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BASELINE STUDY AND MONITORING PLAN

Gas-fired co-generation at the Bratislava 1 heating plant

AIJ Project PSO99/SK/2/1

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Acknowledgement

This report comprises the baseline study and monitoring plan of the AIJ Project PSO99/SK/2/1 'Introduction of a modern co-generation plant to the city of Bratislava, Slovak Republic' (ECN project number 7.7248). This study was carried out for Nuon, the leading company of this project. The project team consisted of Nuon, ZSE, Geveke Motoren and ECN and was financed by Senter Internationaal in the framework of the Dutch program for co-operation with Eastern Europe (Programma Samenwerking Oost-Europa PSO). Det Norske Veritas (DNV) validated the baseline study.

Abstract

The heat and power plant Bratislava I is owned by the distribution company ZSE. It supplies steam for industrial heat demand and hot water (low temperature heat) for the district heating system of Bratislava, as well as electricity to the national electricity grid. To improve the overall efficiency, a 1 MW_e natural gas-fired engine is installed. The project is financed by Senter within the PSO/AIJ programme. The baseline study estimates the GHG emissions during the project time without the project (baseline) as well as the impact of the project on these emissions. The monitoring plan describes how the actual emissions will be monitored. The baseline study and monitoring plan were developed according to the guidelines that were used in the first Emission Reduction Unit Procurement Tender (ERU-PT) of the Dutch Government. The study was carried out by the Energy research Centre of the Netherlands ECN. Nuon, Geveke and the recipient ZSE provided the data. The GHG emission reduction is estimated at 11 kiloton CO_{2eq} during the budget period 2008-2012, which is 3% of the total emissions of the heating plant in this period.

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CONTENTS

SUMMARY

The energy distribution company ZSE supplies steam for industrial heat demand and hot water (low temperature heat) for a district heating system of Bratislava, as well as electricity to the national electricity grid. Six natural gas-fired boilers produce steam and hot water, while two steam turbines are used for electricity production. To improve the overall efficiency for the production of low temperature heat and electricity, a 1 MW_e natural gas-fired engine will be installed. The maximum heat capacity of the existing plant is about 70 MW_{th}; the heat capacity of the gas engine is about 1.3 MW_{th}. The Dutch government supports this PSO/AIJ project with an investment of NLG 1,35 million, which is the largest share of the total project costs. The project started in the year 2000. The gas engine will be operational in 2001.

The project was developed under the AIJ-framework, which was a pilot-phase for the JI-framework. AIJ-projects have been used to gain experience with emission reduction projects in Central and Eastern European Countries (CEEC) and the development of the baseline and monitoring study to quantify the GHG-emission reduction.

At the start of the project, the Joint Implementation Registration Centre (JIRC) was responsible for the validation of the AIJ baseline studies for which it had developed general guidelines. In 2000, the Dutch government launched the Emission Reduction Unit Procurement Tender (ERU-PT). The methodology for baseline study and monitoring plans within ERU-PT were defined in guidelines (Ministry of Economic Affairs, 2000). To create more added value to the work, the baseline study and monitoring plan were developed according to these new ERU-PT guidelines instead of the JIRC-guidelines, as these ERU-PT guidelines are much more elaborated. The baseline study was carried out by the Energy research Centre of the Netherlands ECN. Nuon, Geveke and ZSE provided the data for the baseline study. Det Norske Veritas (DNV) was the validating body ('validator') for this project.

The baseline study estimates the projected baseline GHG emissions during the project period in absence of the project as well as the impact of the project on these emissions. In addition, key factors that will influence the baseline during the course of the project were addressed. To calculate the actual emission reduction of the project, the activity level of the heat and power plant and the performance and production of the gas engine have to be monitored. Therefore, in addition to the baseline study, a monitoring plan has been developed to make available the necessary data.

The GHG emissions are estimated at 11 kiloton CO_{2eq} during the budget period 2008-2012, which is 3% of the total emissions of the heating plant in this period. However, since this project is developed under the AIJ-framework, the actual monitoring will start when the gas engine is put in operation (estimated in May 2001) and will end at the end of the contract period (1st November 2001).

The experiences in application of the ERU-PT guidelines have been used to give feedback to the developers of these guidelines. Moreover, the validator has gained insight in using these guidelines in the validation process.

1. INTRODUCTION

1.1 Project description

This project is carried out under the AIJ-program and financed by the Dutch program for co-operation with Eastern Europe (Programma Samenwerking Oost-Europa; PSO). In the project the following organisations are participating:

Table 1.1 *Project team*

Partner	Task
Nuon (Dutch Energy Distribution Company)	Project leader
ZSE (Slovak Energy Distribution Company)	Recipient gas engine
Geveke Motoren	Supplier gas engine
ECN (Energy research Centre of the Netherlands)	Baseline and monitoring study

A natural gas-fired CHP plant will be installed at a district heating station in Bratislava, Slovak Republic (Heat Plant I). The plant is owned by the energy distribution company ZSE, which supplies steam for industrial heat demand and hot water (low temperature heat) for a district heating system of Bratislava. It also supplies power to the national electricity grid. Six natural gas-fired boilers produce steam and hot water. Two steam turbines are used for power production.

To upgrade the thermal efficiency for the production of low temperature heat, a 1 MW_e natural gas-fired gas engine with an operational time of about 8322 hours per annum will be installed. The Dutch government will finance this PSO/JI project with a total investment of NLG 1,35 million. Installation of the project will be carried out during 2000. The plant will be operational in 2001.

1.2 Baseline study and monitoring plan

According to the framework of Joint Implementation (JI)[1] Annex I countries have the opportunity to realise greenhouse gas (GHG) emission reduction abroad to reach their emission reduction targets in 2010. Under this JI framework, emission reduction projects have to be developed in co-operation with foreign project partners in Annex I countries. The Dutch government decided to have a pilot phase to gain experience with developing JI projects (Activities Implemented Jointly (AIJ) program). The AIJ-programme was finalised in 2000.

In the AIJ-Programme, a baseline study must be developed to quantify the GHG emission reduction. This baseline study estimates the emissions in absence of the project (i.e. the gas engine) and compares it with the emissions related to the implementation of the project. The baseline study addresses the following three key elements:

- emission of greenhouse gases (GHG) and other environmental aspects before the start of the project,
- projection of baseline GHG emissions during the project time without the project,
- impact of the project on GHG emissions.

To quantify the realised emission reduction, monitoring reports are required when the project is operational. Under the Dutch AIJ-framework, the quantification of the GHG emissions is de-

[1] United Nations Framework Convention on Climate Change (Rio de Janeiro, 1992).

fined by the JIRC-guidelines (Joint Implementation Registration and Certification Procedure) for baseline and monitoring studies. This quantification is related to a representative 12-month period (one representative year).

In 2000, the Dutch government launched the Emission Reduction Unit Procurement Tender (ERU-PT). Under this tender, the quantification of the GHG emissions is defined by the ERU-PT guidelines for baseline and monitoring studies. This quantification is related to the budget period 2008-2012 (five years)[2] (Ministry of Economic Affairs, 2000). The ERU-PT guidelines are much more elaborate than the JIRC-guidelines, especially with respect to the argumentation of future developments that have impact on the reduction quantity and the question of additionality. To gain experience in using the ERU-PT guidelines and to give the developers of these guidelines feedback, the baseline and monitoring study are developed according to the ERU-PT guidelines instead of using the JIRC-guidelines. In the baseline study the estimated amount of GHG-emission reduction is related to historical data and to different assumptions regarding future developments of plant performance, operation modes etc. In the baseline developments that will influence the baseline during the course of the lifetime of the project will also be addressed. The assumptions have to be validated by an independent validator. This baseline study has been validated by Det Norske Veritas (www.dnv.com).

The baseline study was carried out by the Energy research Centre of the Netherlands ECN. The data for the baseline were provided by the following sources.

Table 1.2 *Sources for baseline study*

Data	Source
Project description	Nuon, ZSE
Energy consumption	ZSE
Emission rates on-site	based on ERU-PT guidelines

The ERU-PT guidelines for monitoring plan refer to the first commitment period 2008-2012. The monitoring plan of this project also considers this period. However, the contract period for this AIJ-project ends November 1st 2001. Therefore, the actual monitoring will only be done in the period from the commissioning of the gas engine (May 2001) till 1 November 2001. The results will be reported in a monitoring report.

1.3 Time schedule of the project

The project started at 1 December 1999. Due to operational problems at the site, which was first scheduled for upgrading (heating plant at Komarno), the implementation of the gas engine had to be relocated to the power and heating plant Bratislava 1. This caused a three-month delay in the project planning. The preparational work (technical installation, arrangements for transport) started in April 2000. Installation of the CHP-unit and testing on-site is planned for early 2001. The commissioning of the CHP-unit is scheduled for May 2001.

Table 1.3 *Time schedule of the project*

	Time (in quarters)								
	99-4	*00-1*	*00-2*	*00-3*	*00-4*	*01-1*	*01-2*	*01-3*	*01-4*
Project start									
Relocation of project									
Preparation									
Installation and testing gas engine									
Start operation gas engine									
Full operation of the gas engine									

[2] http://www.senter.nl/erupt/ (July 2000)

1.4 Outline of the report

The structure of the report is as follows. Chapter 2 will describe the heat and power plant Bratislava I in a quantitative way. In Chapter 3 the characteristics of the gas engine will be described. Chapter 4 describes the key factors that influence the emission reduction and in Chapter 5 the possible baseline options are described. The most likely baseline option will be indicated in Chapter 5. Based on this chosen baseline, the estimated GHG emission reduction will be calculated for the budget period (2008-2012). The additionality of the project is indicated in Chapter 7 and Chapter 8 describes the monitoring study. In Chapter 9 the experiences and conclusions regarding the use of the ERU-PT guidelines are listed. The Annexes report on key correspondence concerning data for the baseline study.

2. CURRENT DELIVERY SYSTEM

2.1 Production characteristics

Most of the production characteristics such as steam and power production are values measured by ZSE. Individual boiler capacities as well as power capacity of a steam turbine and a gas turbine are design values (plate numbers). In a few cases process parameters are calculated (i.e. individual boiler efficiencies and individual load factor), which are based on the same measured production characteristics. In Table 2.1 the source of the different process characteristics is indicated, which is based on operational data. Information regarding measurement and data collection is given in Table 2.3 and Chapter 8.

Table 2.1 *Source of process parameters*

Source	Measured data	Calculated data	Appendix
Letter ZSE of 16 June 2000	Table 2.2	Table 2.7	A.1
	Table 2.3		
	Table 2.8		
	Figure 2.2		
	Figure 2.3		
Visit ZSE to ECN at 3 August 2000	Figure 2.1	Table 2.6	A.2
	Table 2.2		
Email ZSE of 22 August 2000	Table 2.5		A.3
Email ZSE of 26 October 2000	Table 2.5		A.4

The lower heating value (LHV) of the supplied natural gas in Komarno (the original location for installing the gas engine) is 34.20 MJ/Nm^3 (Appendix A.6). The LHV of the supplied natural gas in Bratislava (the new location of the gas engine) was not known when finishing the baseline study. The LHV is a design parameter of the gas engine. Because the design of the gas engine has not been altered, it is assumed in the baseline study that the LHV of natural gas is not significantly changed and is estimated at 35 MJ/Nm^3, which is a deviation of about 2% compared to the Komarno-value. However, the impact of this assumption on the accomplished emission reduction will be evaluated in the monitoring study.

2.2 Flow chart

The energy distribution company ZSE owns and operates the heat and power plant Bratislava 1. This heat and power plant produces electricity, low-pressure steam (LP-steam) and hot water. The electricity is distributed to the national grid. LP-steam is distributed to local industry and to the district heat grid (DH-system) of Bratislava. Hot water is also distributed to a separate grid. A schematic overview of the plant is given in Figure 2.1.

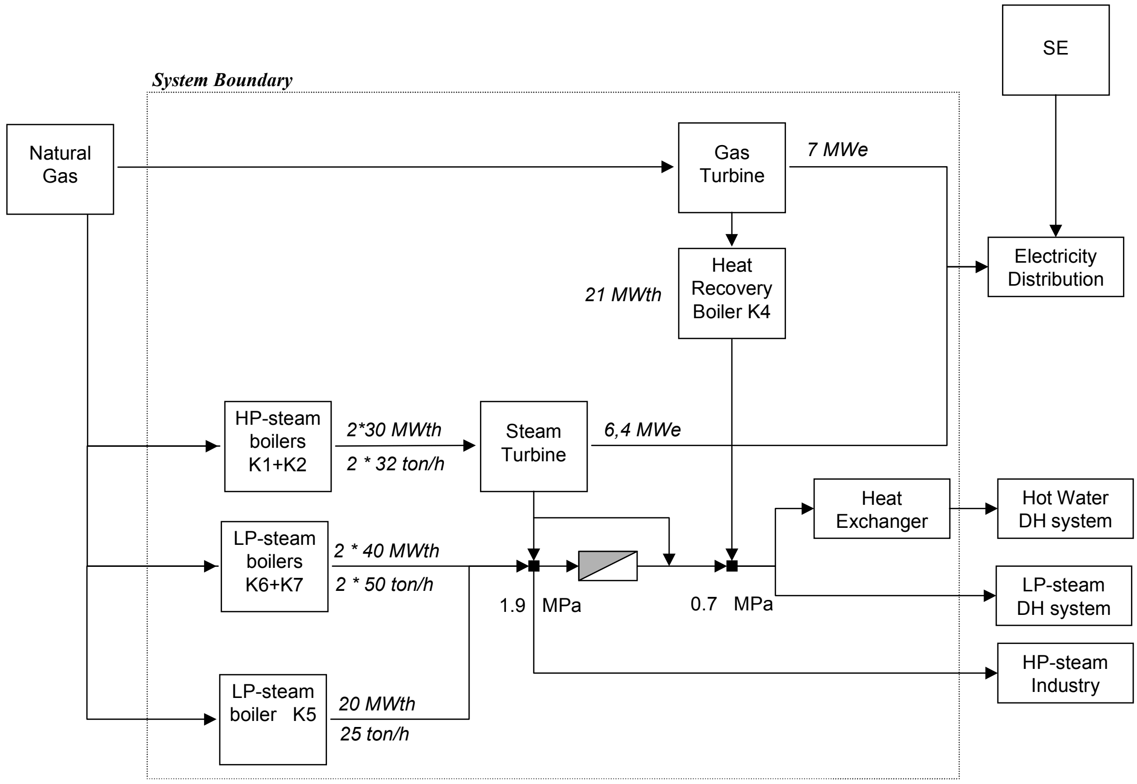

Figure 2.1 *Schematic flowchart of the heat and power plant Bratislava 1 (Appendix A.5)*

For the steam production two high-pressure (HP) -steam boilers and four low-pressure (LP) - steam boilers are installed. Power is produced with a backpressure steam turbine of 6.4 MW_e and a gas turbine (GT) of 7 MW_e. In the steam turbine partial expansion of HP-steam to 19 bar takes place and is extracted to meet industrial steam demand. The remaining steam will be expanded to 7 bar for LP-steam production. The share of steam turbine output, which is distributed to the industry, depends on this industrial demand. The figures in Table 2.2 characterise the different components of the plant.

Table 2.2 *Characteristics steam production (Appendix A.1 en A.2)*

	Steam-type	Steam Conditions P [bar]	T [°C]	Capacity [MW_{th}]	Age [years]
Boiler K1	HP	58,460	460	30	56[2]
Boiler K2	HP	58,460	460	30	56[2]
Boiler K4	LP	7,250	250	21	38
Boiler K5	LP	19,250	250	20	23
Boiler K6	LP	19,250	250	40	30
Boiler K7	LP	19,250	250	40	30

[2] New gas burners installed in early 90's.

2.3 On-site measurement scheme

In order to control the plant in an efficient way and to monitor the energy demand, several process parameters are measured. In Appendix A.5 the measurement scheme of the plant and the used measurement equipment is given. In Table 2.3 a summary of the used instruments is given.

Table 2.3 *Used measurement equipment (Appendix A.3)*

Code	Name	Process parameter	Standard	Accuracy	Frequency
F1-F6	Orifice Plate meter	natural gas flow[1]	DIN 1952 ISO 5167	<1.5%	Once a day
F7-F15	Orifice Plate meter	steam flow[1]	DIN 1952 ISO 5167	<1.5%	Once a day
F16	Water Gauge	water flow[2]	ISO 9001	<1.5%	Once a day
H1	Ultrasonic heat meter	heat supply to DH-system[1]	DANAK (certificate) PTB ISO 9001	<1.5%	Once per hour
H2-H5	Vortex heat meter	heat supply to DH-system[1]	DANAK (certificate) PTB ISO 9001	<1.5%	Once per hour
H6	Orifice Plate meter	heat supply to DH-system[1]	DIN 1952 ISO 5167	<1.5%	Once per hour
E1,E2	Power-meter	power production	ICS 29.240.10	<0.5%	Once per hour
E1,E2	Electricity- meter	electricity supply to the grid	ICS 29.240.10	<0.5%	Once a day

[1] Standard for temperature measurement and/or calculation method is not available.
[2] Standard is not available.

2.4 Heat and electricity production

The entire plant is heat driven with additional power production, except for the gas turbine, which is driven by peak electricity demand. The heat demand will vary during the seasons of a year. Three different periods can be defined: winter period, transition period and summer period. In the following sections the impact of these seasonal differences on the plant operation will be described. See also the load duration curve in Figure 2.3.

2.4.1 Winter period

The heat demand is the highest during the winter period (from end of September/start of October till the end of April). In this period, the HP-steam boilers (K1 and K2) are in operation with some additional steam capacity of boiler K6 and K7.Because the marginal costs of peak-electricity produced with the gas turbine are lower than the purchase tariff of electricity from SE, peak electricity is produced with this gas turbine. During peak load production of electricity, part of the HP-steam capacity (K1 or K2) is replaced by the heat recovery boiler (K4) capacity.

2.4.2 Transition period

During the transition period (May and September) heat demand decreases. In these months boiler K1 and K2 are switched off and HP-steam is produced by boilers K6 and K7. In this period there is only (peak-) electricity production with the gas turbine for on-site use.

2.4.3 Summer period

The heat demand pattern is almost constant during the summer period. The total heat demand is about 10 MW_{th} (2 MW_{th} for the hot water system and 8 MWth for the combined LP-steam DH-system and HP-steam industrial steam demand). During the summer period, the HP-steam boilers K1 and K2 will be switched off, because the DH-demand decreases from 40 MW_{th} on average in the winter period to 10 MW_{th} in the summer period. As a result of this decrease, industrial steam demand is too low for using these boilers, so the steam turbine is not used. However, a minimum peak-power production is delivered by the GT.

The remaining heat demand is produced with the boilers K5, K6 or K7. The boilers K6 and K7 are in operation during the week and boiler K5 is switched off. During the weekend, when there is an increased heat demand, boiler K5 is also in operation. During a hot summer with relatively low heat demand or during the maintenance period of boilers K6 and K7, only boiler K5 (which has a low capacity) is in operation. During peak power production in the summer period, the output from the heat recovery boiler will replace the capacity of boiler K5, K6 and K7 (LP-steam boilers).

2.4.4 Heat and electricity production and supply and gas consumption

In the period 1995-1999 the average annual energy supply is about 878 TJ heat and 83 TJ (23 GWh) electricity. This includes losses within the plant. The average annual gas consumption is about 33.5 million m^3. In Figure 2.2 the annual heat and electricity supply for the period 1995-1999 is represented in combination with the gas consumption.

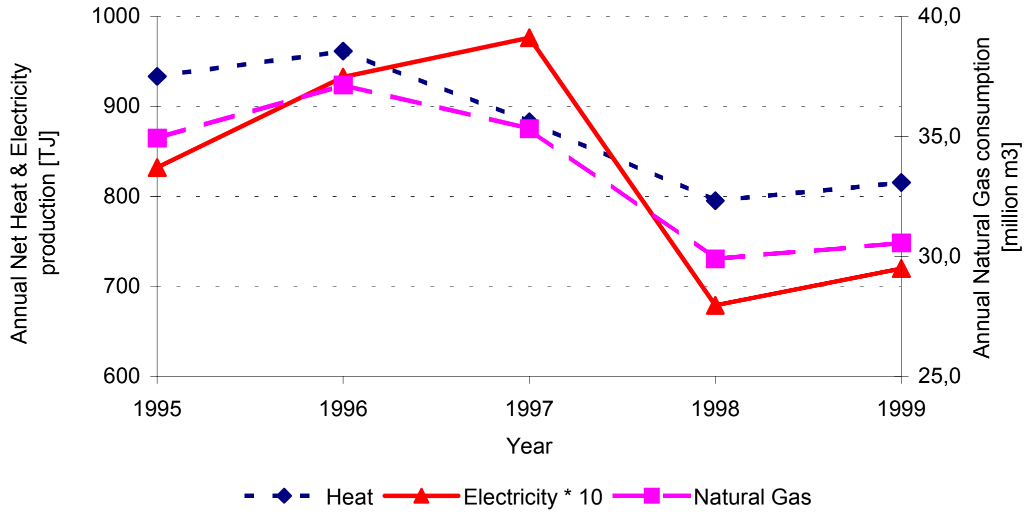

Figure 2.2 *Annual heat and power supply and annual gas consumption (Appendix A.4)*

In Table 2.4 the annual heat and electricity production of the steam boilers (without on-site heat losses) and the steam and gas turbine is represented for the period 1995-1999.

Table 2.4 *Power and steam production (Appendix A.4)*

	1995	1996	1997	1998	1999
Steam production (GJ)					
Boiler K1	297,175	345,733	334,328	283,608	302,771
Boiler K2	293,758	333,698	328,842	329,029	347,470
Boiler K4	51,051	45,386	49,897	7,195	14,092
Boiler K5	35,035	26,716	14,339	31,045	39,800
Boiler K6	193,498	136,353	184,199	121,345	79,788
Boiler K7	174,492	205,826	100,707	127,662	134,994
Total	1,045,009	1,093,712	1,012,312	899,884	918,915
Power production (MWh)					
Gas Turbine	6,975	6,063	7,152	1,750	2,014
Steam Turbine	16,142	19,848	19,969	17,117	17,986
Total	23,117	25,911	27,121	18,867	20,000

The heat to power ratio has a constant value of about 11 except for 1997, where it was about 9 (see Figure 2.2). In this year, the power production of the gas turbine increased (about 15%). With an almost constant total heat supply compared to 1996, the increased steam production from the heat recovery boiler is compensated with a decrease in steam production of boiler K6 and K7, resulting in an overall decrease of the heat to power ratio for 1997. In 1998, the total power production decreases by 30% compared to the level of 1997. The main reason is the decrease of power output of the gas turbine due to ageing of this equipment.

Figure 2.3 shows the load duration curve for the heat production of Bratislava 1.

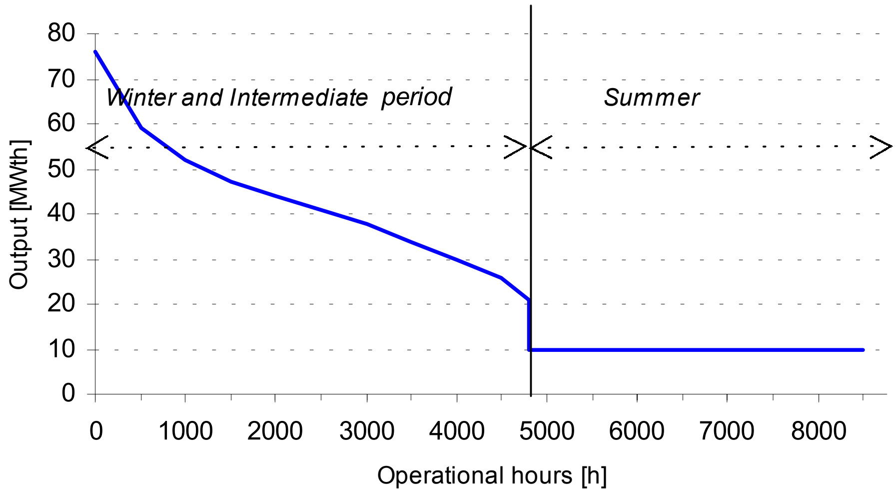

Figure 2.3 *Load duration curve of 1999*

In this figure the impact of the seasonal differences in heat demand can be seen. The maximum heat demand in the winter period (74 MW_{th}) is about seven times higher compared to the heat demand in the summer period (10 MW_{th}). The discontinuity at about 5000 operational hours represents the difference in heat demand between summer period and winter+intermediate period.

Based on production data (Table 2.4) and equation (1) the following load factors of the individual boilers can be calculated for the period 1995 to 2000, see Table 2.5.

$$LF_{x,t} = \frac{SP_{x,t}}{C_x \times 8760 \times 3.6} \tag{1}$$

with

LF = *Load factor (%)*
SP = *Steam Production (GJ)*
C = *Capacity (MW_{th})*
x = *boiler number*
t = *period*

Table 2.5 *Annual load factor individual boilers (based on 8760 hours/annum)*

	Capacity [MW_{th}]	1995 [%]	1996 [%]	1997 [%]	1998 [%]	1999 [%]
Boiler K1	30	31	37	35	30	32
Boiler K2	30	31	35	35	35	37
Boiler K4	21	8	7	8	1	2
Boiler K5[1]	20	6	4	2	5	6
Boiler K6[2]	40	15	11	15	10	6
Boiler K7[2]	40	14	16	8	10	11

[1] only operational during summer weekends.
[2] only operational during summer weekdays.

From these figures it is clear that there is a large overcapacity of heat production at the heat and power plant Bratislava 1.

2.4.5 Boiler efficiency

During this baseline study, no information was available on the natural gas consumption of the individual boilers. Therefore, the average net component efficiencies (including on-site losses) of the heating plant were estimated from the total annual net heat and power production and the total annual gas consumption in 1998 and 1999 (see Table 2.6).

Table 2.6 *Average estimated efficiencies of heat and power plant Bratislava* [1]

		1998	1999
HP-boiler (K1+K2)			
HP-steam production	[TJ]	613	650
HP-boiler efficiency	[%-LHV]	86	87
Natural gas consumption	[mln. Nm^3]	20	21
Steam Turbine			
Electricity production	[TJ]	66	67
HP-steam production	[TJ]	70	58
LP-steam production	[TJ]	438	488
Electric efficiency ST	[%-LHV]	10.8	10.3
H/P-ratio	[-]	7.7	8.2
LP-boiler (K4+GT)			
Electricity production	[TJ]	2.5	4.8
LP-steam production	[TJ]	7.0	14
electric efficiency	[%-LHV]	22	22
overall efficiency	[%-LHV]	85	85
Natural gas consumption[2]	[mln Nm^3]	0.32	0.64
LP-boiler (K5, K6+K7)			
LP-steam production	[TJ]	280	255
LP-boiler efficiency	[%-LHV]	86	86
Natural gas consumption[2]	[mln Nm^3]	9.6	8.5
Total			
Industrial supply	[TJ]	70	58
DH-supply	[TJ]	726	757
Electricity supply	[TJ]	69	72
Natural gas consumption[2]	[mln Nm3]	30	31
Overall efficiency	[%-LHV]	82	82
On-site losses	[TJ]	36	32

[1] See spreadsheet, accompanying the baseline and monitoring study.
[2] LHV-Natural Gas = 35 MJ/Nm^3.

From these figures it is clear that there are no significant differences in the calculated efficiencies of 1998 and 1999. For the baseline calculation the efficiencies from the 1999 figures will be used. As a result of the load duration curve, the shares of the different boilers in the total steam production and heat output is given in Table 2.7 for 1999.

Table 2.7 *Share of individual boilers in total heat production of 1999 (Appendix A.1)*

	Steam-type	Steam Production [TJ]	Share [%]	Heat Output [TJ]	Share [%]
Boiler K1,2[1]	HP	650	71	547	67
Boiler K4	LP	14	2	14	2
Boiler K5	LP	40	4	40	5
Boiler K6,7	LP	215	23	215	25
Total		919		816	

[1] Difference due to electricity production and due to losses steam turbine.

3. PROJECT CHARACTERISTICS

3.1 Characteristics and production CHP unit

The minimum heat demand in the summer period can be divided in 8 MW_{th} LP-steam demand and 2 MW_{th} hot water demand, see also the load duration curve of Bratislava 1 (Figure 2.3). Because the gas engine produces hot water with a capacity of 1.3 MW_{th} it is clear that the gas engine can run maximum operational hours, resulting in the following characteristics (see Table 3.1).

Table 3.1 *Characteristics of CHP unit*

Maximum electric power capacity	MW_e[1]	1.0
Maximum heat generation capacity	MW_{th}[2]	1.3
Electric efficiency	%	36.3
Heat efficiency	%	46.1
Availability[3]	%	95
Full load hours per annum	hours	8322
Electricity production per annum	MWh	8380
Heat production per year	GJ	38314
Fuel consumption	GJ	83110
Natural gas consumption (year 2001)[4]	m^3	2,375,000

[1] 1007 kW_e.
[2] 1279 kW_{th}.
[3] Maintenance are estimated at approximately 440 hours per annum by Geveke.
[4] LHV Natural Gas = 35 MJ/Nm^3.

3.2 System boundaries

In Figure 3.1 a schematic overview is given of the plant after installation of the gas engine. In order to connect the gas engine to the electricity grid, a 1600 kVA transformer has to be installed between the gas engine and the electricity grid. Regarding the heat production, the cogeneration unit will be connected parallel with the existing heat exchangers of the hot water DH-system.

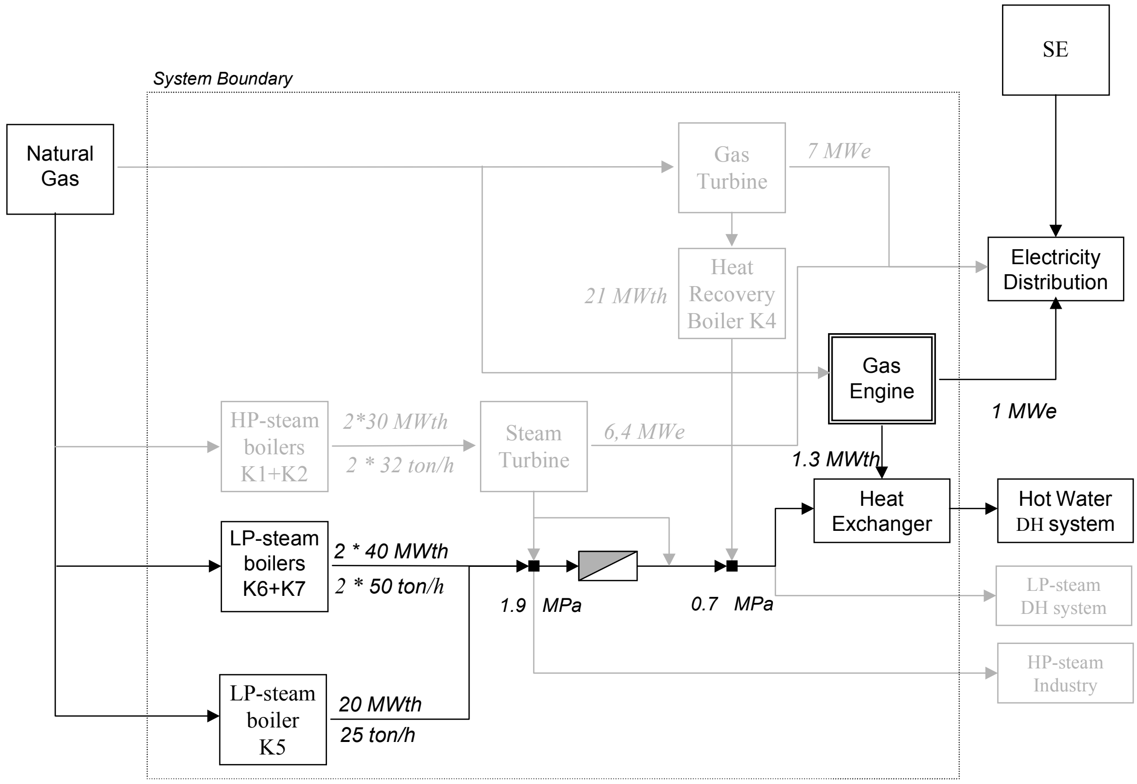

Figure 3.1 *Schematic overview of the heating plant after implementing the gas engine*

The grey shaded components in Figure 3.1 will be decommissioned during the period to 2008, before the start of the commitment period. For more detailed information see Chapter 5.

3.3 Management gas engine

As indicated in Section 3.1 the gas engine will run maximum operational full-load hours, producing base-load heat (hot water) and electricity. Heat production is used for base-load heat demand in the hot water system. Electricity production is used to avoid base-load electricity purchase from the national power producer SE. According to profitability calculations of ZSE, substitution of purchased electricity by own production is the most cost-effective option.

3.4 GHG sources and sinks

3.4.1 On-site emissions

The direct emissions on-site are related to the total fuel consumption of the gas engine, the steam boilers and the gas turbine. Indirect emissions are related to the load-shift of the steam boilers as a result of the gas engine capacity. The capacity of the gas engine is relatively small compared to the capacity of the steam boilers. Therefore, it is assumed that the impact of the gas engine on the load-factor of the steam boilers is negligible.

3.4.2 Off-site emissions

Direct off-site emissions are related to emissions arising from the off-site production of secondary energy carriers. In this situation electricity from the national grid will be replaced by power production from the gas engine. In the ERU-PT guidelines, a scenario for the development of the emission factor and transport efficiency of electricity from the national grid is given (Ministry of Economic Affairs, 2000). Based on interpolation of these figures, emission factors and transport efficiencies for the replaced electricity for each year are estimated, see Table 3.2.

Table 3.2 *Emission factor and grid losses of central electricity production Ministry of Economic Affairs (2000)*

Year	CO_2 factor [kg/kWh]	Grid losses [%]
2000	0.665	6.79
2001	0.649	6.60
2002	0.633	6.42
2003	0.617	6.24
2004	0.600	6.06
2005	0.584	5.90
2006	0.568	5.70
2007	0.552	5.52
2008	0.535	5.37
2009	0.519	5.16
2010	0.503	5.01
2011	0.487	4.80
2012	0.470	4.66

The CO_2 factor for off-site electricity purchase is calculated as follows:

$$GHG_{grid} = \frac{E_{grid}}{1-GL} \times EC_{cep} = E_{grid} \times EC_{grid} \qquad (2)$$

GHG_{grid}	= *absolute emission level*	*($tonCO_{2eq.}$)*
E_{grid}	= *electricity purchase from the grid*	*(MWh)*
GL	= *grid losses*	*(%)*
EC_{cep}	= *emission factor central produced electricity*	*($tonCO_{2eq}$ /MWh)*
EC_{grid}	= *emission factor electricity purchase from the grid*	*($tonCO_{2eq}$ /MWh)*

Indirect emissions are related to the load-shift of other power and heat plants as a result of the project implementation. Because of the small capacity of the gas engine, the impact of this off-site load-shift is neglected.

3.4.3 Other environmental effects

Situation before start of project

The gas-fired CHP unit will be implemented at an existing gas-fired heat and power plant. In both situations electricity is produced with gas-fired equipment. Apart from the emissions of GHG, no other environment effects need therefore be quantified in the baseline. The current emissions from the gas-fired steam boilers and the CHP unit are therefore discussed in a qualitative way only.

Emission of other gases prior to start of project
The current steam boilers at Bratislava 1 meet the local environmental emission standards, particularly regarding NO_x-emissions. The project (gas engine) will increase the local NO_x emissions in comparison to the gas boilers. The supplier gives a delivery guarantee that the gas engine will meet the Dutch en Slovak NO_x emission standards[3]. Therefore, these emissions have not been quantified in the baseline study. During the monitoring period these NO_x emissions will be measured to check if the NO emissions of this gas engine will meet these standards.

[3] Dutch standard is the BEES (Besluit Emissie-eisen stookinstallaties milieubeheer): 140 g $NO_x/GJ_{gasinput}$; Slovak standard is 500mg $NO_x/Nm^3_{exhaustgas}$, (with 5 vol% $O_2/Nm^3_{exhaustgas}$) which equals the German TA-Luft standard (Bundes-Emmissionsschutzgesetz, 1997).

4. KEY FACTORS FOR BASELINE EMISSIONS

The baseline emissions are directly linked to the power and heat production level of the plant and the efficiencies for production of these energy carriers. In this Chapter the expected developments of the production levels and efficiencies will be described.

4.1 Production level

The heat and power production of the current plant depends on the development of the industrial heat demand, heat demand of the DH-system, retrofitting of the DH-system and followed by the electricity demand.

4.1.1 Development of industrial heat demand

The industrial heat demand is located in the centre of Bratislava. The city of Bratislava is allocating other activities in this area instead of industrial activities. Industrial companies have to re-locate their sites to locations with more opportunities for expansion or they will stop their activities. These expected developments will result in a decrease of industrial heat demand to zero in 2010. As a consequence, the heat production at the site for industrial demand will decrease. In a strategic plan, developed by ZSE, the development of this industrial heat demand is estimated for the period 2000-2010, see Table 4.1.

Table 4.1 *Development of industrial heat demand*

Year		1999	2000	2005	2010	2011
Capacity	[ton/h]	64	55	26	15	0
Decrease	[%]	0	14	59	77	100

From these figures it is clear that ZSE expects no industrial heat demand after 2010. Industrial demand in the years between are estimated with a linear interpolation between the period 2000-2005 and 2005-2010 (see Figure 4.1).

4.1.2 Heat demand of DH-system

Development heat supply

The district heating system of Bratislava is well developed and expansion of connections is not expected. Therefore, a slight increase of 1% per annum of the low temperature heat supply is assumed to compensate for any losses due to ageing of the DH-system.

Retrofitting of the DH-system

The current DH-system consists of an LP-steam network and a hot water network. To upgrade the thermal efficiency of this DH-system, ZSE will replace the LP-steam network by extension of the hot water network by 2010. The efficiency improvement of the DH-system when totally retrofitted is estimated at about 7%. When the retrofitted DH-system is fully operational, a decrease of the heat demand due to efficiency improvement can be assumed.

Development heat supply

It is assumed that the combination of increasing heat demand and increasing transport efficiency of the DH-system will result in a net constant required heat supply. Due to a decreasing LP-steam demand from the industry, the overall heat supply will decrease with about 7% of the 1999 total heat supply (see Figure 4.1) by 2010.

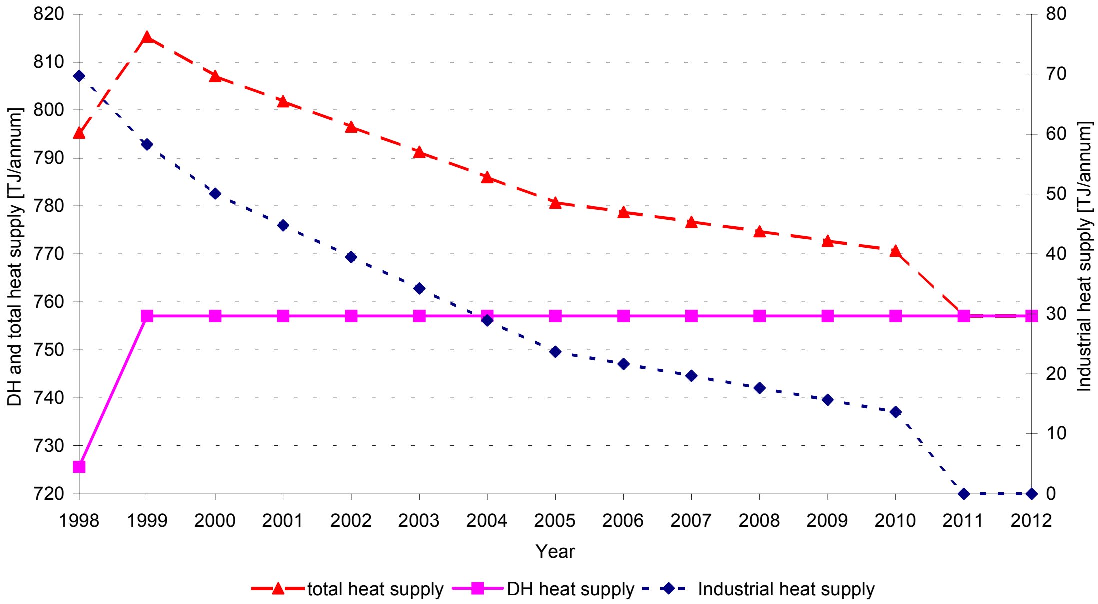

Figure 4.1 *Heat supply at the heat and power plant Bratislava 1*

4.1.3 Electricity supply

In 1996 the electricity company SE developed scenarios for national electricity demand up to the year 2010 (OECD/IEA, 1997). Two basic scenarios were developed, representing a small annual growth of 1.9% and a large annual growth of 3.4%. Growth scenarios of EBRD and MOE are forecasting a growth factor between 1.5% and 3.4% till 2010 (OECD/IEA, 1997). Based on this information, a conservative annual growth factor of 2% for the electricity supply at the heat and power plant Bratislava 1 is assumed (see Figure 4.2).

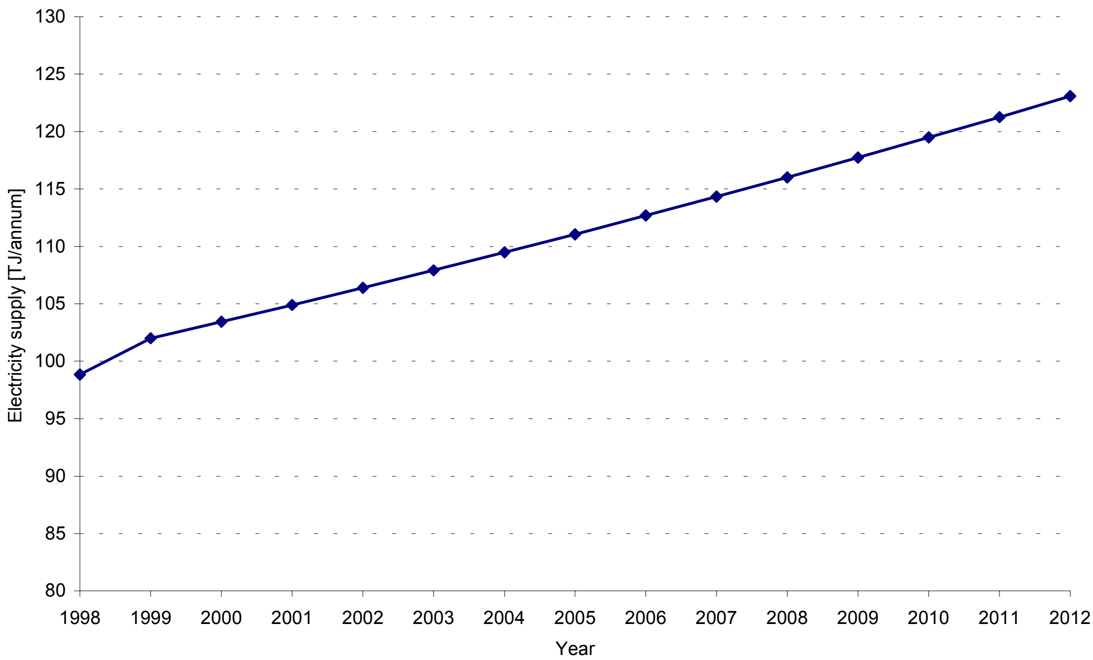

Figure 4.2 *Estimated development of electricity supply (net on-site production and purchases from SE) at heat and power plant Bratislava 1*

4.2 Plant efficiency

The overall efficiency of the current plant is related to the development of the load-factor and individual component efficiencies (see Section 2.4).

4.2.1 Load-factor

In the current situation there is a large thermal over-capacity: the maximum heat demand is about 75 MW_{th} (winter period), while the installed thermal capacity is 180 MW_{th}. This large over-capacity results in a low load-factor and has a negative impact on the efficiency of individual plant components (steam boilers, steam turbine, and gas turbine). However, improvement of this load-factor by a load-shift (i.e. decommissioning boiler capacity) or increasing heat demand will increase production efficiency.

4.2.2 Individual component efficiency

The efficiencies of the different plant components will decrease in time as a consequence of wearing and fouling processes. However, investment in new capacity would increase the efficiency.

4.2.3 Overall efficiency

Due to a lack of information it is assumed that:
1. the impact of a load shift on the efficiency of an individual plant component can be modelled by applying linear interpolation,
2. the impact of wearing and fouling processes on individual plant components are negligible compared to the impact of a load shift.

As a result, it is assumed that the overall efficiency of the plant will only change in case of a load shift or installation of new capacity. Other situations will result in constant overall plant efficiency.

4.3 Emission requirements

Since the heat and power plant has not been out of operation due to local environmental policies it is expected that in the current situation the plant complies with local emissions requirements (NO_x, CO, SO_x and noise). The Slovak Republic wishes to join the EU before 2010. Therefore, it is expected that Slovak environmental acts will develop towards EU policy. In the near future the heat and power plant has to comply with the EU IPPC guidelines (Integral Pollution Prevention and Control). Due to a lack of information it is unclear if the current situation complies with these IPPC guidelines and if not how these could be improved. However, by implementing EU technology (that complies with IPPC guidelines) a positive contribution to meeting these IPPC guidelines is expected.

5. IDENTIFICATION AND SELECTION OF BASELINE OPTIONS

5.1 Assumptions for all options

The following assumptions are made for all baseline options:

1. The configuration of the gas turbine heat recovery boiler (GT+K4) for peak-load production of electricity has a poor energy and economic performance. Without considerable additional investments, this configuration will be decommissioned. Based on information from ZSE it is assumed that these additional investments are not considered to be cost-effective, resulting in decommissioning peak-power production in 2001 for all baseline options.
2. The total heat demand will decrease by 7% in 2012 compared to the 1999 total heat demand as a result of decreasing industrial heat demand. As a result, the heat production at the heat and power plant Bratislava 1 will decrease by 7%.

The characteristics of each developed baseline option are summarised in Table 5.1. In the following sections these baseline options will be described in more detail.

Table 5.1 *Characteristics baseline options*

	Baseline options				
	1	2	3	4	5
Decommissioning GT+HRB	■	■	■	■	■
Status quo current plant situation	■				
Retrofitting K1 and K2		■			
Decommissioning K1, K2 and ST			■	■	■
Diesel engine in stead of gas engine				■	
Delay project with 5 year					■

5.2 Option 1: continuation of the current situation

In this case, a status quo of the current plant situation is assumed. No additional investments are expected. Due to a decreasing total heat demand the production of boiler K5, K1,2 and K6,7 has to decrease by approximately 7%. As a result, on-site power production will decrease. In this case it is assumed that the overall plant efficiency will not change significantly.

5.3 Option 2: retrofitting K1 and K2

Additional investments for lifetime extension of K1 and K2 are assumed to be cost-effective. These investments result in an efficiency improvement of the boilers K1 and K2 to 95% (LHV). Due to decreasing overall heat demand, on-site electricity production will decrease. The overall plant efficiency will change significantly due to efficiency improvement of boilers K1 and K2.

5.4 Option 3: decommissioning K1, K2 and steam turbine

As a result of decreasing industrial heat demand, additional investments for lifetime extension of HP-steam boilers K1 and K2 are assumed to be not cost-effective, resulting in the decommissioning of these boilers in January 2005 (end of lifetime) as well as of the steam turbine. Existing steam production for industrial demand will be taken over by LP-boilers K5, K6 and K7. Because industrial heat demand already decreased to 40% of the 1995-level this will result in a small load-shift of these boilers. The impact of this small load-shift on the efficiencies of these boilers is neglected, assuming a constant overall plant efficiency. After decommissioning the HP-steam capacity there is no power production at the site.

5.5 Option 4: modified project

In this baseline option production of base-load heat and power is performed with a 1 MW_e diesel-fired engine instead of a gas-fired engine. This requires a larger investment due to the installation of a distribution network for diesel. As a result of decreasing industrial heat demand additional investments for lifetime extension of K1 and K2 are not cost-effective, resulting in the decommissioning of these boilers. LP-steam boilers K5, K6 and K7 will cover the remaining industrial demand.

5.6 Option 5: postponement project with five years

In this baseline, the implementation of the gas engine is postponed for five years. Due to decreasing industrial heat demand, additional investments for lifetime extension of K1 and K2 are not cost-effective, resulting in the decommissioning of these boilers. LP-steam boilers K5, K6 and K7 will cover the remaining industrial demand.

5.7 Selection of the baseline

At Bratislava 1 boiler K1 and K2 are almost reaching the end of their lifetime. Without additional investments for lifetime extension they will become very inefficient and unreliable. Therefore the status-quo baseline option is not a realistic option.

At Bratislava 1 a large heat overcapacity exists (Table 2.5) and the steam production will decrease due to relocation of industrial sites (Figure 4.1). Under these circumstances, ZSE expects that additional investments in boiler K1 and K2 will not be cost-effective (large investments, unclarity Slovak energy market). Therefore, ZSE decided[4] not to invest in retrofitting boilers K1 and K2, but to decommission these boilers at the beginning of 2005. These strategic plans of ZSE do not constitute a realistic option for baseline option 2.

Not investing in the retrofitting of boiler K1 and K2 will result in the decommissioning of these boilers after 2004. The remaining industrial heat demand will be taken over by boilers K5, K6 and K7. Power generation by the steam turbine will also be stopped and be compensated for by extra electricity purchase from SE. This development is the least costing option with the lowest financial risks (no large investments) and seems to be a realistic development. Therefore decommissioning boilers K1 and K2 and the steam turbine will be regarded as the most realistic baseline option. This baseline option will be used as a reference scenario for calculating the emission reduction after implementation of the gas engine.

The gas engine is financed by the Dutch government through the PSO-programme. Investments by ZSE involve small adoptions of a gas supply system and connection to the heat network and electricity grid. These investments are relative small compared to the investment in equipment and transport of the gas engine. Furthermore, this project is performed under the AIJ-program of the Dutch government, which is an experimental program for gaining experience with 'real' JI-projects. This AIJ-program has been finalised in 2000. The ongoing AIJ-projects will be implemented according to schedule. Delay or postponement of these final AIJ-projects will endanger the financing of these projects. Therefore, ZSE has no economic interest in modifying the project and investing in a diesel-fired CHP installation or in delaying the implementation of the gas engine. A baseline based on a modified or delayed project is therefore not realistic.

[4] Personal communication with Mr. Sadlek of ZSE.

6. ESTIMATION OF GHG EMISSION REDUCTION

6.1 Emission of GHG prior to start of project

Table 6.1 shows the CO_2 emissions prior to the start of the project for the years 1998 and 1999 in a yearly average.

Table 6.1 *Historical CO_2 emissions 1998 and 1999*

Year	Natural Gas consumption [1000 Nm^3]	On-site emissions [ton CO_2]	Off-site emissions[1] [ton CO_2]
1998	29,909	57,724	6,259
1999	30,563	58,987	6,110

[1] Level of off-site electricity from the grid in the baseline equals power production of the gas engine.

6.2 Electricity and heat supply in the baseline

In 2001 the gas turbine with heat recovery boiler (K4) will be decommissioned followed in 2005 by boilers K1 and K2 (see also Chapter 5). As a consequence, the share of boilers K6 and K7 in the total heat production will increase from about 28% in 1999 to 95% in 2005. Due to the decommissioning of the GT+K4 and K1, K2+ST, the total power supply decreases to zero and will be replaced by electricity purchased from the grid. In Table 6.2 the impact of the decommissioning GT+K4 and KI, K2+ST on the share of boiler capacity in the total annual heat production is given for the baseline.

Table 6.2 *Share of individual boiler capacities in total heat supply in the baseline*

Year	Total heat supply H_{onsite} [TJ]	Share in total heat supply [%]			
		[K1,2/ST]	[GT/K4]	[K5]	[K6,7]
1998	795	64	1	4	31
1999	815	67	2	5	26
2000	807	67	2	5	26
2001	802	67	0	5	28
2002	797	67	0	5	28
2003	791	67	0	5	28
2004	786	67	0	5	28
2005	781	0	0	5	95
2006	779	0	0	5	95
2007	777	0	0	5	95
2008	775	0	0	5	95
2009	773	0	0	5	95
2010	771	0	0	5	95
2011	757	0	0	5	95
2012	757	0	0	5	95

Table 6.2 shows that the efficiency of boiler K6+K7 will increase due to an increasing load factor. As indicated in Section 4.2.3 the increasing boiler efficiency is calculated with equation 3 by applying a linear interpolation.

$$\frac{\eta_t - \eta_{1999}}{95\% - \eta_{1999}} = \frac{h_{fl,t} - h_{fl,1999}}{8760 - h_{fl,1999}} \tag{3}$$

In this equation it is assumed that boiler K6+K7 has a maximum full load efficiency of 95% with an availability of 100% (i.e. 8760 full-load hours per annum). In Table 6.3 the estimated impact of decommissioning GT+K4 and KI, K2+ST on the share of boiler capacity in the total annual electricity production is given for the baseline situation.

Table 6.3 *Share of individual boiler capacities in total power production in the baseline*

Year	Total Electricity Production E_{total} [TJ][1]	Share in total electricity production [%] [K1,2/ST]	[GT/K4]	Grid
1998	99	67	2	31
1999	102	66	5	30
2000	103	64	5	31
2001	105	63	-	37
2002	106	62	-	38
2003	108	60	-	40
2004	109	59	-	41
2005	111	-	-	100
2006	113	-	-	100
2007	114	-	-	100
2008	116	-	-	100
2009	118	-	-	100
2010	119	-	-	100
2011	121	-	-	100
2012	123	-	-	100

[1] $E_{total} = E_{onsite} + E_{grid}$

Based on the figures presented in Table 6.2, individual boiler efficiencies (see Table 2.6) and Equations 4,5 and 6, the on-site natural gas consumption, electricity purchase and overall plant efficiency can be calculated. For the baseline situation the results are given in Table 6.5.

$$\eta_{overall,th} = \left(\frac{\alpha_{1,2}}{r_{hp,st} \times \eta_{e,st} \times \eta_{1,2}} + \frac{\alpha_4}{\eta_{th,(4+gt)}} + \frac{\alpha_5}{\eta_5} + \frac{\alpha_{6,7}}{\eta_{6,7}} + \frac{\alpha_{ge}}{\eta_{th,ge}} \right)^{-1} \tag{4}$$

$$\eta_{overall} = \frac{H_{onsite} + E_{onsite}}{F_{onsite} \times LHV_{ng}} \tag{5}$$

$$E_{grid} = E_{total} - E_{onsite} \tag{6}$$

Table 6.4 *Description of used symbols*

Character			Subscript	
E	Electricity	[TJ]	indices	reference to individual boiler
H	Heat	[TJ]	e	Electric
LHV	Lower Heating Value	[Nm^3]	ge	gas engine
α^1	share total heat production		gt	gas turbine
η^2	efficiency		ng	natural gas
$r_{hp}{}^2$	heat to power ratio		onsite	onsite production/consumption
			st	steam turbine
			th	Thermal
			total	total electricity delivery

[1] See Table 6.2 and Table 6.6.
[2] See Table 2.6, Table 3.1 and Equation 3.

Table 6.5 *Gas consumption and electricity purchase from the grid for baseline situation*

Year	Heat supply H_{onsite} [TJ]	Onsite Electricity Production E_{onsite} [TJ]	Average Heat efficiency[2] $\eta_{overall, th}$ [%]	Average overall efficiency $\eta_{overall}$ [%]	Natural Gas Consumption[1] F_{onsite} [1000 Nm^3]	Electricity from grid E_{grid} [TJ]
2000	807	71	76	83	30,259	32
2001	802	66	77	83	29,892	39
2002	797	65	77	83	29,696	41
2003	791	65	77	83	29,500	43
2004	786	65	77	83	29,304	45
2005	781	-	88	88	25,460	111
2006	779	-	88	88	25,397	113
2007	777	-	88	88	25,334	114
2008	775	-	88	88	25,271	116
2009	773	-	88	88	25,208	118
2010	771	-	88	88	25,145	119
2011	757	-	88	88	24,714	121
2012	757	-	88	88	24,714	123

[1] LHV-Natural Gas = 35 MJ/Nm^3.
[2] Boiler efficiency of K6+K7 increases due to load shift.

6.3 Electricity and heat production after project implementation

The gas engine will replace heat capacity of boilers K1, K2 and K5 (see Paragraph 3.4). The share of the gas engine in the total heat production is very small. Therefore, the gas engine has a very small impact on the load-shift of the steam boilers and additional gas consumption of the boilers is not assumed. On-site power production will reduce electricity purchase from SE. As a result, the electricity production of the gas engine will substitute electricity purchase from the grid. Because the gas engine has a very small capacity compared to the heat demand of the DH-system (load duration curve Figure 2.3), the expected decrease of heat demand has no impact on the operational hours of the gas engine. As a result, production of heat and power only depends on the service intervals indicated by the manufacturer (load factor of 95%, see Paragraph 3.1). In Table 6.6 the impact of decommissioning GT+K4 and KI, K2+ST on the share of boiler capacity in the total annual heat production is given for the project.

Table 6.6 *Share of individual boiler capacities in total heat production with project*

Year	Total heat supply [TJ]	Share in total heat supply [%]				
		[K1,2/ST]	[GT/K4]	[K5]	[K6,7]	Gas Engine
1998	795	64	1	4	31	-
1999	815	67	2	5	26	-
2000	807	67	2	5	26	-
2001	802	64	-	5	27	5
2002	797	64	-	5	27	5
2003	791	64	-	5	27	5
2004	786	64	-	5	27	5
2005	781	-	-	5	90	5
2006	779	-	-	5	90	5
2007	777	-	-	5	90	5
2008	775	-	-	5	90	5
2009	773	-	-	5	90	5
2010	771	-	-	5	90	5
2011	757	-	-	5	90	5
2012	757	-	-	5	90	5

From Table 6.2 it is clear that the efficiency of boiler K6+K7 will increase due an increasing load factor. As indicated in Section 4.2.3 the increasing boiler efficiency is calculated with equation 3 by applying a linear interpolation. In Table 6.7 the estimated impact of decommissioning of GT+K4 and KI, K2+ST on the share of boiler capacity in the total annual power supply is given for the project.

Table 6.7 *Share of individual boiler capacities in total power supply with project*

Year	Total power supply [TJ][1]	Share in total power supply [%]			
		[K1,2/ST]	[GT/K4]	Gas Engine	Grid
1998	99	67	2	-	31
1999	102	66	5	-	30
2000	103	64	5	-	31
2001	105	60	-	29	11
2002	106	59	-	28	13
2003	108	57	-	28	15
2004	109	56	-	28	16
2005	111	-	-	27	73
2006	113	-	-	27	73
2007	114	-	-	26	74
2008	116	-	-	26	74
2009	118	-	-	26	74
2010	119	-	-	25	75
2011	121	-	-	25	75
2012	123	-	-	25	75

[1] including electricity from the grid

Based on the figures presented in Table 6.6, individual boiler efficiencies (see Table 2.6) and Equation 3,4 and 5 (Section 6.2), the on-site natural gas consumption, electricity purchase and overall plant efficiency can be calculated. For the project situation the results are given in Table 6.8.

Table 6.8 *Gas consumption and electricity purchase from the grid for the project*

Year	Heat supply H_{onsite} [TJ]	Electricity supply E_{onsite} [TJ]	Average Heat efficiency $\eta_{overall, th}$ [%]	Average overall efficiency $\eta_{overall}$ [%]	Natural Gas Consumption[1] F_{onsite} [Nm^3]	Electricity from grid E_{grid} [TJ]
2000	807	71	76	83	30,259	32
2001	802	93	74	83	30,842	12
2002	797	92	74	83	30,646	14
2003	791	92	74	83	30,450	16
2004	786	92	74	83	30,253	18
2005	781	30	84	87	26,623	81
2006	779	30	84	87	26,560	83
2007	777	30	84	87	26,497	84
2008	775	30	84	87	26,434	86
2009	773	30	84	87	26,370	88
2010	771	30	84	87	26,307	89
2011	757	30	84	87	25,875	91
2012	757	30	84	87	25,875	93

[1] LHV-Natural Gas = 35 MJ/Nm^3

[2] Boiler efficiency of K6+K7 increases due to load shift, see Section 6.2.

6.4 Estimate of CO_2 reduction

As indicated in Paragraph 6.3 the CO_2 emission reduction is realised by substituting boiler capacity and purchased electricity from the grid with power and heat production from the gas engine. The reduction potential therefore depends only on the activity level of the gas engine. As indicated in Section 3.1 the actual full-load hours of the gas engine are estimated at 8322 hours per annum, which results in an estimated power production of 8380 MWh i.e. 30 TJ_e. In the next paragraphs this reduction will be quantified.

6.4.1 Projection emissions during project period

The annual on-site CO_2 emissions are calculated based on the total annual gas consumption, using an emission factor of 1.93 kg/Nm^3 for natural gas. Off-site emissions are related to the purchased electricity from the grid, using the emission factor for centrally produced electricity (see Section 3.4.2). In Table 6.9 and Table 6.10 the calculation results are given for the baseline and project emissions based on the projected natural gas consumption on-site and the amount of electricity purchased from the grid.

Table 6.9 *Estimated baseline CO_2 emissions*

Year	On-site		Off-site		Total Emissions
	Natural Gas [1000 Nm^3]	Emissions[1] [ton CO_2]	Electricity[2] [TJ]	Emissions[3] [ton CO_2]	[ton CO_2]
2000	30,259	58,399	32	6,404	64,803
2001	29,892	57,692	39	7,531	65,223
2002	29,696	57,314	41	7,691	65,004
2003	29,500	56,935	43	7,837	64,772
2004	29,304	56,556	45	7,970	64,526
2005	25,460	49,137	111	19,146	68,284
2006	25,397	49,016	113	18,850	67,865
2007	25,334	48,894	114	18,545	67,439
2008	25,271	48,773	116	18,219	66,992
2009	25,208	48,651	118	17,906	66,557
2010	25,145	48,529	119	17,575	66,104
2011	24,714	47,699	121	17,228	64,927
2012	24,714	47,699	123	16,855	64,554

[1] emission factor natural gas is 1.93 kg/Nm^3
[2] based on 8322 full load hours of the gas engine, i.e. 32 TJ_e production by gas engine
[3] emission factor central produced electricity (see Table 3.2)

Table 6.10 *Estimate project CO_2 emissions*

Year	On-site		Off-site		Total Emissions
	Natural Gas [1000 Nm^3]	Emissions[1] [ton CO_2]	Electricity [TJ]	Emissions[2] [ton CO_2]	[ton CO_2]
2000	30,258	58,399	32	6,404	64,803
2001	30,842	59,525	12	2,316	61,842
2002	30,646	59,147	14	2,616	61,763
2003	30,450	58,768	16	2,902	61,670
2004	30,253	58,389	18	3,173	61,562
2005	26,623	51,383	81	13,945	65,328
2006	26,560	51,261	83	13,803	65,064
2007	26,497	51,139	84	13,651	64,790
2008	26,434	51,017	86	13,481	64,498
2009	26,370	50,895	88	13,318	64,213
2010	26,307	50,773	89	13,137	63,910
2011	25,875	49,940	91	12,942	62,882
2012	25,875	49,940	93	12,724	62,664

[1] emission factor natural gas is 1.93 kg/Nm^3.
[2] emission factor central produced electricity (see Table 3.2).

The difference between baseline and project emissions indicates the emission reduction achieved by the project, see Table 6.11.

Table 6.11 *Estimate CO_2 emission reduction 2000-2012 (ton CO_2)*

Year	Baseline Emissions	Project Emission	Emission Reduction	Emission Reduction [%]
2000	64,803	64,803	0	0
2001	65,223	61,842	3,382	5
2002	65,004	61,763	3,242	5
2003	64,772	61,670	3,102	5
2004	64,526	61,562	2,964	5
2005	68,284	65,328	2,955	4
2006	67,865	65,064	2,801	4
2007	67,439	64,790	2,649	4
Start First Budget period				
2008	66,992	64,498	2,493	4
2009	66,557	64,213	2,345	4
2010	66,104	63,910	2,194	3
2011	64,927	62,882	2,045	3
2012	64,554	62,664	1,891	3
End First Budget period				
Total	329,134	318,167	10,967	3

See also Figure 6.1 for a graphical representation of the emission projection.

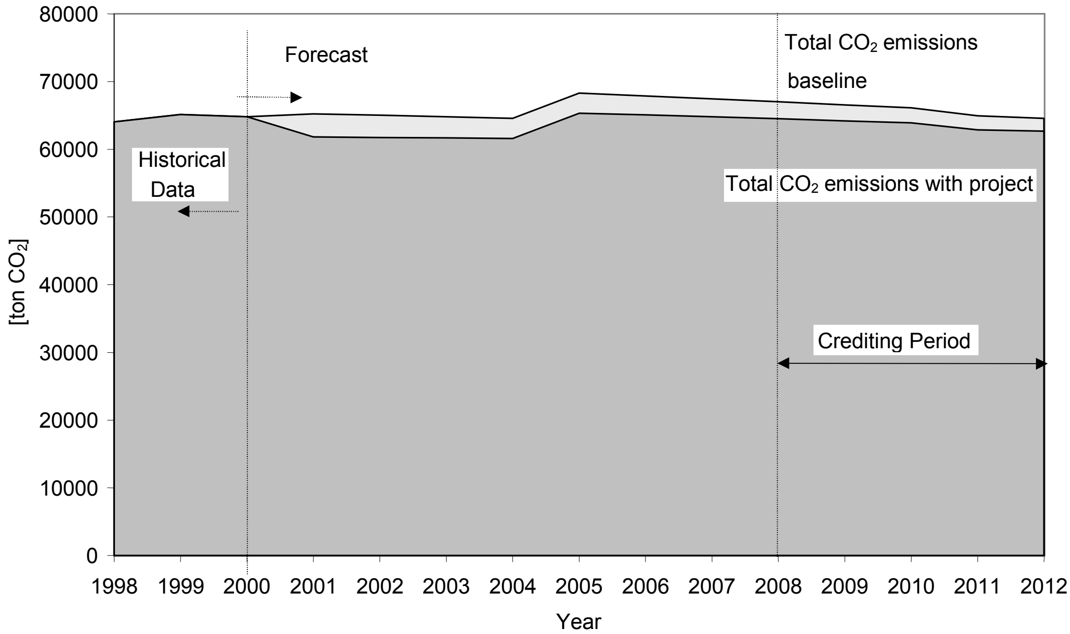

Figure 6.1 *Historical and forecasted baseline CO_2 emissions at Heat and Power plant Bratislava1 and impact of project*

The reduction is decreasing slightly due to the decreasing of the specific CO_2 emission factor for central electricity production as well as an increasing transport efficiency of the electricity grid (Ministry of Economic Affairs, 2000).

6.4.2 Crediting time

Projects can only generate Emission Reduction Units (ERUs) for a fixed and limited period of time, depending on the project category. For this CHP project, a maximum crediting time of 15 years is assumed, based on (Ministry of Economic Affairs, 2000). With a technical lifetime of 15 years, the gas engine will generate ERUs during the full five years of the first budget period from 2008 till 2012.

6.4.3 Reduction potential

Based on figures in Table 6.11 the total emission reduction in the first budget period is estimated at 10967 ton CO_2. Because possible emissions of other GHG (e.g. CH_4 and N_2O) are neglected, this reduction potential equals 10967 ton CO_{2eq}.

7. EVALUATION OF ADDITIONALITY

Table 2.5 shows that a large overcapacity of heat production exists at Bratislava 1. The decommissioning of boilers K1 and K2, based on these figures, will result in a load shift to boilers K6 and K7. Due to this improved load shift, it is expected that the efficiency of these boilers will increase. Since the operation of the heating plant adheres to the current regulatory emission requirements (i.e. no indication by ZSE that this is not the case) it is expected that this load shift will not endanger the permit. However, due to a lack of information there is no insight in future developments of these regulatory emission requirements.

Based on this information, it is clear that from a technical, economic and environmental point of view there is no need to invest in a small-scale CHP installation, despite the environmental benefits. Therefore, additional funding for investment in a small-scale CHP installation is essential to gain these environmental benefits.

8. MONITORING PLAN

In the baseline study the GHG-emission reduction realised by the project was estimated ex-ante. Assumptions are made regarding future developments of the activity level and performance of the plant. These assumptions have to be confirmed by monitoring relevant process parameters that have to be defined in the monitoring plan. Monitoring should include specific indicators, constants and variables that are considered necessary to sustain the claimed emission reduction as well as create a transparent picture for verification. To obtain reliable emission reduction figures, the monitoring plan also defines the measurement procedure of these parameters, the method for calculating the GHG-emission reduction from these parameters and responsibilities of the project partners regarding the monitoring and processing of plant production figures. The monitoring results will be documented in the monitoring report. In the following sections the developed monitoring plan for this PSO/AIJ project will be described.

8.1 Parameter for monitoring

As indicated in Chapter 4 of the baseline study, the GHG-emissions of the project are determined by several key-factors, process parameters and baseline assumptions, which are divided in project-specific indicators, constants and baseline indicators (see Table 8.1).

Table 8.1 *Definition of indicators for monitoring*

Indicator	Key-factor	Assumption/Estimate
Baseline indicator	heat demand DH-system	decrease with 7% in the period 1999-2010
	total electricity production[1]	annual growth of 2%
	decommissioning GT+K4	2001
	decommissioning K1+K2	2005
Project indicator	heat production gas engine	38314 GJ/annum
	electricity production gas engine	8380 MWh/annum
	natural gas consumption gas engine	2374570 Nm^3/annum
	total efficiency gas engine	82.4%
	electric efficiency gas engine	36.3%
	on-site heat production	see Table 6.8
	on-site electricity production	see Table 6.8
	on-site fuel consumption	see Table 6.8
	load shift boiler K6+K7	≈ 27% → 90% in 2005 (see Table 6.6)
	overall thermal efficiency	see Table 6.8
Constants	LHV-natural gas	35 MJ/Nm^3
	emission factor electricity from grid	see Table 3.2

[1] electricity purchase from SE is included.

To validate these assumptions the indicators listed in Table 8.1 are monitored using measured production data as well as calculations.

8.2 Monitoring scheme

To measure and calculate the key factors listed in Table 8.1 the following simplified scheme is used to indicate the process parameters that will be monitored (Figure 8.1).

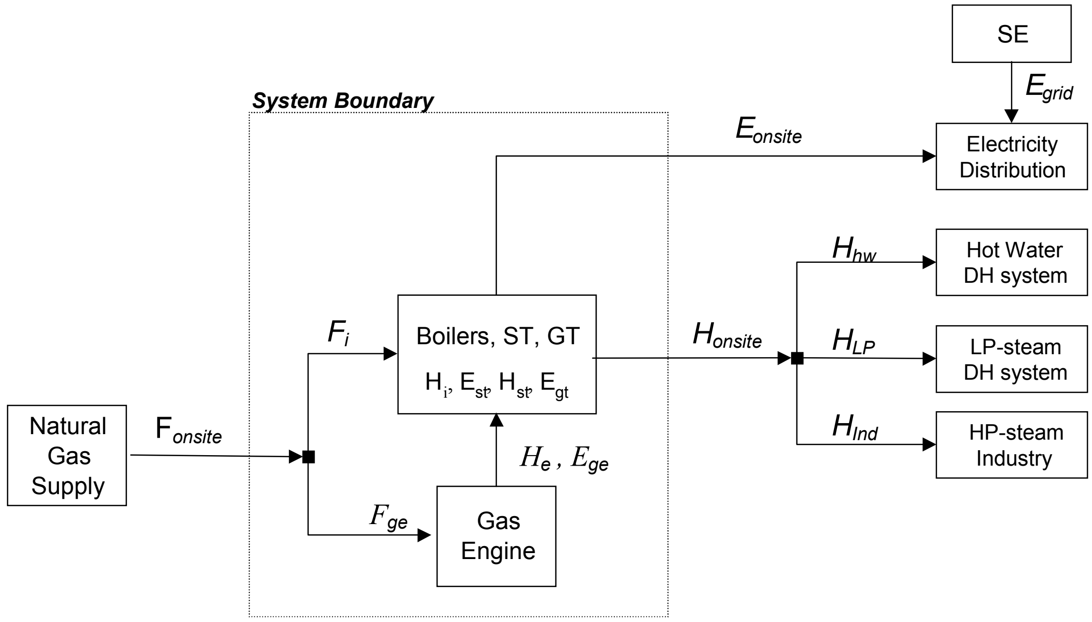

Figure 8.1 *Scheme for calculating plant performance*

In Table 8.2 the used symbols of Figure 8.1 are described as well as the symbols used in the next subsections.

Table 8.2 *Description of used symbols*

Capitals			Subscripts	
C	Capacity	[MW]	bl	baseline
F	Fuel consumption	[Nm^3]	e	electricity
E	Electricity supply	[MWh]	ge	gas engine
EC	Emission Coefficient	[$kgCO_{2eq.}/Nm^3$]	grid	electricity purchase from SE
		[$kgCO_{2eq.}/kWh$]		
h	annual operation hours	[hours/annum]	gt	gas turbine
H	Heat production		fl	full load
LHV	Lower Heating Value	[GJ]	hw	hot water
		[MJ/Nm^3]	i	reference to individual boiler
R	Heat to power ratio		ind	industrial demand
GHG	Greenhouse gas emissions	[-]	LP	low pressure steam
η	efficiency	[ton $CO_{2eq.}$]	ng	natural gas
		[-]	overall	overall
			st	steam turbine
			onsite	onsite production/consumption
			t	monitoring period

8.3 Calculation methods

In the following subsections the calculation of the key factors and realised GHG-emission reduction will be given.

8.3.1 Total heat and power demand

Total heat supply to DH-system: $$H_{onsite} = H_{hw} + H_{LP} + H_{Ind} \quad (7)$$

Total electricity production: $$E_{onsite} = E_{st} + E_{gt} + E_{ge} \quad (8)$$

$$E_{total} = E_{onsite} + E_{grid} \quad (9)$$

8.3.2 GHG-emission reduction

Project emissions: $$GHG_{project} = F_{onsite} \times EC_{ng} + (E_{total} - E_{onsite}) \times EC_{grid} \quad (10)$$

Emission reduction[5]: $$\Delta GHG = GHG_{baseline} - GHG_{project} \quad (11)$$

8.3.3 Evaluation of baseline validity

The realised emission reduction is influenced by the key factors listed in Table 8.1. Deviations from these key-factors with respect to the baseline situation will influence the calculated emission reduction. Therefore, these possible deviations have to be determined by measurement (baseline indicators and project specific indicators), calculations (project specific indicators) and external information (LHV natural gas from supplier, emission factor of electricity purchased from the grid). Regarding the project specific indicators, the following calculations are applied:

Overall efficiency gas engine: $$\eta_{overall,ge} = \frac{3.6 \times E_{ge} + H_{ge}}{F_{ge} \times LHV_{ng}} \quad (12)$$

Electric efficiency gas engine: $$\eta_{e,ge} = \frac{3.6 \times E_{ge}}{F_{ge} \times LHV_{ng}} \quad (13)$$

Overall thermal efficiency of the plant: $$\eta_{overall,th} = \frac{H_{onsite}}{F_{onsite} \times LHV_{ng}} \quad (14)$$

Load shift boiler K6+K7: $$\alpha_{6,7} = \frac{H_{6,7}}{H_{onsite}} \quad (15)$$

[5] For baseline emissions see Table 6.9.

In case the key factors deviate more than 5% from the values in the baseline study (situation with project), it is recommended that a new estimate of the baseline emissions be made by using the following 2-step procedure:

Step 1: Determine:

- share of individual plant components in total heat production,
- differences of these shares with baseline with project values (Table 6.6),
- efficiencies of individual plant components based on monitored data,
- difference of these efficiencies with baseline values(Table 2.6 and Table 3.1).

Step 2: Estimate:

- share of individual plant components based on difference for the project situation and Table 6.2,
- efficiency of individual plant components based on difference for the project situation and Table 2.6.

Step 3: Adjust GHG emission level for the baseline situation in absence of project:

- estimate overall thermal efficiency,

$$\eta_{overall,th} = \left(\frac{\alpha_{1,2}}{r_{hp,st} \times \eta_{e,st} \times \eta_{1,2}} + \frac{\alpha_4}{\eta_{th,(4+gt)}} + \frac{\alpha_5}{\eta_5} + \frac{\alpha_{6,7}}{\eta_{6,7}} \right)^{-1} \quad (16)$$

- estimate natural gas consumption,

$$F_{onsite,bl} = \frac{H_{onsite}}{\eta_{overall,th,bl} \times LHV_{ng}} \quad (17)$$

- estimate baseline GHG emission level.

$$GHG_{baseline} = F_{onsite,bl} \times EC_{ng} + \left(E_{total} - E_{onsite}\right) \times EC_{grid} \quad (18)$$

8.4 Measurement equipment

For the monitoring study, the existing measurement equipment will be used. For details, see Table 2.3 in Section 2.3 of the baseline study. Characteristics of new measurement equipment for monitoring the performance of the gas engine are given in Table 8.3.

Table 8.3 *New installed measurement equipment for monitoring performance gas engine*

Code	Name	Measurement of	Standard	Accuracy	Frequency
F17	Water Gauge	hot water production[1]	ISO 9001	<1.5%	Once a day
E3	Power-meter	power production	ICS 29.240.10	<0.5%	Once per hour
E3	Electricity- meter	electricity supply to the grid	ICS 29.240.10	<0.5%	Once a day
F18	Orifice Plate meter	natural gas flow[1]	DIN 1952 ISO 5167	< 1.5%	Once a day

[1] Standard for temperature measurement and/or calculation method is not available.

In Table 8.4 the source of the different process variables is indicated.

Table 8.4 *Used measurement equipment*

Process parameter	Equipment
Natural gas consumption	
F_I, F_{total}	F1-F6
F_{ge}	F18
Heat supply	
H_{total}	F16, H1-H6
H_{hw}	F16, H1
H_{LP}	H2, H3, H4, H6
H_{Ind}	H5
H_I	F7-F11
H_I	F7-F11, F14
H_{st}	F12
Electricity supply	
E_{total}	E1, E2, E3
E_{GE}	E3
E_{GT}	E1
E_{ST}	E2

8.5 Data collection

8.5.1 Historic and current situation

In the current situation the controlling and monitoring of the heat and power plant is decentralised in three control units:

- control room for boiler K1 and K2 and steam turbine,
- control room for boiler K5, K6, K7,
- the gas turbine is a stand-alone option, it has an on-site control panel.

The following process parameters are monitored:

- steam: temperature (^{0}C,) pressure (kPa) and flow (ton/h),
- electricity: power (MW) and production (MWh),
- gas consumption: pressure (kPa), opening valve (%),
- water consumption: flow (ton/h).

Process operators at the plant monitor these data during daytime (07:00-17:00) by filling in preprinted tables with a frequency of approximately 30 minutes. During the evening and night there are no monitoring activities. However, every 24 hours the total steam production and the total gas consumption from the individual gas boilers are recorded manually. The same procedure is used for total heat delivery to the different branches in the DH-system and total electricity to the grid. All manually recorded production data are sent to Mrs. Marta Gabelova (ZSE) who is responsible for:

1. storing and processing the manually monitored production data,
2. carrying out evaluations of production performance based on these manually recorded data.

This monitoring procedure will be maintained after implementation of the gas engine.

8.5.2 After implementation of gas engine

The gas engine is also a stand-alone construction and is placed as a package by placing it in a container. The monitoring and control equipment is located near/inside this container. The procedure for collecting and processing the necessary production data of the gas engine to evaluate the performance and production of the gas engine is not changed.

8.6 Data processing

In Table 8.5, Table 8.6 and Table 8.7 a schematic overview is given concerning the process parameters that are monitored and stored by ZSE, using an Excel-spreadsheet. The format of this spreadsheet was developed by ECN in co-operation with ZSE. All figures are based on daily production data.

Table 8.5 *Parameters to monitor heat production including used measurement equipment*

Process parameter	Unit	Boiler K1+K2	Boiler K5	Boiler K6+K7
Heat capacity	[MW_h]	F7+F8	F11	F9+F10
Heat production	[GJ]	F7+F8	F11	F9+F10
Gas Consumption	[Nm^3]	F2+F3	F6	F4+F5

Table 8.6 *Parameters to monitor power production including used measurement equipment*

Process parameter	Unit	ST	GT+Boiler K4	Gas Engine	Grid
Heat production	[GJ]	F12	F14	F17	-
Electricity production	[MWh]	E2	E1	E3	E4
Steam consumption	[GJ]	F7+F8	-	-	-
Running hours	[hours]	-	-	onsite meter	-
Natural gas consumption	[Nm^3]	-	F1	F18	-

Table 8.7 *Parameters to monitor heat distribution including used measurement equipment*

Process parameter	Unit	HW-net	LP-steam				HP-steam
			North	South	West	Kablo	Gumon
Heat capacity	[MW_h]	F16+H1	H2	H3	H4	H6	H5
Heat production	[GJ]	F16+H1	H2	H3	H4	H6	H5

8.7 Responsibilities

In order to get reliable and accurate figures to calculate the realised emission reduction, the following responsibilities have been defined. The gas engine and heat and power plant will be operated by ZSE. Therefore, ZSE will be responsible for collecting and storing the process parameters during the monitoring period. In order to be able to operate the gas engine efficiently and safely, operators of ZSE will be instructed by specialists from the supplier of the gas engine (i.e. Geveke). Maintenance of the gas engine will be performed by the local Caterpillar dealer. However, at the time of writing of this report, the negotiations between Nuon and ZSE about a maintenance contract are still in progress. Based on the input from ZSE, the achieved emission reduction will be calculated and reported by ECN. This calculation is based on the method addressed in Section 8.3. An estimate of the variance of the calculated emission reduction will be based on the variance of the monitored production figures and the accuracy of the used measurement equipment. The tasks and responsibilities regarding monitoring activities are summarised in Table 8.8.

Table 8.8 *Responsibilities regarding development monitoring study*

Action	ZSE	ECN
Collection daily production data		
Processing production data		
Sending processed data to ECN on a weekly basis		
Evaluation of the plant performance/emissions		
Calculating emission reduction		
Developing a monitoring report after monitoring period		

8.8 Time table

According to the project planning (Section 1.3) the gas engine will be operational in the first quarter of 2001. Since this project involves AIJ-activities, the project will only be monitored during 2001. The contract for developing these AIJ-activities will end at 1 November 2001. Therefore, the monitoring period will end 31 October 2001. One monitoring report will describe the monitored data and the realised emission reduction.

8.9 Monitoring report

In the monitoring report GHG and other environmental impacts must be described. However, since the only environmental impact that has been addressed in the baseline study is CO_2 emission (Paragraph 3.4.3), no other GHG or environmental impacts will be monitored. The monitoring report will address the total of realised GHG-emission reduction, containing the following information:

1. Presentation of the plant performance by listing the following process parameters, presented with a weekly resolution:
   - gas consumption of the individual boilers, gas turbine and gas engine,
   - total heat distribution to the net,
   - electricity production of the steam turbine, gas turbine and gas engine,
   - efficiencies of the individual plant components,
   - overall efficiency of the plant.

   In addition, the load-curve of the distributed heat during the monitored period will be presented.
2. Calculation of the GHG emission reduction realised in the monitored period, in a transparent way and following the calculation described by the monitoring plan.
3. Evaluation of realised GHG emission reduction with respect to the estimated level of GHG-emission reduction.
4. Results of project audits.
5. Results of project non-conformances and deviations.
6. Evaluation of validity of the baseline study.

9. EXPERIENCE WITH ERU-PT GUIDELINES

For this baseline study and monitoring plan, the ERU-PT guidelines were used to gain experiences and provide recommendations for further development of these guidelines. In this section, the main conclusions and recommendation are listed.

9.1 Guidelines for the baseline study

1. The introduction to the guidelines should provide more background information on this JI-framework and the related concepts and terminology used in the guidelines. This is necessary to give the baseline developer a clear picture of the function of the baseline study in relation to the JI-framework.
2. Project developers with little or no experience in developing energy scenarios will encounter more problems in interpreting the guidelines, especially regarding the impact of legal, political and social-demo-graphical factors (Section 2.5 *Key factors influencing project and baseline emissions*) on the performance of the project. Although several factors are listed, it is sometimes difficult to quantify or qualify the impact of these factors (e.g. what is a robust and accurate methodology for developing socio-demographic developments or future price scenarios). Elaboration on this section with several relevant examples addressing the relation between the meaning of these factors in relation to their impact would therefore be helpful.
3. The difference between baseline options and key factors is not clear. For instance, is the development of energy prices a key factor that influences the activity level of the project, or is it a baseline option? More elaboration on this point is recommendable.
4. The guidelines recommend describing the situation with project before the baseline situation (in absence of project). However, in case of a project that is implemented in an existing situation (e.g. retrofitting of a heating plant), it is easier to start describing the current situation followed by a description of the impact of the project. Is the baseline developer free to choose the structure of the study?
5. Guidelines on the use of historical production data as a basis for the baseline study could be elaborated. How much should be presented and in what detail?
6. The current guidelines do not address the presenting of possible ranges in emissions as an indication of uncertainty in data and assumptions. Given the amount of work involved, the related guidelines should be very clear. It is also unclear if the baseline options could be regarded as a kind of uncertainty analysis.

9.2 Guidelines monitoring plan

1. In the ERU-PT the guidelines of the monitoring plan are elaborated in less detail than the guidelines for the baseline study. They should be developed further, because experience in this project has shown that the existing guidelines leave too much room for interpretation.
2. The guidelines concerning the description of the impact of the differences between the estimated (in the baseline study) and the monitored activity level of the project on the realised GHG emission reduction have to be elaborated further.
3. The guidelines with respect to the required level of detail of description of measurement methods, instruments and accuracy should be elaborated.
4. The guidelines should clarify the required relation and consistency between the baseline and monitoring methodology.

9.3 Communication between baseline developer and validator

The current ERU-PT guidelines for baseline study and monitoring are detailed, but still leave much room for interpretation. As a result, it is very likely that the baseline studies for similar projects validated by different bodies will turn out to be different, particularly in level of detail. When updating the guidelines and validation procedures, it should be investigated if this also leads to different validation standards. If this is the case, the guidelines should be adjusted.

Furthermore, under current practice, the communication between baseline developer and validator is formal. The validator has to treat any submission from the developer according to its validation procedures. However, in a situation where guidelines require substantial interpretation from the validator, this lead to a very inefficient and slow working relations and communication. It is therefore recommended that the guidelines be extended with guidelines on procedures and communication with the validator as follows:

1. The project developer and the validator can agree on an initial drafting period. In this period, the developer can submit drafts of (sections of) the baseline study and monitoring plan, which are commented upon by the validator in a more informal way without going through the complete validation procedures. This way, feedback from the validator can be obtained much earlier.
2. The project developer can indicate when a final baseline study and monitoring plan is submitted, which is then subject to the full validation procedure.

REFERENCES

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APPENDIX A

A.1 Letter from ZSE d.d. 16 June 2000

Západoslovenské
energetické
závody

Západoslovenské
energetické závody, š. p.
Čulenova 6
816 47 Bratislava

Netherlands Energy
Research Foundation ECN
Policy Studies
Mr. Alex de Raad
Westerduinweg 3
1755 ZG Petten
The Netherlands

VAŠ LIST ZNAČKY / ZO DŇA	NAŠA ZNAČKA	VYBAVUJE / KLAPKA	BRATISLAVA
	521/2000/90	Ing. Sadlek/2501	16.06.2000

VEC
Subject: Base - line study CHP unit ZSE

Dear Mr. de Raad,

allow me let you know that cogeneration project in ZSE was relocated from Komarno to Bratislava. New location was found in Heat and power plant Bratislava 1. Nuon is preparing new proposal for Senter now and Geveke Motoren designs unit for Bratislava conditions.
We have first meeting in May and there was agreed that ZSE will send new data for base - line study. I also send copy of this letter to Nuon.

There are data of heat supply and gas consumption of Heat and power plant Bratislava 1 in appendix. The years 1998 and 1999 represent normal heat production. We expect decrease total heat demand but only in steam supply (situation in hot water production will be stable). Development of heat supply from this plant is determined by increasing electricity share in total production (heat plus electricity) in Bratislava - East area.

We plan to produce by the newest CHP blocks and boilers and the focus is energy savings (in production, in net - reconstruction steam net to hot water net).
Several main 110 kV electricity nets supply energy to Bratislava and there are some power sources in Bratislava area (in oil company Slovnaft, other lower factories, 3 heat and power plants ZSE, combined cycle Bratislava 2 with 220 MWe). Electricity net in Slovakia is mutually connected and it´s hard to say which electricity source supply electricity to customers in Bratislava. The biggest source is combined cycle Bratislava 2. This plant also supply heat to district heating net which is connected to Heat and power plant Bratislava 1.

Tel.: 07/52 96 17 41-5 Fax: 07/52 92 53 14 IČO: 152153 DIČ: 152153 / 600 Bankové spojenie VÚB Bratislava-mesto Č. ú. 2107 - 012 / 0200

Recent estimate for the transport and distribution losses for electricity at level more than 22 kV is about 3,5 - 4 %. Because new CHP unit is small the distance to customer is also small (part of production will be used for own consumption in Heat and power plant Bratislava 1 - about 500-800 kWe), the electricity losses would be lower - at level 2,5 %.
I hope the data are sufficient and I am looking forward to next meeting (date will be agreed with Nuon).

Best regards,

Sadlek
Ján Sadlek

Appendix : 3xA4
Copy : ZSE, Nuon

Appendix to letter from ZSE d.d. 16.6.2000

Season	**1998**	**1999**
Total heat supply in GJ	795 321	815 310
Total gas consumption in thousands m^3	29 909	30 563
Share industrial heat demand in total heat demands	69 724	58 257
Operation hours: boiler K1	4 314	4 287
boiler K2	4 682	4 954
boiler K4	124	265
boiler K5	902	1 124
boiler K6	2 318	1 657
boiler K7	2 738	2 989
Age of existing boilers: K1	56 years	
K2	56 years	
K4	38 years	
K5	23 years	
K6	30 years	
K7	30 years	
Average lifetime of these boilers	30 years	

Annual gas consumption in thousands m^3 – total/average

1995	1996	1997	1998	1999	2000
34 934	37 149	35 320	29 909	30 563	28 133

Total gas consumption in thousands m^3 (1995 – 200): 196 008
Average gas consumption in thousands m^3 (1995 – 2000): 32 668

Annual heat supply in GJ

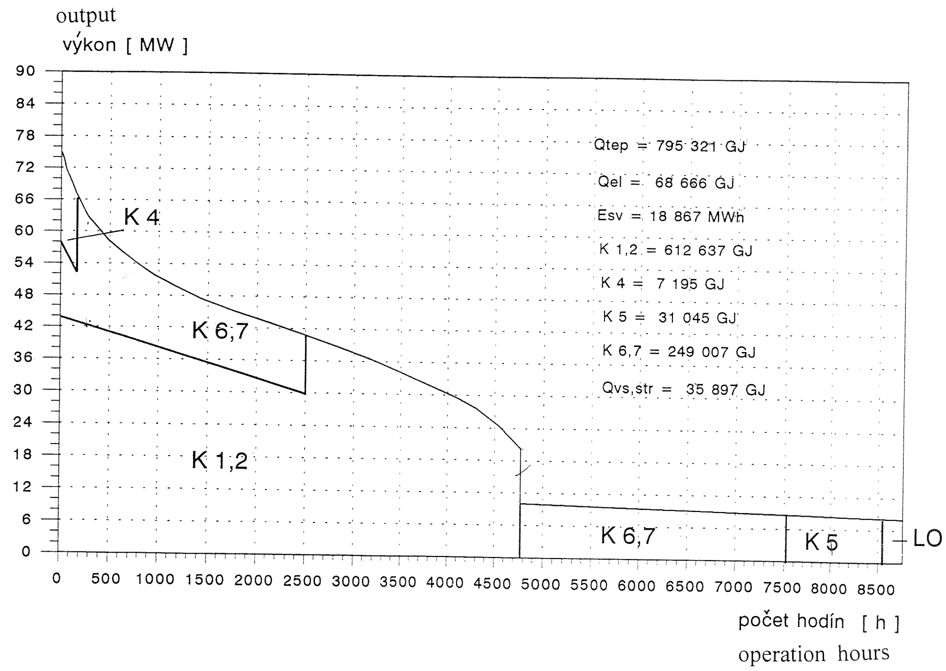
1995	1996	1997	1998	1999	2000
933 520	961 597	883 019	795 321	815 310	730 000

Total heat supply in GJ (1995 – 2000): 5 118 767
Average heat supply in GJ (1995 – 2000): 853 128

Heat and power plant Bratislava
Load duration curve of 1998

Tp I

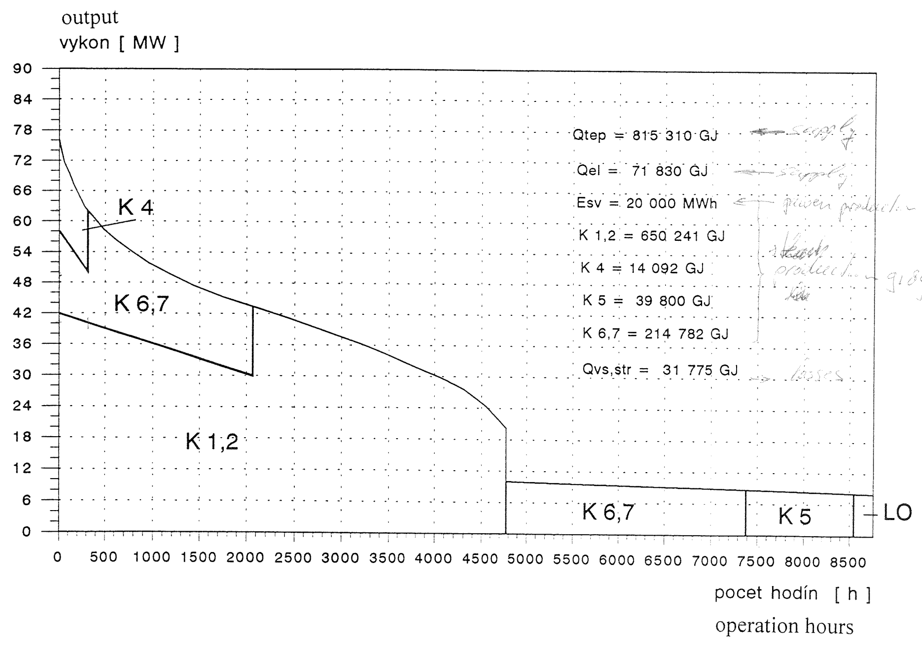
diagram ročného trvania dodávky tepla - r. 1998



Heat and power plant Bratislava I
Load duration curve of 1999

Tp I

diagram rocného trvania dodávky tepla - r. 1999



A.2 Notes during visit ZSE at ECN d.d. 3 August 2000

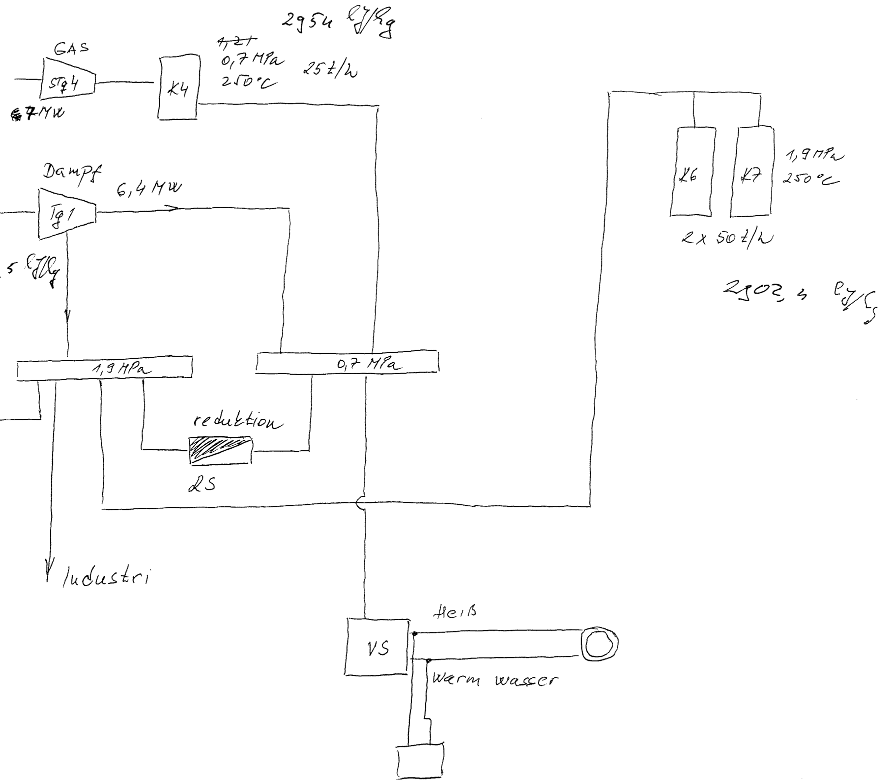


Figure A.1 *Schematic overview of the heating plant Bratislava 1*

A.3 Email message from ZSE d.d. 22 August 2000

-----Original Message-----
From: Sadlek Jan [SMTP:SadlekJ@ba.zse.sk]
Sent: 22 August 2000 15:47
To: deraad@ecn.nl
Cc: Edwin.Normann@nuon.com
Subject:

Dear Mr. de Raad,

I apologize for lossing data in last mail. There isn´t confidential some data but it was in tables and some mistake happened at the transport.
Now it is again (without table):

1) Power production of turbines (MWh per year)

Year season	1995	1996	1997	1998	1999
Gas turbine	6975	6063	7152	1750	2014
Steam turbine	16142	19848	19969	17117	17986

2) Steam production is expected on following levels:

Year season	2000	2005	2010
Steam (ton per hour)	55	26	15

3) The minimum of heat demand was around 10 MWth in 1999. It represents steam for industry and to the steam net and also hot water to the net. Share of hot water is around
2,5-3 MWth. Maximum of hot water supply is 17 MWth because a capacity of exchange station is the same.
Hot water net from plant Bratislava 1 is connected to large net in Bratislava - East (it has capacity around 400 MWth). So during every year is reached minimum 2,5-3 MWth
and maximum 17 MWth from plant Bratislava 1 (in hot water).

4) Electricity production will be taken over by gas and steam turbines and cogeneration unit following:

from gas turbine -	till summer 2001 (low efficiency)
from steam turbine -	till 2004 (low heat demand)
from CHP unit -	continuously

5) After 2005 no turbine will operate, only cogeneration unit.

6) We expect finishing of industrial demand around 2010 (because it is area in the middle of city and municipality plan other funkcions here). Steam for industry will be produced by K5, K6, K7after 2005.

7) Current energy losses at steam net are 12-16 % (5-7% at hot water net).
Estimate of the energy efficiency improvement by converting the steam net to a hot water net is around 7 %, similary.

Best regards,

Ján Sadlek

A.4 Email message from ZSE d.d. 26 October 2000

Odesílatel: Sadlek Jan
Odesláno: 26. október 2000 11:24
Komu: 'deraad@ecn.nl'
Kopie: 'Edwin.Normann@nuon.com'
P•edm•t: Additional information

Dear Mr. de Raad,

now I can send you next data about Heat and power plant Bratislava 1 (by tables):

a) Operational hours

Boiler	1995	1996	1997	1998	1999
K1	3934	4452	4587	4314	4287
K2	3961	4401	4580	4682	4954
K4	928	849	937	124	265
K5	905	681	450	902	1124
K6	3422	2490	3636	2378	1657
K7	3266	3988	2109	2738	2989

b) Heat production (in GJ)

Boiler	1995	1996	1997	1998	1999
K1	297 175	345 733	334 328	283 608	302 771
K2	293 758	333 698	328 842	329 029	347 470
K4	51 051	45 386	49 897	7 195	14 092
K5	35 035	26 716	14 339	31 045	39 800
K6	193 498	136 353	184 199	121 345	79 788
K7	174 492	205 826	100 707	127 662	134 994

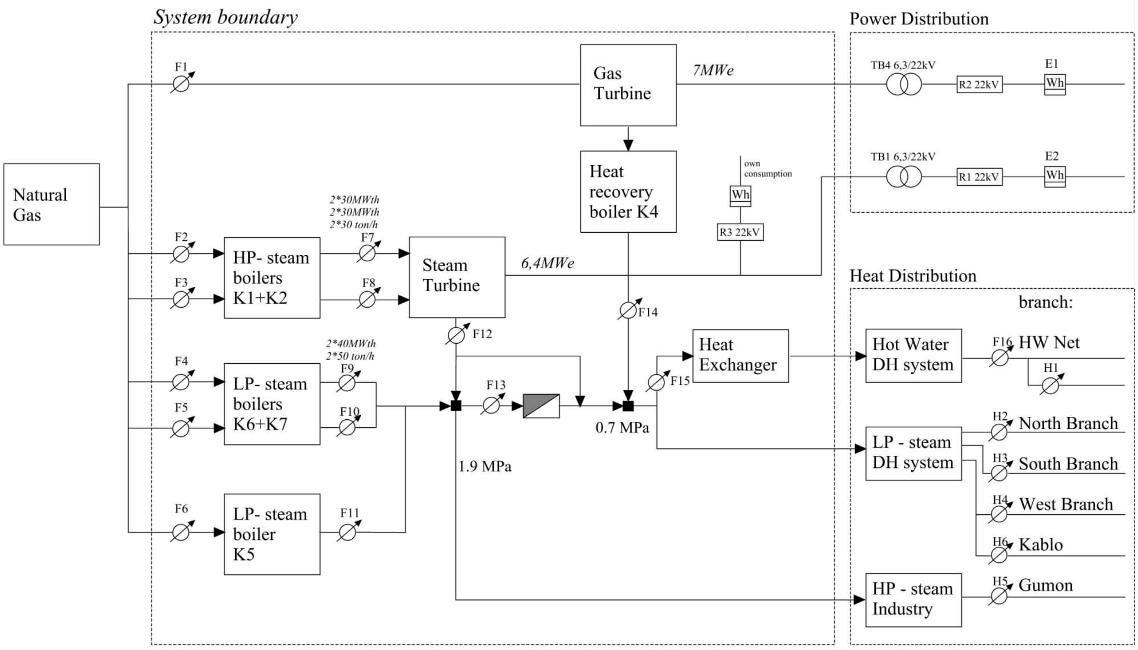
The flow diagram with measurement specification will be sent later.

Best regards,
Ján Sadlek

A.5 Schematic flowchart of the heat and power plant Bratislava 1

Flowchart is based on discussion during visit ZSE to ECN, see Section A.2.

Schematic Flowchart of the Heat and Powerplant Bratislava 1



F1 - F15 - Flow; Orifice Plate Meter; Data - once a day; Accuracy - Max. error < 1.5%
H1- Heat; Ultrasonic Heat Meter; Data - once per hour; Accuracy - Max. error < 1.5%
H2 - H5 - Heat, Vortex (Danfoss); Data - once per hour; Accuracy - Max. error < 1.5%
H6 - Heat; Orifice Plate Meter (Rosemount); Data - once per hour; Accuracy - Max. error < 1.5%
E1, E2 - Electricity - once a day; Power - once per hour; Accuracy - Max. error < 0.5%
F16 - Flow; Water-gaugue; Data - once a day; Accuracy - Max. error < 1.5%

Figure A.2 *Schematic Flowchart of the Heat and Power plant Bratislava 1*

A.6 Analysis natural gas composition

Notulen van de bijeenkomst op 8 mei 1996

Parameters van het gasregelstation

Basisgegevens van het regelstation

Type installatie: Tweetraps-, tweesets-, hogedrukgasregelstation (VTL [= afkorting voor hoge druk, opm. van de vertaler]), middendrukdistributie (STL [= afkorting voor middendruk, opm. van de vertaler]).
Jaar van inbedrijfname: 1982.

Basisgegevens van het regelstation

Medium	-	dieselaardgas	
ingangsdruk max.	-	2,5 MPa	VTL
uitgangsbedrijfsdruk	-	2,- MPa	VTL
minimale ingangsdruk	-	1,0 MPa	STL
druk op de tussentrap	-	0,9 MPa	STL
uitgangsdruk	-	0,3 MPa	STL
aantal regelsets		2 + bypass	
aantal regeltrappen		2	
vermogen van het regelstation		5000 m^3/Nh.	

Samenstelling van het gas

1. Volumepercentages:

C_{44}	97,23 %
C_3H_6	1,33 %
C_4H_{10}	0,12 %
C_5H_{12}	0,04 %
C_6H_{14}	0,02 %
CO_2	0,33 %
N_2	0,90 %

2. Relatieve dichtheid 0,576
   De dichtheid in kg/m^3 bij 15°C en 101,325 kPa is 0,702 kg

3. Warmte-afgevend vermogen 34,20 MJ/m^3

4. Totaal zwavelgehalte mg/m^3 0,8

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