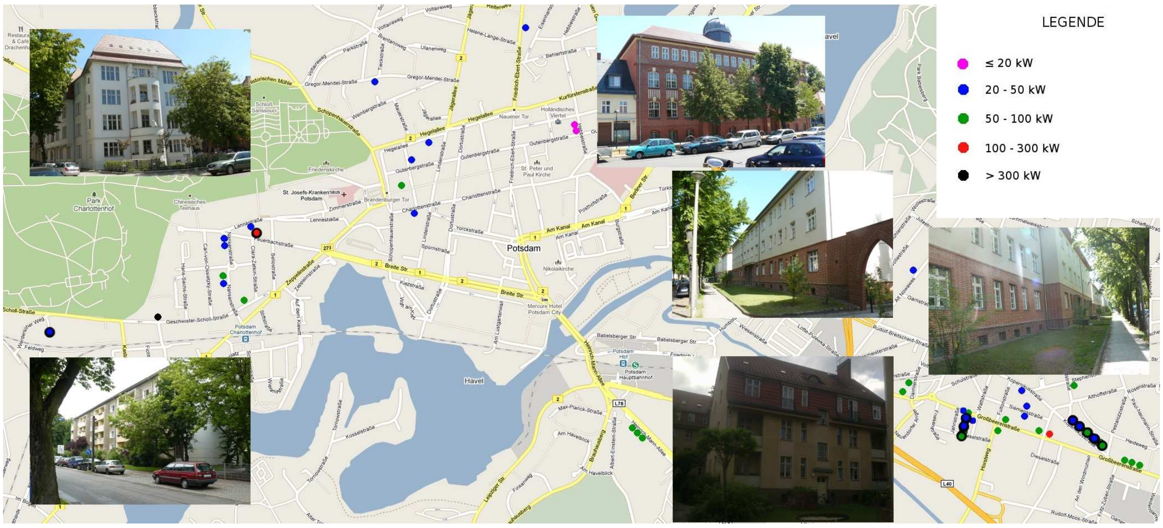
Energy Efficient and Integrated Urban Development Action

URB Energy

Baltic Sea Region Programme 2007-2013

Part-financed by the European Union (European Regional Development Fund and European Neighbourhood and Partnership Instrument)



Executive Summary

Biogas for Potsdam

Concept for the application of renewable energy sources in selected residential buildings

Projektnummer:2009-010

Auftraggeber: ProPotsdam, KIS und EWP in Kooperation mit der IHK Potsdam

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BioenergieBeratungBornim GmbH
Eine Ausgründung des ATB

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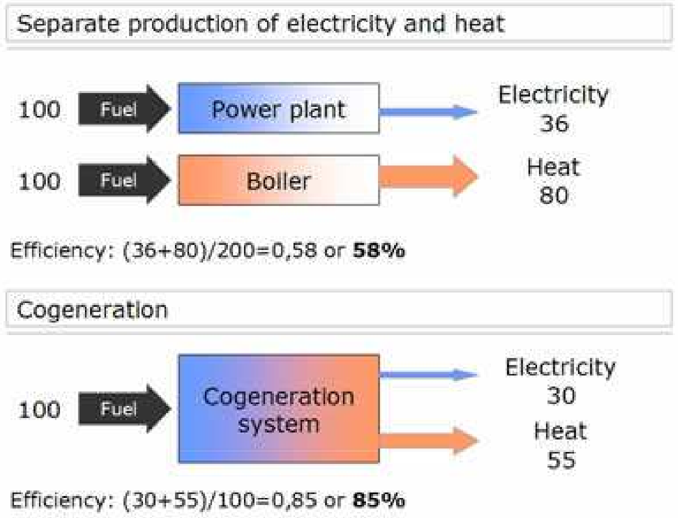
1. Introduction

There are manifolds of energy sources and conversion technologies for residential energy supply in Europe. Up to now the widespread standard configuration for the housing sector in Germany is a centralized power generation in combination with a decentralized heat conversion.

1.1. cogeneration

cogeneration of heat and power is more efficient, especially if adjusting the respective profiles of heat and power of the objects to be supplied.



However, except from existing district heating-systems in the housing sector, cogeneration configurations have not attracted further recognition yet.

Nowadays micro CHP units for natural gas are available down to 5 kW_{el} electrcial power and 12 kW_{th} heat. Especially for biogas use the smallest cogeneration unit available on the German market delivers 18 kW_{el} and 34 kW_{th}. This gives an opportunity for cogeneration in neighbourhood or small clusters in local heating systems.

1.2. Legal framework

Reconfiguring energy supply for housing by sustainable, more efficient and economic solutions is forced and fostered by the existing German and European legal framework.

The German Renewable Heat Act (EWärmeG) demands the proportionate employment of renewable resources for new and substantially modernized old buildings, for the use of solar systems 10%, for solid biomass 50% and for biogas 30%. Expected long-term price developments for oil and natural gas urge for the reconfiguration of the energy supply in old buildings as well.

Under the German Renewable Energy Law (EEG), a framework for the promotion and implementation of innovative resources and technologies, since 2000 feed-in tariffs are successfully guaranteed for electricity from renewable sources including cogeneration based on biomass, biogas and biomethane (biogas upgraded to natural gas standard).

The German cogeneration Act (KWK-Gesetz) is less important for the consideration of renewable sources, as it promotes combined heat and power production for conventional sources such as natural gas and oil.

2. Biogas for Potsdam

Large section of the housing in Potsdam, including individual and public buildings as well as private and municipal housing societies, was consequently reconstructed and modernized during the last decades. A public utility company provides electricity, natural gas and district heat from the communal grid. Nevertheless, a defined group of buildings could be identified to be inadequately equipped with district heat, especially inner-city listed buildings.

Due to orders from building laws concerning heat insulation or solar systems and their respective location stray from the municipal heat grid, listed houses are likely to fail to identify adequate solutions for an efficient and economic recon-figuration of their heating system.

In this case biogas or biomethane based cogeneration is a very interesting option. Biogas (varying qualities CH_4: 50-60%) may be used directly, whereas biomethane (defined quality CH_4: i.e. 95% - equivalent to natural gas) is fed into the natural gas grid after complex conditioning and concentration. While the biogas route affords complete piping to supply every installed CHP unit most suitable in rural areas without gas grid, biomethane supply via the natural gas grid is the easier way in urban areas.

the subsequent analysis was commissioned by an alliance of the communal housing societies ProPotsdam (residentials) and KIS (public buildings, i.e. schools and sport arenas) together with the public utility company EnergieWasser Potsdam GmbH (EWP) and the regional Chamber of Industry and Commerce.

2.1. Objects of investigation

The residential assets mostly incorporate blocks of flats, and a few one- and two-family houses. In total they add up to 60 residential objects containing 749 units with a total of 49,400 m² of effective area. The heat demand of this objects summed to 6,925 MWh/a. In addition, 10 school objects are listed involving 28 buildings with 27,800 m² of effective area and a heat demand of 3,133 MWh/a.

2.2. The showcase objects

The selected showcase objects representing the variety of objects and clusters under investigation are the following:

- apartment block with 9 units (425 m² effective area)- Dieselstraße (garden house 1)
- apartment block with 24 units (1,536 m² effective area)- Kopernikusstraße (block 1)
- apartment block with 13 units (2,081 m² effective area)- Feuerbachstraße
- apartment block with 31 units (1,616 m² effective area)- Dieselstraße (main house, garden house 1 & 2)
- apartment block with 64 units (3,598 m² effective area)- Geschwister-Scholl-Straße)
- apartment block with 81 units (4,987 m² effective area)- Kopernikusstraße (block 1, 2 & 3)

- school with 4 buildings (3,375 m² effective area)- Karl-Liebknecht-Straße
- school plus residential neighbour buildings - Karl-Liebknecht-Straße

3. Methodological Approach

A limited list of buildings was selected for systematic analysis. This list included residential buildings, schools and sport halls, where direct access was assured.

Object analysis
The complete list of buildings was analysed taking into account location, cluster-relevance according to proximate buildings from the area of investigation and heating output. Buildings, situated in direct neighbourhood or less than 100 meter away, where a direct short-distance heating without crossing streets is feasible, were grouped into supply clusters.

Showcase buildings/clusters
For five selected representative objects (with one up to three buildings) defining seven showcase buildings a profound on-site inspection was arranged producing a complete record for each showcase building containing energy specific data, heating-system data, site plan, photos, energy consumption data, remarks etc.

CHP design
An appropriate cogeneration design layout was developed for every showcase building . An adjusted design divides the object specific heat profiles in two areas of operation, the base load and the peak load area. The selected CHP unit size may merely cover the base load profile and must lead to an over-match of the maximum full load operation runtime of at least 5,000 h/a. Complying with EEG feed-in regulations for biomethane, the CHP units are to be operated heat led, i.e. only while co-generated heat is used for heating or charging the integrated heat storage tank, the CHP unit may be active. Based on the specific design total investment were calculated followed by an economic efficiency calculation for each showcase building.

Scale-up to objects of investigation
Layout and cost calculation of the seven showcases served as a basis to up-scale the results to the selection of buildings in the area of investigation.

Two different implementation strategies were analysed. Next to the strategy "Complete cogeneration" a second strategy called "Economic cogeneration" was calculated estimating their respective necessary biogas demand, total investment and CO_2-reduction.

"Complete cogeneration"
All locations in the area of investigation that allow the integration of a cogeneration unit of at least 5 kW_{el} and 12 kW_{th} are taken into account.

"Economic cogeneration"
based on strategy "Complete cogeneration" locations with CHP designs under 26 kW_{th} are omitted.

Adjusting these results with the necessary biogas production, in both cases supply can be provided either by biomethane trading, being established for short, or by building up own biogas production capacities. Therefore, input quantities and area under biogas crops are reported respectively.

4. Combined Heat and Power Design

The annual profile of residential heat supply mainly depends on climate specificities and the heated potable water. The bigger residential blocks are, the lower are the incurring heat losses, and concurrent flat-specific supply profiles reduce line losses in the whole building. Mainly building size and its insulation standard mark its heat demand. Therefore, variations between residential objects are low.

Exemplary heat profile, its sorted annual load duration graph and the respective CHP unit design for showcase object No 5 is documented in the appendix.

Taking into account adequate locations for setting up CHP unit, boiler tank and peak load boiler, necessary piping and implementation in the existing system and all other necessary attachment. Total investment were calculated for each showcase based on a designed CHP configuration.

5. Results

The results presented reflect different levels of evaluation. The showcase results refer to on-site inspections, object-specific design and cos accounting, each completed with a specific economic efficiency calculation.

The calculations undertaken for the complete list of objects is finally an estimation. Ought to similarities concerning residential energy supply, the estimations made for this type of buildings are conceptually well founded. However, buildings with a specific type of use, such as schools and sport halls do not allow simple estimations or scale-up without object specific calculations. Therefore, apart from the exemplary inspected school, no further estimations were made.

5.1. Showcase results

5.1.1. Investments

The summarized investments for all showcases are below.

Object	CHP-size	CHP-Costs K_{BHKW}	Total costs K_{Gesamt}	spec. costs [€/kW_{el}]	K_{Gesamt} / K_{BHKW}
Dieselstraße (Gartenhaus-G1)	4,7 kW_{el} 12,5 kW_{th}	20,900 €	24,528 €	522	1.17
Kopernikusstraße (Block 1)	8 kW_{el} 22 kW_{th}	18,500 €	42,007 €	5,251	2.27
Feuerbachstraße	8 kW_{el} 22 kW_{th}	18,500 €	37,529 €	4,691	2.03
Dieselstraße (VH & G1 & G2)	14,5 kW_{el} 26 kW_{th}	30,660 €	64,193 €	443	2.09
Geschwister-Scholl-straße	50 kW_{el} 88 kW_{th}	64,850 €	117,932 €	2,359	1.82
Kopernikusstraße (Block 1, Block 2, Block 3)	34 kW_{el} 78 kW_{th}	55,547 €	136,338 €	3,469	2.45
GS16-Karl-Liebknechtstraße 29	16 kW_{el} 35 kW_{th}	34,368 €	61,476 €	3,842	1.79
GS16-Karl-Liebknechtstraße 29 & 3 Objekte	34 kW_{el} 78 kW_{th}	55,547 €	128,255 €	3,772	2.31

For evaluation of site-specific expenses for installation and integration the ratio of total investment and CHP-unit investment was calculated respectively.

5.1.2. Economic efficiency

The economic efficiency calculation compares EEG promoted biomethane based cogeneration with conventional supply. KWKG related calculations are difficult to compare with, as tariffs are only partially subsidised and depend more on individual electricity profiles and related delivery conditions and contracts.

The economic efficiency calculation is taking into account assumptions as follows:

- calculation period 20 years
- two different price levels are assumed, reflecting trading and self-production. For biomethane prize is 81 €/MWh (77 €/MWh), The natural gas price given by ProPotsdam is set at 51,3211 €/MWh
- conform with statistic data price development for biomethane is 3,5%, for natural gas it is 7%, for maintenance and administration 1% respectively
- financing is set to 10 years with an equity ratio of 10%
- the revenue based EEG feed-in is triggered to 24,42 Cent/kWh (2010)

Exemplary results concerning the economic evaluation of showcase No 5 is listed in the Appendix.

The specific production costs for CHP integration concerning all showcases are summarized in the following table.

		2029				biogas-CHP-unit		natural gas	
Object	**CHP-unit-size**	**heat prize biogas trade [€/kWh]**	**heat prize biogas production [€/kWh]**	**heat prize natural gas-CHP-unit [€/kWh]**	**heat prize natural gas conventiona l [€/kWh]**	**2010-2029 average heat prize trade [€/kWh]**	**2010-2029 average heat prize production [€/kWh]**	**average heat prize CHP-unit [€/kWh]**	**average heat prize conventional [€/kWh]**
Dieselstr. (Gartenhaus-G1)	4,7 kW_{el} 12,5 kW	0.186	0.177	0.238	0.203	0.135	0.128	0.150	0.119
Kopernikusstr. (Block 1)	8 kW_{el} 22 kW_{th}	0.173	0.165	0.216	0.179	0.118	0.112	0.131	0.105
Feuerbachstr	8 kW_{el} 22 kW_{th}	0.176	0.169	0.214	0.193	0.116	0.111	0.128	0.112
Dieselstr. (VH & G1 & G2)	14,5 kW_{el} 26 kW_{th}	0.173	0.165	0.223	0.191	0.110	0.104	0.133	0.111
Geschwister-Scholl-Str.	50 kW_{el} 88 kW_{th}	0.178	0.193	0.238	0.202	0.107	0.099	0.133	0.116
Kopernikusstr. (Block 1, 2 & 3)	34 kW_{el} 78 kW_{th}	0.151	0.144	0.197	0.190	0.097	0.091	0.117	0.110
GS16-Karl-Liebknechtstr. 29	16 kW_{el} 35 kW_{th}	0.167	0.162	0.203	0.187	0.108	0.104	0.123	0.109
GS16-Karl-Liebknecht str. 29 & 3 Objekte	34 kW_{el} 78 kW_{th}	0.151	0.143	0.197	0.186	0.097	0.091	0.116	0.107

5.2. Residential scale-up results

As described above two scale-up strategies for the listed objects of investigation were checked. The technical data and related estimated investment costs are shown in the following table:

	complete CHP-Integration	economic CHP-Integration	konventional
Number of locations	59	59	59
locations with CHP-qualification	34	15	
Number of selected CHP-locations	27	12	
single objects thereof	15	5	
Heat supply to CHP-locations in MWh/a	7,133	4,476	
Heat supply total portfolio in MWh/a	7,133	7,133	6,925
Biogas share (MWh/a)	3,690	2,540	
Natural gas share (MWh/a)	3,443	4,593	6,925
electricity from biogas (MWh/a)	1,708	1,273	
losses	176	19	
Biomethane demand (MWh/a)	5,574	3,831	
Natural gas demand (MWh/a)	3,443	4,593	6,925
Total demand in natural gas quality (MWh/a)	9,017	8,424	6,925
Investment costs CHP excluding heat pipework	768,216 €	466,716 €	
Investment costs for heat pipework	239,000 €	179,000 €	
additional costs (peak load boiler, connection, etc.)	597,022 €	460,943 €	
Total investitment costs	1,604,238 €	1,106,659 €	
security supplement 10%	160,424 €	110,666 €	
Total estimated Investment	**1,764,662 €**	**1,217,325 €**	

Evaluation reveals cost advantages for the economic CHP-integration.

	complete CHP-Integration	economic CHP-Integration	konventional
annuity of Investment costs	207,756 €	143,317 €	
including security supplement 10%	228,532 €	157,649 €	
Service	2,078 €	1,433 €	
Maintenance	78,147 €	57,027 €	17,712 €
Renovation	41,620 €	23,837 €	18,347 €
Administration	13,500 €	6,000 €	
variable costs			
purchase biomethane	451,482 €	310,350 €	
purchase natural gas	176,612 €	235,607 €	355,273 €
Total annual costs	991,971 €	791,904 €	391,332 €
electricity bound allowances	581,524 €	464,066 €	
Wärmekosten	410,446 €	327,838 €	391,332 €
prime costs heat 2010	**0.066 €**	**0.053 €**	**0.063 €**

Evaluating a period of observation for 20 years with price developments as described above the effect becomes more obvious:

	complete CHP-Integration	economic CHP-Integration	conventional
prime costs heat 2029	0,175 €/kWh	0,175 €/kWh	0,212 €/kWh
Average prime costs heat (2010-2029)	0,122 €/kWh	0,103 €/kWh	0,123 €/kWh

Under the defined conditions economic CHP-integration offers positive cost effects of roundabout 9%.

6. Summary

Biogas based cogeneration offers long-term cost advantages in comparison to conventional residential energy supply as well for micro-CHP configurations down to 26 kW thermal.

Apart from locational technical applicability price developments for conventional sources and biomethane production prices define the critical CHP capacity, from which CHP integration is economically feasible.

Systematically clustering appropriate communal user groups with complementing heat profiles promoting smart-grid oriented decentralized energy infrastructures, is a well sensible and consequent approach to for the sustainable efficient and cost effective energy supply-of tomorrow.

7. Appendix

7.1. Design - showcase No 5

Object : Geschwister-Scholl-Str. (gesamt)

dwelling unit(s) :	64	envelope surface :	5,844 m²
Persons :	90	building volume :	14,950 m³
Initial operation :	1993	effective area :	3,598 m²
Insulation level :	194 kWh/m²	Demand (total) :	699,670 kWh/a
heating power (installed) :	270 kW	Demand (heating) :	598,288 kWh/a
efficiency factor :	0.85	Demand (drinking water) :	101,382 kWh/a
		annual electricity demand :	224,000 kWh/a

B3

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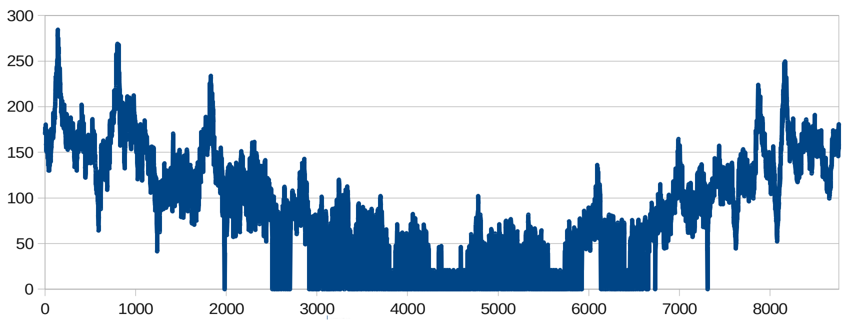
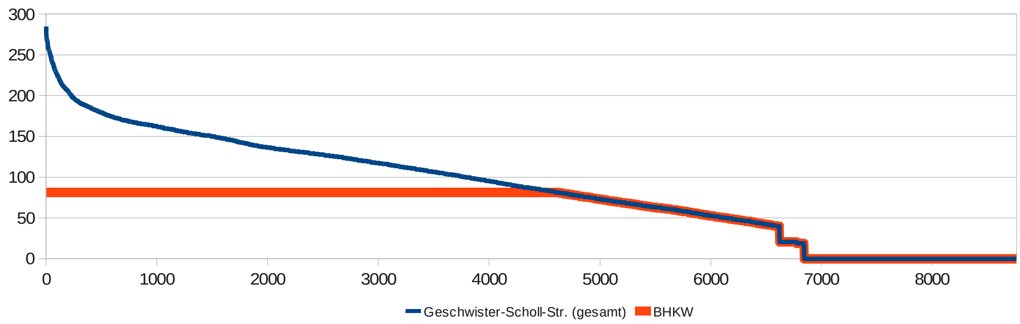
demand profile - Geschwister-Scholl-Str. (gesamt)

Jan	119,921
Feb	102,915
Mar	93,969
Apr	64,972
May	34,942
Jun	15,979
Jul	12,072
Aug	13,728
Sep	32,693
Oct	61,901
Nov	87,677
Dec	110,552
Total :	751,321



Grid (efficiency) :	85.0%	CHP-unit :	50 kW el	hours (full load) :	6,132 h/a
5			82 kW th.		

sorted annual load duration graph :



hours of operation :	6845 h/a	electric power (CHPU) :	50 kW
heat production :	502,831 kWh/a	electric efficiency factor :	32.2%
heat share (CHPU)	66.9%	thermal efficiency factor :	56.8%
electricity share (CHPU)	136.9%	electricity production :	306,604 kWh/a

7.2. Investment costs and revenues - showcase No 5

Objekt : Geschwister-Scholl-Str. (gesamt)

dwelling unit(s) :	64		envelope surface :	5,844 m^2
Persons :	90		building volume :	14,950 m^3
Initial operation :	1993		effective area :	3,598 m^2
Insulation level :	194 kWh/m^2		Demand (total) :	699,670 kWh/a
heating power (installed) :	270	kW	Demand (heating) :	598,288 kWh/a
efficiency factor :	0.85		Demand (drinking water) :	101,382 kWh/a
			annual electricity demand :	224,000 kWh/a

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Investment costs, subsidies and operation costs

Total investment :					105,032 DM
costs (construction) :	15,579 €	annuity (construction) :	20	a	1,250 DM
costs (technics) :	6,391 €	annuity (technics) :	10	a	828 DM
costs (CHP-unit) :	69,311 €	annuity (CHP-unit) :	15	a	6,678 DM
costs (pipework) :	9,625 €	annuity (pipework) :	40	a	561 DM
			11.3	a	9,316 €
	100,907 €	Total costs (investment & financing) :			155,881 €
		additional investments for operation(20 years)			30446.47
Subsidies :					
	Micro-CHP-unit (M):	Quote :	0.0%		0 €
	heat grid (W) :	Quote :	30.0%		-4,125 €
Total costs minus subsidies					100,907 €
Excess charge for unexpected			3.0%		3150.96
Equity ratio for financing :			10.0%		-10,091 €
financial requirements :					93,967 €
annnuity (10 years)			10	a	12,169 DM
variable costs :					
natural gas :					51 €/MWh
Biogas :					81 €/MWh

Maintenance :		Full load	kW	€/Bh	€/kWh	
	CHP-unit :	6132	50	1.3	0.000	7,972 €
	peak load :					417 €

revenues, credits & tax refunds

Initial operation : 2010

EEG

	basic feed-in tariff			
	to 150 kW	50	kW	0.1155 €
	to 500 kW	0	kW	
	to 5 MW	0	kW	
		50	kW	0.116 €
	boni			
	renewable bonus till 500 kW			0.0693 €
	renewable bonus over 500 kW			
	Cogeneration bonus			0.0297 €
0	technology bonus			
1	formaldehyde			0.010 €
1	gas feed-in till 350 m^3/h			0.0198 €
0	gas feed-in till 500 m^3/h			
0	landscape preservation bonus			
0	avoided net acess fees			
	Total EEG feed-in tariff			0.2442 €

KWK

0	heat credit :	
1	energy exchange tariff (6/10 4,102 Ct/kWh)	0.041 €
0	supply contract (local use)	0.000 €
	Cogen-addition	0.051 €
1	electricity fee order	0.003 €
	energy tax law	
0	Fuel refunding	
1	Energy tax refunding (0,55 Ct/kWh natural gas)	0.017 €
1	Electricity tax refunding (local use)	0.021 €
	Electricity & heat (EEX=const.)	
	total cogen tariff (till 10a)	0.133 €
	total cogen tariff (beyond 10a)	0.082 €
	tariff including energy exchange base load till 10	0.092 €
	0	0.041 €

7.3. Economic efficiency calculation - showcase No. 5

Object :	Geschwister-Scholl-Str. (gesamt)		
dwelling unit(s) :	64	envelope surface :	5,844 m²
Persons :	90.0	building volume :	14,950 m³
Initial operation :	1993	effective area :	3,598 m²
Insulation level :	194.5 kWh/m²	Demand (total) :	699,670 kWh/a
heating power (installed) :	270 kW	Demand (heating) :	598,288 kWh/a
efficiency factor :	0.85	Demand (drinking water) :	101,382 kWh/a
		annual electricity demand :	224,000 kWh/a

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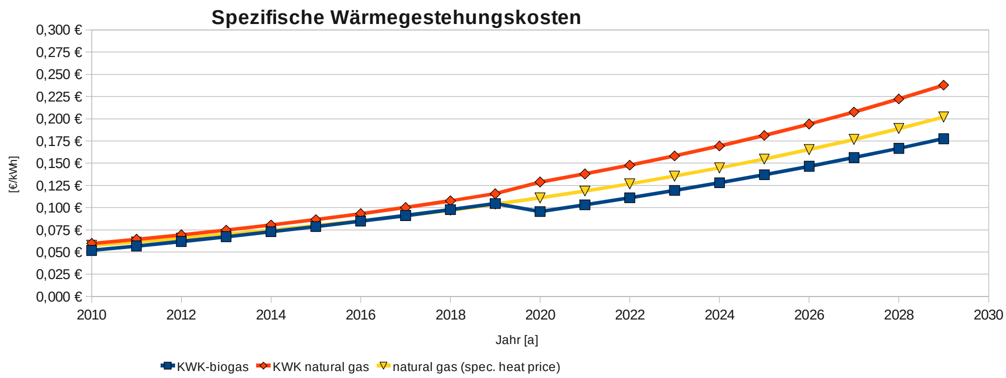
net costs			**biogas**				**natural gas 51.32 €/MWh**						
			biogas CHP-unit (EEG)				natural gas CHP-unit (KWK)				gas burner *		
interest rate 5%		10 a	biogas and natural gas delivery	EEG	haeating costs	spec. heat price	natural gas delivery	KWK & EEX	haeating costs	spec. heat price	Serv., maint., renov. and administration	natural gas delivery	spec. heat price
years	annuity	fix costs	Total	fee	heat	KWK-biogas	Total	fee	heat	KWK natural	fix costs		natural gas
0	12,169 €	11,808 €	89,880 €	74,883 €	38,975 €	0.052 €	61,620 €	40,779 €	44,819 €	0.060 €	1,682 €	38,559 €	0.058 €
1	12,169 €	11,908 €	93,472 €	74,883 €	42,666 €	0.057 €	65,934 €	41,659 €	48,352 €	0.064 €	1,692 €	41,258 €	0.061 €
2	12,169 €	12,008 €	97,221 €	74,883 €	46,516 €	0.062 €	70,549 €	42,601 €	52,125 €	0.069 €	1,702 €	44,146 €	0.066 €
3	12,169 €	12,110 €	101,135 €	74,883 €	50,531 €	0.067 €	75,487 €	43,609 €	56,157 €	0.075 €	1,712 €	47,236 €	0.070 €
4	12,169 €	12,212 €	105,222 €	74,883 €	54,720 €	0.073 €	80,771 €	44,687 €	60,465 €	0.080 €	1,723 €	50,543 €	0.075 €
5	12,169 €	12,315 €	109,489 €	74,883 €	59,091 €	0.079 €	86,425 €	45,841 €	65,069 €	0.087 €	1,733 €	54,080 €	0.080 €
6	12,169 €	12,420 €	113,948 €	74,883 €	63,654 €	0.085 €	92,475 €	47,076 €	69,988 €	0.093 €	1,744 €	57,866 €	0.085 €
7	12,169 €	12,525 €	118,606 €	74,883 €	68,417 €	0.091 €	98,948 €	48,397 €	75,246 €	0.100 €	1,754 €	61,917 €	0.091 €
8	12,169 €	12,632 €	123,473 €	74,883 €	73,392 €	0.098 €	105,875 €	49,811 €	80,865 €	0.108 €	1,765 €	66,251 €	0.097 €
9	12,169 €	12,740 €	128,562 €	74,883 €	78,588 €	0.105 €	113,286 €	51,324 €	86,871 €	0.116 €	1,776 €	70,888 €	0.104 €
10	0 €	12,848 €	133,882 €	74,883 €	71,848 €	0.096 €	121,216 €	37,275 €	96,789 €	0.129 €	1,787 €	75,851 €	0.111 €
11	0 €	12,958 €	139,446 €	74,883 €	77,521 €	0.103 €	129,701 €	39,007 €	103,653 €	0.138 €	1,798 €	81,160 €	0.119 €
12	0 €	13,069 €	145,266 €	74,883 €	83,452 €	0.111 €	138,780 €	40,860 €	110,989 €	0.148 €	1,809 €	86,841 €	0.127 €
13	0 €	13,181 €	151,356 €	74,883 €	89,654 €	0.119 €	148,495 €	42,843 €	118,833 €	0.158 €	1,821 €	92,920 €	0.135 €
14	0 €	13,294 €	157,729 €	74,883 €	96,140 €	0.128 €	158,890 €	44,964 €	127,219 €	0.169 €	1,832 €	99,425 €	0.145 €
15	0 €	13,408 €	164,400 €	74,883 €	102,926 €	0.137 €	170,012 €	47,234 €	136,186 €	0.181 €	1,843 €	106,385 €	0.155 €
16	0 €	13,524 €	171,386 €	74,883 €	110,027 €	0.146 €	181,913 €	49,663 €	145,773 €	0.194 €	1,855 €	113,831 €	0.165 €
17	0 €	13,640 €	178,702 €	74,883 €	117,459 €	0.156 €	194,647 €	52,262 €	156,024 €	0.208 €	1,867 €	121,800 €	0.177 €
18	0 €	13,758 €	186,367 €	74,883 €	125,242 €	0.167 €	208,272 €	55,043 €	166,986 €	0.222 €	1,879 €	130,326 €	0.189 €
19	0 €	13,877 €	194,398 €	74,883 €	133,392 €	0.178 €	222,851 €	58,019 €	178,709 €	0.238 €	1,891 €	139,448 €	0.202 €
average over period of examination (20 years)						0.105 €				0.132 €			0.116 €
cost difference biogas cogeneration to compared concept										25.1%			9.6%
payback period						7.55							



* if not reported differently inclusive one renovation during an operation period of 20 years