants

Plant, MW_{el}	0.3	1	5	20
Investments, EUR million	8.19	77	160	738

5.3. Primary energy and CO_2 savings

Using the additional CHEG potential in the industry will lead to primary energy and • •$_2$ savings. These savings are evaluated by comparing them against the separate production of electricity and heat. In making the calculations it is assumed that introduction of CHEG systems will replace part of the electricity produced at an efficiency rate of 37.3 %. As concerns the heat-only production, it is assumed that the heat is generated by a gas-fired steam generator with efficiency rate of 90 %. The specific emission rate of the natural combustion process is 247 gCO_2/kWh [16].

Table 5.7. Primary energy and CO_2 savings

Plant capacity	MW_{el}	0,3	1	5	20
Primary energy savings	MWh	48189.4	451256.6	999095.1	4544751.6
	TJ	173.5	1624.5	3596.7	16361.1
• •$_2$ emissions savings	• t	0.012	0.111	0.247	1.122

Table 5.7 demonstrates that realization of the potential for introduction of CHEG plants in the industrial sector can save up to **2.2 • t** of CO_2 emissions and decrease the consumption of primary energy sources by up to **22 PJ** per annum.

5.4. Estimated CHEG potential of the industrial sector by 2020

The future development of the CHEG potential in the industrial sector will depend on the development of demand for heat in the temperature range, which is suitable for use of CHEG. To determine the future potential, it is important to know the future development of industrial production in each branch as well as the eventual structural changes in the industry as a whole. The analysis becomes even more complicated due to the need to take into account additional factors such as changes in final energy consumption and final energy intensity as well as the increasing energy efficiency and productivity of labour.

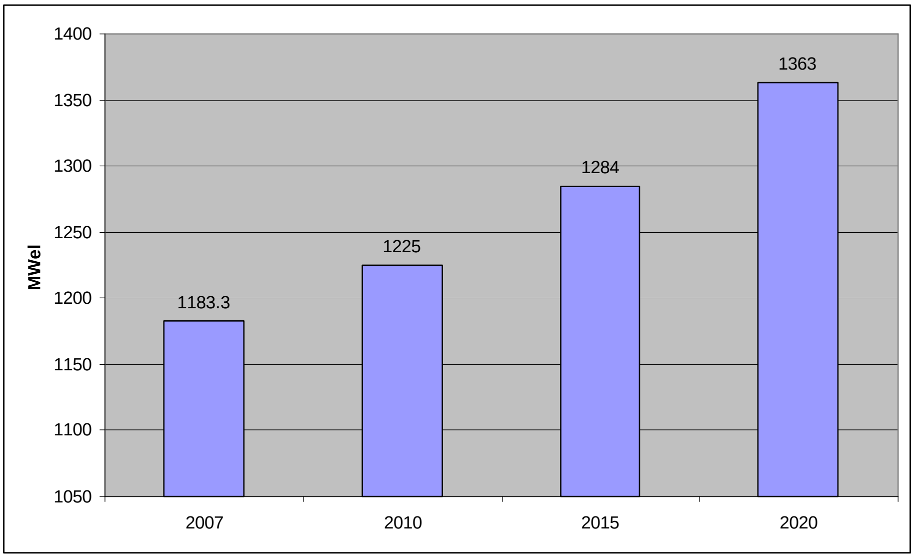
Based on the projected growth of Gross Value Added (GVA) in the industrial sector, the established trends during the period 1997-2003 and the average European level, the National long-term energy efficiency programme estimates the Final Energy Intensity (FEI) of the industry by 2015. After a slight increase in the beginning of the period, FEI is expected to continually decrease after 2004 down to 0.24 koe/€00p in 2015. Then, the Final Energy Consumption (FEC) is estimated on the basis of GVA and FEI predictions for the industrial sector. The result is that FEC in the industrial sector is expected to grow by 4.8% per annum. Based on the so established FEC values, it has been estimated that, within the overall structure of the fuel mix, during the period 2005-2013 there will be a slight decrease of the share of liquid fuels (from 24.2% to 23.4%) and of heat energy (from 8.6% to 7.4%), while the share of timber/wood is set to increase slightly (from 2.4% to 4.4%).

According to NSI statistics for the energy balance of Bulgaria, in 2004 FEC decreased by 3.3 % vs. 2003 and increased in 2005 by about 0.4 % vs.2004, but still remained below the 2003 level. During the same period, the relative weight of the industrial sector in the overall FEC structure decreased from 38,3 % to 36,9 %. The total consumption of heat in 2006 grew by 5.2 % vs. 2005 (NSI). During the same period the industrial sector increased its consumption of heat by about 9.5%. The greatest contributors to this growth are the following industries: foods and beverages, coke and crude oil refining and processing of non-metal minerals. At the same time, one of the most energy-intensive industries - steelmaking and foundry, dropped by about 63%. On this basis it can be predicted that the future growth of heat demand in the industry as a whole will be driven by the abovementioned sectors, bearing in mind however that the coke and oil refining sector is already saturated with CHEG plants, which have the capacity to cover the increased demand.

Our own estimate of the future heat requirements in the various industrial sectors is based on the following parameters:

- Heat demand in the food and beverage sector and in the sector for processing of non-metal minerals will be growing by 5.5 % per annum until 2010, by 4% per annum until 2015 and by 3% per annum until 2020.
- Heat demand in the other sectors will be decreasing by 3 % per annum until 2015 and by 2% per annum until 2020.

The combined impact of these trends shown in the chart below.



By the end of 2020 the potential for introduction of new CHEG plants is expected to grow by 15% and reach 1363 MW_{el}.

6. BIOMASS AS A POTENTIAL ENERGY SOURCE FOR COMBINED HEAT AND ELECTRICITY GENERATION

6.1. Technical potential wood biomass from the forest industry

The technical potential of biomass in the form of timber waste and firewood during the period 2002 - 2006 is shown in fig. 6.1.

The following calorific values have been used for assessing the energy potential of timber [21, 23] at mean moisture content of 40 %:

- Deciduous timber (beach, oak, hornbeam) - 15 GJ/t ;
- Coniferous timber (spruce, pine, fir) - 16 GJ/t .

The actual heating effect depends first and foremost on the moisture content of the timber material. The best-burning material is dry wood with moisture 15-20 %, which can be achieved after storage at a dry place for 1 or 2 years. The density, expressed in kg/m^3, depends on the type of timber material. Hardwood (beach, oak, hornbeam, acacia, ash-tree) is denser than softwood (spruce, pine, poplar, willow). The following density values have been used for evaluating the energy potential of timber biomass:

- Deciduous timber (beach, oak, hornbeam) - 600 kg/m^3;
- Coniferous timber (spruce, pine, fir) - 450 kg/m^3.

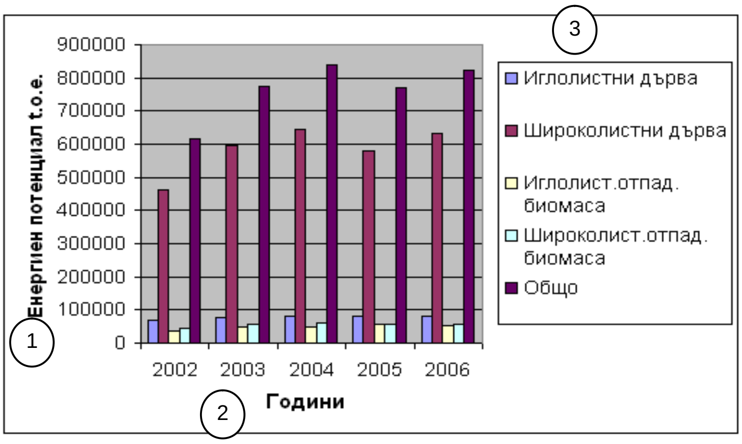


Fig. 6.1.Technical potential of timber-derived biomass in t.o.e. during the period 2002-2006

Legend:
1......Energy potential, t.o.e.
2......Years
3......Top to bottom: coniferous timber, deciduous timber, confiferous waste, deciduous waste, total

A large portion of the potential, mainly firewood, is used for energy purposes. Each year this saves vast amounts of coal, heating oil and electricity. To a large extent, this potential can be used for installation of heat and electricity cogeneration plants. This process should be managed very professionally to avoid affecting the social interests of a large strata of the population in supplying them with heating fuel.

6.2. Technical potential of forest wood biomass by Regional Forestry Boards

Regional Forestry Boards (RFBs) are specialized territorial divisions of the National Forestry Board, they are responsible for managing the state-owned forests and for controlling other forests and forest lands, as well as the state-owned forest farms and game-breeding farms in the territory of the Republic of Bulgaria. There are 16 RFBs: Berkovitsa, Blagoevgrad, Bourgas, Varna, Veliko Tarnovo, Kystendil, Kardjali, Lovech, Pazardjik, Plovdiv, Rousse, Sliven, Smolyan, Sofia, Stara Zagora and Shoumen. All Regional Forestry Boards are mapped in fig. 6.2.

Fig.6.2. Map of Regional Forestry Boards

By their functions, forests and forest lands are classified as felling and environment-building forests and lands, protective and reactive forests and forest within protected areas. Depending on their owner, the forests can be state-owned, private, forests belonging to the Ministry of Environment and Waters and forest belonging to legal entities and religious organizations. Regional Forestry Boards keep registers of all forests and forest lands, including details of their owners, area, type and any changes occurring with these forests and lands. The main objective of Regional Forestry Boards is management and preservation of forests by environmentally responsible usage of the forest resources. Afforestration is also a priority of Regional Forestry Boards. Mainly local tree species are used for aforestration and are planted in areas planned in advance or devastated by wildfires as well as after sanitation felling and also for assisting the renovation of forests. Fig. 6.3 presents the energy potential of RFBs in 2006. The chart shows that the areas around large cities such as Sofia, Plovdiv, Varna, Bourgas, etc. possess a significant potential of timber biomass. These data sets can be used in the elaboration of projects for construction of heat and electricity cogeneration plants in the large cities of the country.

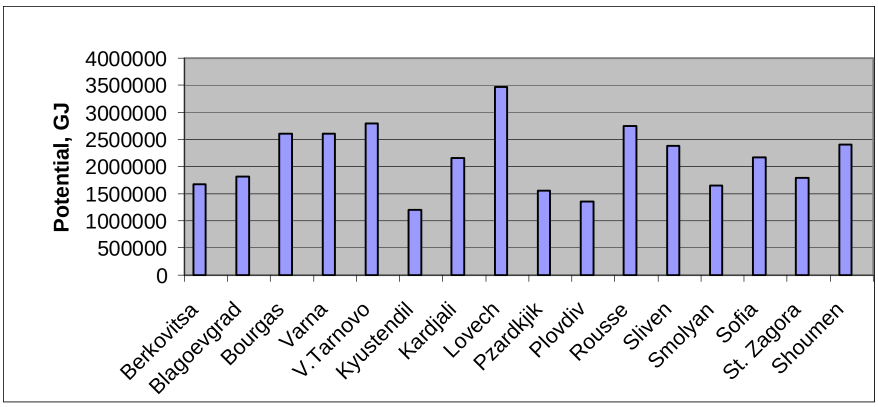


Fig. 6. 4. Energy potential of RFBs in 2006

6.3. Timber production estimates by 2015-2020

Timber volumes produced in Bulgaria equal 50% of the total annual growth of Bulgarian forests. Each year timber production is regulated by forest management plans. During recent years, the amounts actually produced have been between 86 and 92 % of the volumes envisaged in the forest management plans. These circumstances, together with the better utilization of forest derived biomass, allow for production of additional amounts of timber until 2015. The National strategy for sustainable development of the Bulgarian forest sector 2006 - 2015 [26] envisages that timber production will reach 7 500 000 m^3 in 2015 and 8 500 000 m^3 by 2020. According to the predictions, to ensure maximum sustainable forest use, timber production should reach 8 301 000 m^3 in 2010, 8 587 000 m^3 by 2015 and 8 825 000 m^3 by 2020 [29]. If these predictions are realized in practice, the volumes of firewood and waste biomass will maintain their levels. Based on these assumptions, an estimate has been made of timber production volumes and of the technical potential of biomass as a energy source up to 2015-2020 - see Fig. 6.5 below.

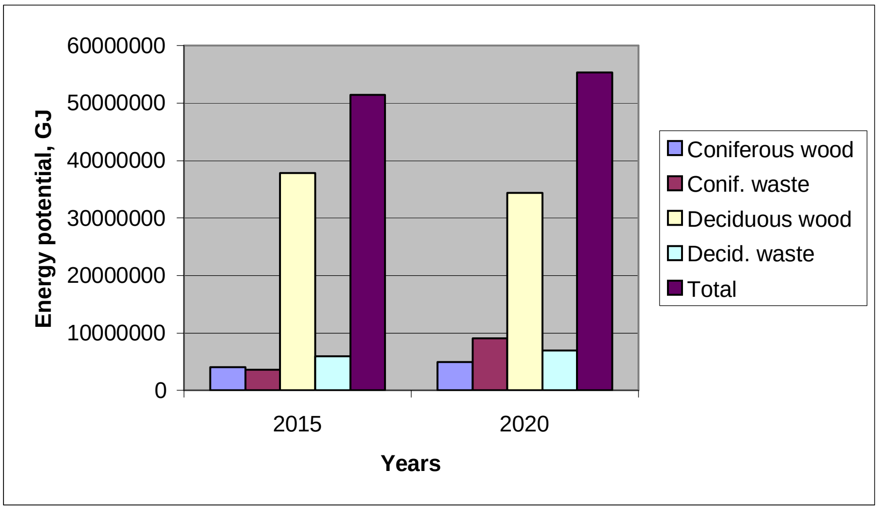


Fig. 6. 5. Technical potential of biomass as an energy source, 2015 - 2020

6.4. Biomass potential of the wood processing industry

Timber processing at woodworking and furniture factories generates various waste materials, which in many cases are used for energy purposes. Wastage levels in sawmills are 28 – 46%. Yields in the veneer industry are relatively low - between 38 and 48% and are determined by the primary material. Wastage levels in the other wood processing industries are between 7 and 23%. Generally, the waste materials from the wood processing industries are used for the energy requirements of the plants as well as for firewood by the population. No use is made of the soft waste (saw dust, grinding dust, shavings, etc.). These are realistic options for efficient energy use mainly in the form of energy chips and pellets.

The technical potential of many large wood processing mills and factories is a very good basis for evaluation, design and construction of heat and electricity cogeneration plants. They can be very efficient since the production process of these mills and factories is related to year-round use of heat (steam, hot water) and electricity. Presently, heat is obtained by combusting the mill's own timber biomass in conventional boilers of low efficiency. Some mills have boilers rated 10 – 12 MW.

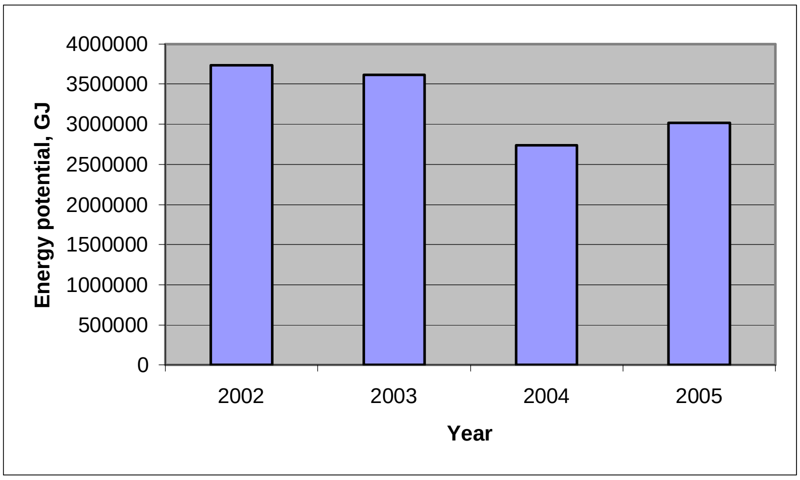


Fig. 6.6. Technical potential of biomass from the wood processing industry, GJ, 2002-2005

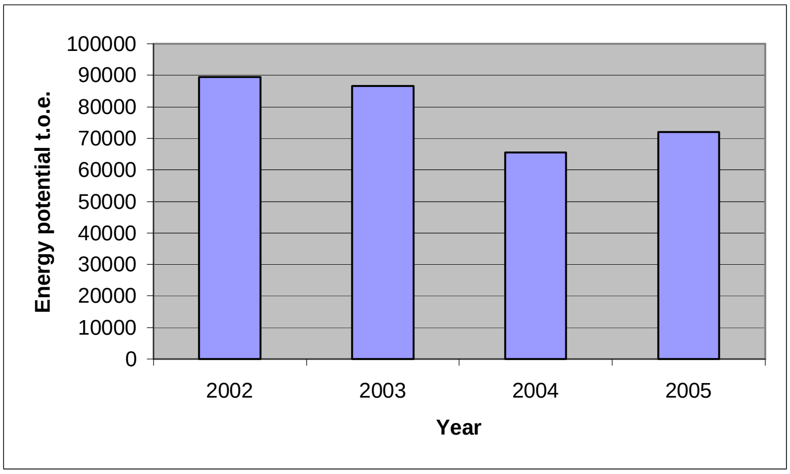


Fig. 6.7. Technical potential of biomass from the wood processing industry in crude oil equivalent, t.o.e., 2002-2005

6.5. Agricultural biomass potential

The Republic of Bulgaria has 6 planning regions corresponding to level 2 of the European Nomenclature of territorial statistical units (NUTS 2):

- Northwest planning region comprising the districts of Vidin, Vratsa and Montana;
- Central North planning region comprising the districts of Rousse, Veliko Tarnovo, Gabrovo, Pleven and Lovech;
- Northeast planning region comprising the districts of Varna, Targovishte, Shoumen, Razgrad, Silistra and Dobrich;
- Southwest planning region comprising the city of Sofia and the districts of Sofia, Kyustendil, Blagoevgrad and Pernik;
- Central South planning comprising the districts of Plovdiv, Kardjali, Haskovo, Pzardjik, Smolyan and Stara Zagora;
- Southeast planning region, comprising the districts of Bourgas, Sliven and Yambol.

Based on 2005 statistics for the planning regions [7], Fig. 6.8. and Fig. 6.9 summarise the energy potential of agricultural biomass for these six planning regions.

Resources of maize stems are mainly concentrated in two regions: Northeast and Northwest.

Many companies in the energy sector, learning from the experience of EU Member-States such as Denmark, Germany, Italy, etc. and taking into account the available agricultural biomass resources, are considering installation of local boilers for the farmers' own requirements. Boilers fired by baled straw and chipped agricultural biomass have been adopted. Studies are under way for installation of straw-fired cogenerators near the cities of Varna and Nikopol.

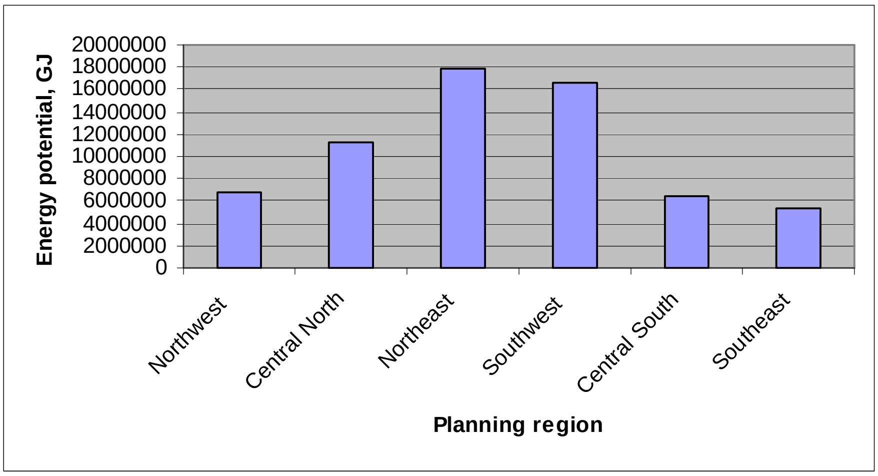


Fig. 6.8. Energy potential of agricultural biomass by planning regions, GJ

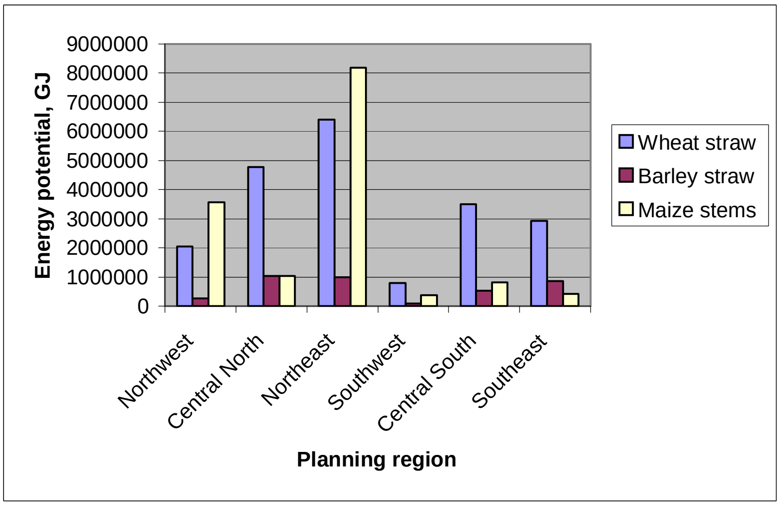


Fig.6.9. Energy potential of straw and maize stems by planning regions, GJ

6.6. Summary of biomass potential as a primary energy resource

The potentials of timer/wood-processing biomass and biogas in 2006, and of agricultural biomass in 2005, are presented in table 6.1 and Fig. 6.10.

Table 6.1. Summary of the biomass technical potential by biomass types

No.	Type of biomass, product	Energy potential	
		GJ /year	t.o.e.
1	Forest derived biomass	34436710	823037
2	Biomass derived from the wood processing industry	3017015	72107
3	Biomass derived from the agricultural sector	45419719	1085351
4	Biogas	2929077	70000
5	**Total**	**85802521**	**2050495**

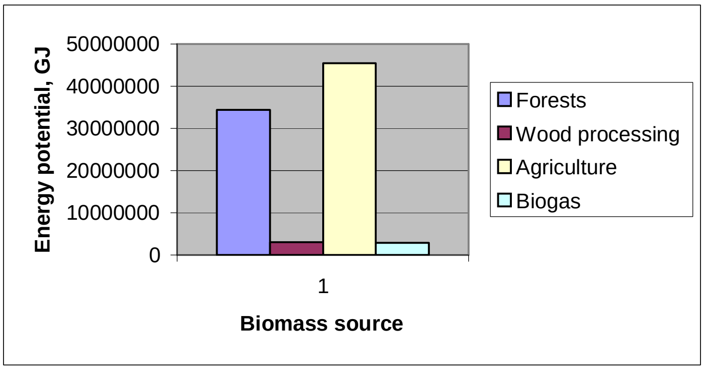


Fig. 6.10. Summary of the biomass technical potential

6.7. Residential urban waste as a potential energy source for combined heat and electricity generation

The technical, economic and investment potential of using urban residential waste for production of heat and electricity refers to the residential waste of Sofia.

The utilization of residential waste in Sofia for energy purposes has been evaluated on the basis of the results provided by Consortium FICHTNER in their Feasibility study and supporting documents for project: „Management of the residential waste of Sofia Municipality" for funding by EU funds, in particular Interim report on Task 4 „Future waste management system", February 2008 [11].

Consortium FICHTNER have considered the following four alternatives:

Alternative 1

- Reduce and stabilize the waste currently generated by Sofia, now between 470 000 and ca. 640 000 MT/year, to about 300 000 MT/year for final disposal in landfills by recycling and compositing part of the waste. This alternative does not envisage incineration of and energy generation from any part of the urban waste.

Alternative 2

- The second alternative also proposes mechanical and biological treatment of the waste, but also production of highly calorific Refuse Derived Fuel (RDF) and disposal of the stabilized refuse in landfills. With this alternative 400 000 MT will be processed, of which 30 000 MT will be recycled, 90 000 MT RDF of calorific value 17 000 kJ/kg will be obtained, 50 000 MT of low-quality compost will be produced and 150 000 – 180 000 MT will be disposed in landfills. The waste treatment process will consume energy with capacity 56 MW_{th}.

Alternative 3

- After the mechanical and biological treatment, this option proposes maximum production of RDF and disposal of the inert residue. It is proposed to produce 190 000 – 210 000 MT of RDF with calorific value 14 500 kJ/kg and 13500 kJ/kg respectively, plus additional energy and disposal costs for 70 000 – 80 000 MT inert waste, 20 000 MT slag and 20 000 MT dust and ash from the boiler's waste treatment equipment.

Alternative 4

- This option does not envisage any biological treatment, instead the biodegradable content in the refuse will be destroyed thermally to produce energy.

  This scenario is compliant with the Landfill Directive. Following separation, recycling and composting, the residential refuse will be incinerated. Only 85 000 MT slag and 25 000 MT dusts from the incinerators' waste treatment system will be disposed in landfills.

The first alternative is not analysed since it does not envisage that any refuse will be incinerated.

The second alternative envisages utilization of 90 000 RDF in a cement plant. This study examines the option of burning this fuel in a Thermal Power Plant (TPP) in Sofia. The plant uses a Rankin cycle grille boiler /40 bar 400 ˚•/ and condensing steam turbine with extractions – 10 MWel and 35 MWth.

Electricity output is limited, while heat output is satisfactory (table 6.5). Provision is made for limited makeup combustion of natural gas. The overall energy efficiency and primary energy savings are high and meet the requirements of the Cogeneration Directive 2004/8/••.

The analysis does not take into account any potential schemes for providing investment support to the future investor.

Alternative 3 is further elaborated by examining three scenarios:

- FICHTNER have considered a Rankin cycle plant with low steam parameters and capacity 12 MWel / 60 MWth (table 6.5) with limited electricity and satisfactory heat output, the energy efficiency values being lower than those required by Directive 2004/8/••.
- This study analyses the same cycle, but adding natural gas to the combustion process - 15 % of all the fuel consumed, increasing the electrical capacity to 20 MW_{el} and keeping the heat capacity unchanged at 60 MW_{th}. Again, this scenario fails to meet the energy efficiency requirements of Directive 2004/8/••.
- To increase the economic efficiency with the same amount of fuel - 210 000 MT, it is proposed to use a scheme with higher steam ratings /100 bar and 540 ˚•/. The grille boiler, which will incinerate the RDF, is for saturated steam to avoid high-temperature chlorine corrosion, and the steam will be superheated in a separate superheater using gases from a gas turbine. This scheme increases the electrical and heat capacity to 50 MW_{el} and 83.7MW_{th} respectively. Additional amounts of gas will be combusted in the steam superheater for the superheated steam to reach the rated parameters. Energy efficiency and primary energy savings exceed the referential values laid down in Directive 2004/8/••, i.e. all the electricity produced will be certified and will benefit from a preferential purchase price. These results clearly demonstrate that the scenario can be economically and financially viable, at the assumption made in the beginning, only if an appropriate system of stimuli is applied (preferential electricity purchase tariffs, financial support for the investment, advantageously priced RDFs, etc.).

Alternative 4 is also developed further by proposing three production schemes:

- Based on the data of FICHTNER it is possible to use a Rankin scheme for an energy boiler /40 bar and 400 ˚• / and a steam turbine of electrical capacity 15,5 MW_{el} and heat capacity 76

MW_{th}. The electricity output will be limited and indeed only 48% of the electricity will be certified. Energy efficiency is below the referential values laid down in Directive 2004/8/• •.

- Options with high steam ratings and inclusion of a gas turbine in the scheme are proposed to solve these difficulties. With this scheme an 150 t/h energy boiler and a 33.58 MWel gas turbine, with combustion of 10% additional fuel, will drive a 40 MWel steam condensing turbine, thus producing four times more electricity. The energy efficiency is lower than the standard set forth in the Directive, that is why only 69.5% of the electricity will receive a certificate and preferential price.
- Instead of one 150 t/h boiler, it is proposed to install two 90 t/h boilers, two gas turbines rated 22.35 MWel each with combustion of 10% additional fuel, and two steam turbines rated 17.7 MWel each. This scheme meets the requirements of the EU Directive and all the electricity produced will receive a certificate and preferential price.

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Table 6. 2. Key technical and economic parameters

No.			Alternative 2		Alternative 3			Alternative 4		
			Fichtner	SOFIA 2.1	Fichtner	SOFIA 3.1	SOFIA 3.2	Fichtner	SOFIA 4.1	SOFIA 4.2
1	Amount of solid waste	MT/year	90 000	90 000	210 000	210 000	210 000	400 000	400 000	400 000
2	Operational calorific value	kJ/kg	17 000	17 000	13 500	13 500	13 500	9 000	9 000	9 000
3	Residue for final disposal	MT/year		18000	20 000	20 000	20 000	85 000	85 000	85 000
4	Residue for neutralization	MT/year		9000	20 000	20 000	20 000	25 000	25 000	25 000
5	Daily transport of fuel	MT/day	288	288	672	672	672	1 280	1 280	1 280
6	Daily transport of slag	MT/day		58	64	64	64	272	272	272
7	Daily transport of hazardous waste	MT/day		29	64	64	64	80	80	80
8	Steam boiler capacity	t/h		52.8	92	116	116	2 • 75	150	2 • 90
9	Steam ratings	pressure/temp		40/400	40/400	40/400	100/540	40/400	100/540	100/540
10	Electrical capacity of the scheme	MW		10	12	20	50	15.5	70.8	80
11	Heat capacity of the scheme	MW		35	60	60	83.7	76	90	116
12	Electricity output	MWh	0	74 000	90 000	138 500	378 400	116 000	438 000	600 000
12.1	Electricity from CHEG	MWh	0	74 000	60 000	97 650	378 000	56 000	304 517	600 000
13	Electricity sold	MWh	0	72 000	85 500	135 000	370 000	110 000	427 000	585 000
14	Heat output	MWh	0	276 000	450 000	525 600	643 500	570 000	622 800	975 500
15	Heat released	MWh	0	261 000	400 000	450 000	595 500	500 000	575 000	880 000
16	Fuel consumption	MWh		420 990	787 350	932191	1285740	1139550	1597593	1962320
17	Incl. consumption of natural gas	cbm '000		8 716	0	15 570	53 577	0	64241	103450
18	Energy efficiency	%		79.57	62.23	63.13	75.75	61.6	63.4	75.42
19	Primary energy savings	%		26.77	14.01	13.08	29.86	8.2	18.96	22.87
20	Investment costs	EUR million		55	107	98	130	183	170	193
		EUR /kW		5500	8917	4900	2600	11806	2401	2413
21	Operational and maintenance costs	EUR million		7.3	17	16	21.7	27	26.4	33
	Including depreciation	EUR million		3.7	7	6.5	9	13	11.4	13
	Labour, consumables and other costs	EUR million		3.6	5.7	5.5	9	9	10	15
	Disposal of hazardous and other waste	EUR million		0	4.3	4	4	5	5	5
2	Fuel income/costs	EUR million		Cost 0.66	Income 4.2	Income 0.6	Cost 7.9	Income 12	Cost 2.78	Cost 11.8

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7. ANALYSIS OF THE BARRIERS TO HEAT AND ELECTRICITY COGENERATION AND MEASURES FOR OVERCOMING THESE BARRIERS

7.1. Analysis of the national policy for support of high-efficiency heat and electricity cogeneration and of the potential legal barriers to its development

The national policy for supporting the high-efficiency cogeneration of heat and electricity has been developed in on the basis of Directive 2004/8/• • of the European Parliament and of the Council of 11 February 2004 on the promotion of heat and electricity cogeneration, and is also regulated in the Energy Act, in the Ordinance on the determination of the amount of electricity produced by combined heat and electricity production systems and the Ordinance on the issuance of certificates of origin for electricity obtained from renewable energy sources and/or by using cogeneration methods.

I.* THE ENERGY ACT, *published in the State Gazette (SG) no. 107/2003, amended SG no. 18/20, amended SG no. 18 and 95/2005, amended SG no. 30, 65 and 74/2006

Bulgaria, in the face of the Ministry of Energy and Energy Resources (MEER), undertook measures to harmonize the Bulgarian legislation with Directive 2004/8/• • of the European Parliament and of the Council of 11 February 2004 on the promotion of heat and electricity cogeneration yet before the Directive was finally adopted by transposing its major provisions in the Energy Act, which was adopted in December 2003 and subsequently amended several times, the last amendment being in force since September 2006.

The Energy Act established a framework, which supports and facilitates the development of heat and electricity cogeneration as a generally recognized form of efficient and environmentally responsible method of power production. The Act is based on Directive 2004/08/• • and still takes into account the specific energy structure and energy development strategy of Bulgaria.
The main preferences, which the Energy Act offers for promotion of cogeneration, are along the following lines:

- Purchase of the electricity produced by cogeneration plants;
- Pricing of the electricity produced by cogeneration plants;
- Construction of cogeneration plants;
- Connection of cogeneration plants to transmission and distribution systems.

The main incentives in these main areas are detailed below:

1. Preferential terms of purchasing the electricity produced by cogeneration plants

Both the previous and the present Energy Act obligate the public supplier and accordingly the final suppliers of electric energy to purchase all the electricity produced by heat and electricity cogeneration systems, if it possesses a certificate of origin, except the volumes, which the producer uses for own purposes or for placement in the free electricity market.

Taking into account the specificity of the national energy structure and the fact that the presently operated cogeneration plants were built in the 1970's and their renovation requires significant financial resources, Bulgaria availed itself of the liberty, which Directive 2004/8/• • provides to each Member-State to select various support mechanisms, and adopted a transitional period for the existing plants. Until 1 January 2010 it is mandatory to purchase their cogenerated electricity even if the high efficiency criteria are not satisfied.

This measure dismantled one of the barriers, which hindered the accumulation of sufficient financial resources for retrofitting of cogeneration plants in Bulgaria.

2. Preferential terms of pricing the electricity produced by cogeneration plants

The cogeneration support approach of the Energy Act 2003 envisaged two types of incentives in two consecutive phases. At phase 1 the electricity generated by high-efficiency cogeneration technologies had to be purchased obligatorily at preferential prices. Subsequently, a system for issuance of and trade in green certificates had to be established as this system was regarded to be better suited to the liberalized energy market.

The following measures were envisaged in the framework of the two the support phases:

<u>Phase 1</u>

Mandatory purchase of the electricity produced by heat and electricity cogeneration systems, if it possesses a certificate of origin, except the volumes, which the producer uses for own purposes, for contracting at freely negotiated prices or for participation in the balancing electricity market.

The electricity was purchased with the following terms:

1. at preferential prices for the volumes produced by each plant of the producer, up to 50 MWh per hour;

2. at negotiated and/or balancing market prices for the volumes produced by each plant of the producer in excess of 50 MWh per hour.

The preferential price of the cogenerated electricity had to be at least 80% of the average sales price charged to residential users in the country during the previous calendar year**.**

It was envisaged that mandatory purchase of electricity at preferential prices would apply until the establishment of a system for issuance of and trade in green certificates.

<u>Phase 2</u>

The Minister of Energy and Energy Resources had to determine minimum volumes of electricity from high-efficiency cogeneration systems for each producer, expressed as a percentage of the producer's total electricity output and for a period of 10 years after the establishment of a system for issuance of and trade in green certificates.

This obligation of the producer was to be considered discharged if the producer presented to the State Commission of Energy and Water Regulation (SCEWR) green certificates for the volumes of electricity from high-efficiency cogeneration systems, which the producer was obligated to produce, and these certificates could have been:

1. Issued directly to the producer; and/or

2. Purchased from another producer of electricity, provided that the purchase and sale contract is valid only if entered in a register.

Limiting the preferential regime to 50 **MW**, which was envisaged in the 2003 Energy Act, created conditions for discrimination between the various producers of cogenerated electricity. This cap of the support provided by Member-States indeed existed in the draft Directive, but was removed by the European Commission after strong criticism by the European Parliament and the Council.

To fully harmonize Bulgaria's legislation with that of the EU and to ensure respect for the principle of equality between all energy producers, this barrier was also removed and does not exist in the present Act.

The European Commission's report on the implementation of the requirements of Directive 2001/77/• • , published in December 2005, highlights the fact that preferential pricing systems lead to much faster growth of RES investments compared to green certificates trading systems, which lead to higher profits for investors in the short-term, but are much more insecure in the long term.

To remove this kind of barrier to the development of electricity cogeneration and to ensure predictability of the investments, par. 105 of the Energy Act was amended in September 2006 such that the preferential purchase prices of cogenerated electricity will be determined on annual basis until 31.12.2019.

The existing scheme is as follows:

1. The mandatory purchase of electricity produced by high-efficiency cogeneration systems at preferential prices will exist for a period of 8 years starting from 8 September 2006 and will apply to the producers existing at that date.

2. For electricity producers that start high-efficiency cogeneration of electricity after 08.09.2008, the eight-year period will begin to count from the respective start date, but not later than 31 December 2011.

3. By 31 December 2011 the Minister of Economy and Energy must propose to the Council of Minister for their approval a draft law introducing a market mechanism for promotion of electricity cogeneration.

4. The preferential selling prices of electricity from cogeneration plants built by 31.12.2011 will apply until 31 December 2019 and will be determined by SCEWR in accordance with the Price Regulation Ordinance.

The preferential prices of cogenerated electricity produced by electricity and heat generation plants are determined **on the basis of the individual production costs plus a margin determined by SCEWR** for the various producers on the basis of criteria laid down in the Price Regulation Ordinance issued under Art. 36(3) of the Energy Act.

The criteria used for determining the groups of producers and the respective margins are:

1. Prevailing use of the main heat load - for production purposes or for heat and HDW (hot domestic water);

2. Type of the fuel used;

3. Cogeneration technology;

4. Plant/installation capacity.

3. Preferences for construction of cogeneration plants

The Act contains a special provision, according to which if there is an established need for additional heat energy, all new plants rated 5 MW or more and using natural gas must implement the principle of combined generation of heat and electricity.

4. Connecting with all priority plants

1. The transmission operator and all electricity distribution operators must connect with all priority plants that generate electricity using high-efficiency cogeneration systems with rated capacity up to 10 MW.

2. Extension and reconstruction of the lines/systems related with the connection of such plants is the responsibility of the transmission or distribution operator, as the case may be.

3. To accomplish such extension/reconstruction of the lines/systems, the transmission and/or distribution operator is entitled to apply for external financing.

II. ORDINANCE on the determination of the amount of electricity produced by combined heat and electricity production systems

The ORDINANCE on the determination of the amount of electricity produced by combined heat and electricity production system was developed on the basis of Directive 2004/8/EC and in particular Annexes II and III*.*

In March 2008 the Ordinance was amended in order to be harmonized with the Directive. The main criteria used by the previous and current Ordinance for determining the volumes of cogenerated electricity and certifying such electricity as a high-efficiency one are explained below.

Criteria for determining the amount of cogenerated electricity:

Ø *Former legal basis*

The gross electricity output of the plant is recognized as cogenerated, if the reported **total energy efficiency** of fuel consumption is equal to or greater than:

75 %, for:

- counter-pressure turbines
- steam extraction turbines using coal and/or RES as boiler fuel
- mictroturbines, Stirling engines, fuel cells, steam machines, Rankin organic cycles

80%, for:

- steam extraction turbines using natural gas or liquid boiler fuels
- steam-gas cycles, gas turbine installations and internal combustion engines

Ø *Current legal basis*

The gross electricity output of the plant is recognized as cogenerated, if the reported **total energy efficiency** of fuel consumption is equal to or greater than:

75 %, for:

- counter-pressure turbines
- steam extraction turbines using coal and/or RES as boiler fuel
- gas turbines with economizing boilers
- internal combustion engines
- microturbines
- Stirling engines
- fuel cells

80%, for:

- steam extraction turbines using natural gas or liquid boiler fuels
- steam-gas cycles

Criteria for high-efficiency production

Ø *Former legal basis*

The combined production of heat and electricity is a high-efficiency one, if the **fuel savings** compared to the fuel necessary for separate production of the same amounts of heat and electricity is not lesser than:

1. **5%, for plants:**

    - ***built before 12 December 2003***

    - using RES and/or ***with single electrical capacity up to 1MW***

2. **10%, for** plants built after 12 December 2003

Ø *Current legal basis*

The new criteria for determining whether the cogeneration process is a high-efficiency one and for calculating the fuel savings is fully consistent with Annex III of Directive 2004/8/• • and with Commission Decision of 21.12.2006 establishing harmonised efficiency reference values for separate production of electricity and heat (notified under document number • (2006) 6817).

In taking this decision, the European Commission took the view that stable conditions for investment in cogeneration and continued investor confidence are needed. From this point of view the Commission considered it appropriate to maintain the same reference values for a cogeneration unit over a reasonably long period of ten years, and apply stricter rules from the eleventh year of its construction.

Having regard to the economic conditions in Bulgaria and the age structure of our energy plants, this rule will be a serious barrier to the accumulation of financial resources necessary for retrofitting old cogeneration units in order to improve their energy efficiency.

III. ORDINANCE on the issuance of certificates of origin for electricity obtained from renewable energy sources and/or by using cogeneration methods

Bulgaria has designated the State Commission of Energy and Water Regulation (SCEWR) to be the independent competent authority responsible for certifying the origin of electricity and for ensuring compliance with the criteria and rules for granting the certificates of origin.

Mechanism for issuing certificates of origin:

1. *Each producer submits to SCEWR an application for issuance of a certificate of origin for the electricity from each plant owned by the producer.*

2. *The application covers the amount of electricity produced during the previous three months.*

3. *The certificate contains the following details:*

a) Type of the certificate;

b) Unique ID code, consisting of the producer's registration number and serial number of the certificate issued;

c) Name of the authority, which has issued the certificate;

d) Date of issuance, electricity production period;

e) Amount of cogenerated electricity certified by the certificate of origin;

f) Technology used for production of electricity, including:

– Amount of useful heat produced simultaneously with the electricity

– Type and lower calorific limit of the fuel used

– Results of the efficiency assessment of cogeneration systems made in accordance with the Ordinance issued under Art.162(3) of the Energy Act, including primary energy savings of fuel or RES used for the plant;

g) The production plant:

h) Combined (total) rated capacity of the production plant;

i) Rated capacity of electricity cogeneration facilities;

j) Name and statistical ID code (BULSTAT) of the producer.

4. *- When examining the producer's initial application for a certificate of origin, SCEWR must take a decision on the application within fifteen days after the application is lodged if the applicant is a licensed producer and within two months if the applicant is not a licensed producer.*

- When examining any subsequent application, the Commission must decide within fifteen days from the date of lodgement.

5. *The issued certificate of origin becomes effective upon its entry in the register.*

6. *At the producer's request SCEWR issues a paper-based statement confirming that the producer holds a certificate of origin.*

7. *SCEWR* ***rejects*** *the application for issuance of certificate of origin* ***in the case that****:*

- *The information provided by the producer is incomplete, inaccurate or incredible;*
- *The regulatory requirements for determining the amount of cogenerated electricity are not met.*

8. *SCEWR* ***can grant*** *an origin certificate* ***for an amount of*** *electricity* ***different from the one applied for*** *by the producer if there is sufficient information to determine this amount in accordance with the requirements of the legislation in force.*

9. *SCEWR* ***revokes*** *a certificate of origin* ***in the case that****:*

- *Any document, on the basis of which the certificates is issued, is held to be invalid;*
- *It is established that the holder of the certificate had provided untrue information, in reliance of which the certificate was granted.*

10. *A certificate of origin can be revoked* ***within one year*** *after its entry into force.*

Payments and protecting the interests of electricity producers and purchasers:

1. Protecting the producer

Ø *Until a certificate of origin is granted, all the electricity invoiced by the producer as cogenerated electricity must be paid at the referential price applicable to that producer;*

Ø *A reconciliatory payment for the relevant period is made within 10 days after the certificate of origin is granted.*

2. Protecting the purchaser

If there are regular or significant differences between the amounts covered by the certificate of origin and the amounts invoiced by the producer at a preferential price, the electricity purchase agreements can include special provisions concerning advance payments.

Register of certificates of origin

1. *SCEWR creates, maintains and publishes on its website a public register containing:*

- *Details of the producers to whom certificates of origin have been granted;*
- *Details of the certificates of origin granted or revoked.*

2. *The grant or revocation of a certificate of origin comes into effect as soon as such grant or revocation is entered in the register.*

3. *SCEWR enters the changes in the register by the end of the working day immediately following the date, on which the corresponding decision is taken.*

Mutual recognition of certificates of origin granted by EU Member-States:

1. SCEWR recognizes certificates of origin granted by EU Member-States on reciprocal basis. Certificates of origin granted by an EU Member-State serve as proof of the integrity of the facts and circumstances certified thereby.

2. Any refusal of SCEWR to recognize a certificate of origin, including for the purposes of fraud prevention, must be based on objective, transparent and non-discriminative criteria, and must be properly reasoned.

3. Disputes relating to SCEWR decisions, by which SCEWR refuses to recognize certificates of origin and which have duly entered into force, can be referred to the European Commission.

At the time of this analysis the system for issuance of origin certificates is not launched yet and it is difficult to predict whether or not it may raise barriers to the development of heat and electricity cogeneration. Use of this system for commercial payments is planned to start in the beginning of 2009.

7.2. Barriers to cogeneration development

7.2.1. Legal barriers

- **The unresolved problems with heat trading in the centralized heat supply sector have a negative impact on the development of cogeneration.**

Bulgaria is the only country in Europe, where district heating companies do not sell their heat "to the building", but to each apartment in that building. Given that the heating systems inside the apartment buildings are shared and it is not possible to disconnect from the heat supply system individually the apartments that do not pay their bills, all heat distribution companies end up with enormous amounts of bills unpaid by consumers and incur losses, which can not be overcome.

At the same time, with this method of sale consumers come to expect that district heating companies are responsible for the quality of service provided to each apartment in the apartment building, which is not possible because quality largely depends, among other factors, on the condition and functioning of the indoor systems and these are beyond the boundary of ownership on the facilities. This gives rise to additional, groundless dissatisfaction of consumers, which in turn reflects negatively on the collection of bills and thus on the financial and economic standing of the companies.

- **The rules for establishing the prices of cogenerated heat and electricity should be revised such that the price of heat energy remains competitive and the price of electricity becomes truly incentivising.**

To ensure conditions for development of cogeneration, heat prices should be competitive when compared to the prices of other heating alternatives. Investor interest in constructing cogeneration capacities should be stimulated by electricity tariffs, which ensure return of the invested capital and profit for the companies.

- **Producers of electricity from Renewable energy sources (RES) have stimuli to use cogeneration methods, because the pricing of RES output gives them sufficient financial guarantees for return of their investments at much more simplified procedures - both for certification of origin and establishment of prices.**

- **Municipalities have insufficient administrative capacity for creating town and country planning schemes based on energy master plans and demonstrating the most beneficial alternative, both economically and environmentally, for energy supply in their areas.**

- **Farmers, livestock breeders, timber producers, wood processing factories, food and beverage producers and similar enterprises are not subject to a consistently defined obligation for energy-efficient utilization of their waste. This leads to unreasonably high prices of the biomass offered for sale.**

7.2.2. Technical barriers

- **The terms for connecting the new plants to the electrical system are a surmountable barrier and are not a factor that restricts the construction of new cogeneration capacities. The same applies to the supply of natural gas.**

- **Urban waste is not utilized as fuel in heat and electricity cogeneration plants in Bulgaria for various technical reasons, although resources of this kind are available.**

- **A technical barrier for construction of systems for combined generation of useful heat and electricity in the heat-supply enterprises (heat suppliers) is the limited operational time of these systems due to the heat load diagramme of these enterprises.**

7.2.3. Financial barriers

- **Expectations for high natural gas prices in the mid-term are a serious barrier for the construction of cogeneration systems.**

The cost structure of heat-supply enterprises includes low levels of constant costs and high levels of variable costs for purchase of fuels. This suggests that their cash flows are quite sensitive to the final selling prices of the electricity and to the purchase prices of the fuels used in their production. At the same time, the relatively low return on equity of heat suppliers leaves little room for flexible financial and economic responses to any significant changes occurring in the extra-corporate economic environment. The enterprises are channelling their cash to cover the increased operational costs related with the purchase of fuels, which in turn threatens the realization of retrofitting and new investment projects.

A mid-term scenario with high natural gas prices and maintaining heat prices at competitive levels means unacceptable economic performance of new cogeneration plants.

The Bulgarian market for • • $_2$ emissions is underdeveloped and this is a barrier to the usage of this vehicle, broadly used in other countries, for compensating part of the investment costs.

7.2.4. Barriers to the usage of biomass

The most significant barriers to the usage of biomass for energy purposes can be summarized as follows:

- **The level of timber production equipment and technology is too low to support the production and utilization of the potentially available wood biomass;**
- **Insufficient investments for acquisition of specialized equipment for production, transport and processing of wood biomass;**
- **Insufficient practice in implementing the national policy for promotion and subsidizing of energy crops;**
- **A large portion of waste biomass from the wood processing industry is used for production of MDF boards and for export;**
- **Land ownership is quite fragmented among large numbers of owners with diverging interests;**
- **Lack of funding for research and development activities in the area of biomass fuels.**

8. ESTIMATED REALIZATION OF BULGARIA'S CHEG POTENTIAL BY 2020

8.1. Estimated realization of the CHEG potential in centralized heat supply systems

The technical potential for generation of electricity by CHEG plants in Bulgaria's centralized heat supply sector is 6 686 GWh$_{el}$/year, which includes the existing output, the baseline scenario and the technical scenario for enlargement by 2020.

The existing output of 1 496,3 GWh$_{el}$/year is rated to a mean annual temperature of the ambient air during the heating (winter) season) of • $_{air}$ = 3 ˙• and • $_{air}$ = 17 ˙• during the non-heating (summer) season. These temperature conditions underlie the calculations of the technical potential of centralized heat supply systems in Bulgaria (tables 3.2, 3.3 and 3. 4).

The probable forecast for realization of the CHEG potential is:

- By 2010 some individual CHEG plants can be installed and the annual electricity output can reach 1950 GWh$_{el}$/year;
- By 2015 the annual electricity output from CHEG plants can reach 2 800 GWh$_{el}$/year;
- By 2020 the annual electricity output can reach 3 500 GWh$_{el}$/year.

8.2. Estimated realization of the CHEG potential in residential and public buildings

The technical potential for generation of electricity in residential and public buildings is 2 570 GWh$_{el}$/year.

Realization of this potential is related to the development of gas distribution systems in the populated settlements as well as modern technologies for low-capacity CHEG systems such fuel cells using natural gas, gas generators and Stirling engines for wood waste, which are expected to become competitively priced in the market some time around 2015.

No realization is expected in this sector before 2010. In 2015 electricity output from CHEG plants will probably reach ca. 10% of the potential output or 257 GWh$_{el}$/year, and is expected to reach 520 GWh$_{el}$/year by 2020.

8.3. Estimated realization of the CHEG potential in the industrial sector

The technical potential for generation of electricity by CHEG plants in the industrial sector is 4 047 GWh$_{el}$/year, which includes the existing production of 2 411 GWh$_{el}$/year. Taking also into account the estimated increase of the heat load, electricity production in the industrial sector is expected to increase by another 15 % and reach 4 047 • 1,15 = 4 654 GWh$_{el}$/year by 2020.

The probable forecast of the CHEG potential in the industrial sector is:

- By 2010 the annual electricity output from individual pilot plants can reach 2 480 GWh$_{el}$/year;
- By 2015 the output can reach 2,818 GWh$_{el}$/year;
- By 2020 the entire CHEG potential can be consummated and the annual output of cogenerated electricity is expected to stabilize at 3 490 GWh$_{el}$/year.

8.4. Estimated realization of the biomass potential for CHEG

Realization of the primary energy potential of biomass and residential waste is expected to lead to the following cogeneration of electricity by CHEG plants:

- 74 GWh_{el}/year from the residential waste of Sofia after processing the waste into highly calorific Refuse Derived Fuel as envisaged in Alternative 2 of Consortium FICHTNER. Selection of Alternative 4, which envisages separation, recycling and composting of the waste, and then incineration with addition of natural gas, can increase the electricity output to 600 GWh_{el}/year. This alternative involves a range of environmental concerns, which will lead to considerable increase of the investments required, for this reason it is assumed that the possible realization of the production potential will be 74 GWh_{el}/year;

- 48 GWh_{el}/year from wood waste for centralized heat supply at preferential prices of the electricity as a RES-derived product;

- 58 GWh_{el}/year from agricultural waste.

The estimated realization of the potential for electricity generation by RES-using CHEG plants is as follows:

- No realization is expected before 2010;

- By 2015, realization of the annual electricity output potential can reach 74 GWh_{el}/year;

- By 2020 the entire potential can be consummated and thus annual electricity output is expected to reach 180 GWh_{el}/year.

The estimated annual levels of electricity production by CHEG plants by 2020 are presented in table 8. 1.

Table 8. 1. Estimated annual production of electricity by CHEG plants until 2020 by sectors, GWh_{el}/year

Electricity production by sectors:	***Existing production***	***2010***	***2015***	***2020***
Centralized heat supply	1 469	1 950	2 800	3 500
Residential and public buildings	0.03	0.06	257	520
Industry	2 411	2 480	2 818	3 490
Biomass and waste	-	-	74	180
Total	**3 880**	**4 430**	**5 950**	**7 690**

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