Feasibility of a fuel-switch from fuel oil for bioheat (0.4 MW in-house heat-only boilers)

Horizon 2020 Coordination and Support Action number 646495: Bioenergy4Business – A project for the uptake of solid biofuels in promising European heat market segments

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Executive Summary

In this feasibility study a fuel switch from fuel oil for wood-chips (0.4 MW in-house heat-only boilers) is assessed techno-economically. The assessment is made by and based on default investment, cost and price figures of the "**B4B BioHeat Cost Calculator**", developed within the project Bioenergy4Business (B4B). The study is based on a real fuel switch, which took place 2014 in an Austrian hotel, as the oil boiler has reached his end of service life.

- The assessment, whether to invest in a new fossil fuelled or new wood-chip fuelled boiler is based on Austrian default values for investment components, running costs and prices. The investment / cost / price data finally used for calculations for this study were aligned with a sales director of an Austrian heat plant contracting company in March 2016.

- The total investment for the biomass heating (**bioheat**) system is assumed to be 239,200 EUR, excl. VAT (see table below). The existing oil boiler is used as a back-up / stand-by boiler for the biomass system. The investment of the fossil fuelled reference (**fossil**) system is 101,400 EUR. The bioheat system investment is 135.9% beyond the investment of the fossil system.

	Biomass Heat System				Fossil Fuelled Reference System		
7006	Fuel type	Wood Chips & Fuel Oil			Fuel type	Fuel Oil	
7008	**Technical Parameters**						
7009	Total nominal biomass boiler capacity	0.4 MW			Total nominal fossil fuelled boiler capacity	0.4 MW	
7010	Fossil fuelled peak/back-up boiler capaci	0.4 MW					
7011	Heat Grid - Trass/trench length	0 m			Heat Grid - Trass/trench length	0 m	
7012	Annual heat sold/delivered	737 MWh/a			Annual heat sold/delivered	737 MWh/a	
	Investment						
	Total initial Investment (year 0-3)	239,200		EUR	Total initial Investment (year 0-3)	101,400	EUR
	Thereof Investment Subsidy (if any)	56,810		EUR			
	Surplus investment, year 1-3		137,800	EUR	% of fossil RefSystem	135.9	

In Austria the typically higher up-front cost of bioheat systems over the last 30 years normally were offset / balanced by lower biofuel purchase cost over project lifetime together with investment subsidies lowering the upfront investment.

- In this example is assumed that 25% of the eligible bioheat investment is granted by available public funds in the third year after commissioning (i.e. 56,810 EUR). The fossil system is not eligible for public investment grants. 30% of (the remaining) required investment budget is financed by equity capital in both cases. Interest for equity is assumed to be 7.5% (after tax, for both systems). The loan interest rate is 4% with a lent term of 10 years (for both systems).

- The purchase price of wood chips (27.0 EUR/MWh NCV[1], excl. VAT) in Austria despite the low oil prices in the first quarter of 2016 is still much lower than the price of fuel oil

[1] NCV … Net Calorific Value

(52.0 EUR/MWh NCV), see table below. It is assumed that both fuel prices equally increase by 2.0% p.a. within the calculated service life of 25 years (until 2040).

- In the fourth year of operation (i.e. 2020), for example, the fuel payment saving of the bioheat system would be 22,805 EUR/a (46.7% less than those of the fossil system). The total payment savings (of all operating and capital expenditures) in 2020 would be 10,321 EUR (16.4% less than those of the fossil system). The lower total payment savings is because of higher capital and other (than fuel related) operating cost of the bioheat system.

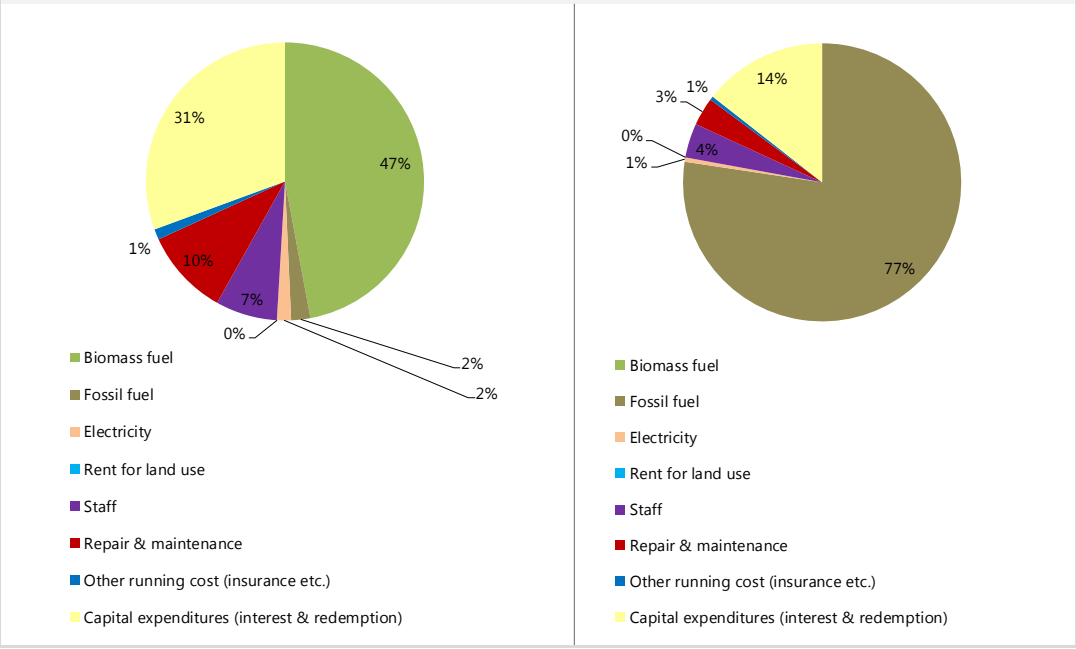
	Biomass Heat System			Fossil Fuelled Reference System		
7006	Fuel type	Wood Chips & Fuel Oil		Fuel type	Fuel Oil	
	Fuel purchase price (NCV, year 1)	27.0	EUR/MWh	Fuel price (NCV, year 1)	52.0	EUR/MWh
	Fuel payment savings (year 4)	22,805	EUR/a	% of fossil RefSystem	46.7	
	Annual total payment savings (year 4)	10,321	EUR/a	% of fossil RefSystem	16.4	
	Fossil fuel subsituted by bioheat system	820	MWh/a	% of fossil RefSystem	97.9	
	Greenhouse gas savings	230.3	t CO_2-eq/a	% of fossil RefSystem	97.4	
	Saving of fuel input (NCV)	-30	MWh/a	% of fossil RefSystem	-3.5	

The bioheat system avoids 97.9% of the fossil fuel and saves 230.3 t CO_2-eq/a (-97.4%) compared to the fossil system. The annual fuel input (NCV), due to somewhat lower energy efficiency is 3.5% higher.

The greenhouse gas savings and other positive (local economy, energy system security / resilience related) effects of the bioheat systems are not always compensated for (e.g. by investment subsidies, CO_2-taxes) adequately (for establishing a level playing field) compared to fossil fuel systems, however.

The next two figures show the shares of the annual payment components for the year 2020.

Figure(s): Share of Payments (Opex and Capex) in year 4 (full capacity operation) for a calculated service life of 25 years



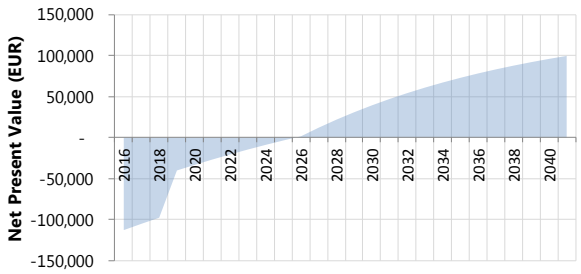
It can be clearly seen that the fuel payment share of the fossil system with more than three quarters is much higher than this share of the bioheat system with less than 50%.

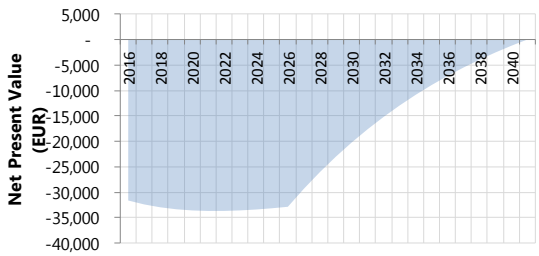
- If the fossil fuel price doubles from one year to another, which has happened ago, the annual payments would increase substantially, because the fuel payments share is more than three quarter of total payments.
- If the biomass fuel price would double from one year to another, which has not happened in Austria for solid biomass so far, the annual payments would increase much less because its share is (less than) half of total payments.
- This means that a fossil system is much more vulnerable for unforeseen price increases than the bioheat systems. This makes the owners businesses, in case he decides for a fossil system less resilient. Furthermore a lot of bioheat plants are operating with fuel supply contracts, with binding (and predictable) biomass prices for a period of several years.

The data and figures below show the result of the discounted cash-flow analysis performed by the "B4B BioHeat Cost Calculator" for the bioheat compared to the fossil system.

7035	**Discounted Cash-flow analysis (based on VDI Guideline 2067) - Results**				
7036	**Biomass Heat System**			**Fossil Fuelled Reference System**	
7036	**Discounted Payback Time**	**10.7 yrs**		**Discounted Payback Time**	**25.0 yrs**
7037	**Net Present Value (NPV, t=25 yrs.)**	**99,508**	EUR	**Net Present Value (NPV, t=25 yrs.)**	**3** EUR
7038	**Internal Rate of Return (IRR, t=25 yrs.)**	**13.12%**		**Internal Rate of Return (IRR, t=25 yrs.)**	**7.92%**
7039	**Calculatory Heat Generation Cost**	**66.16**	EUR/MWh	**Calculatory Heat Generation Cost**	**78.64** EUR/MWh

7041 **Figure(s): Development of the NPV for a calculated service life of 25 years - visualization of the dynamic payback time.**





- The calculatory heat generation cost of the fossil system are 78.64 EUR/MWh (without VAT) at a discounted payback time of 25 years, equally to service life assumed for both systems. The net present value of the fossil fuel reference system is 0 under this assumption.
- The calculatory heat generation cost of the bioheat system is 66.16 EUR/MWh (without VAT). The heat production cost is lower as those of the fossil fuelled reference system.
- If the calculatory heat revenues per MWh of the bioheat system are set to be as high as the heat generation cost of the fossil system (opportunity cost), the bioheat systems'
    - discounted payback time is 10.7 years, its internal rate of return is 13.12% and
    - the net present value of the bioheat investment is 99,508 EUR (all figures calculated with a service life of 25 years).

This figures show that a fuel-switch for bioheat can be attractive despite currently low oil prices.

1. Introduction

Bioenergy4Business involves partners from twelve EU Member States and Ukraine. Eleven of these project partners (AT, DE, BG, HR, FI, EL, NL, PL, RO, SK and UA, except BE and DK) are target countries, where tailor-made activities for the most promising market segments are taking place until the end of the project in August 2017.

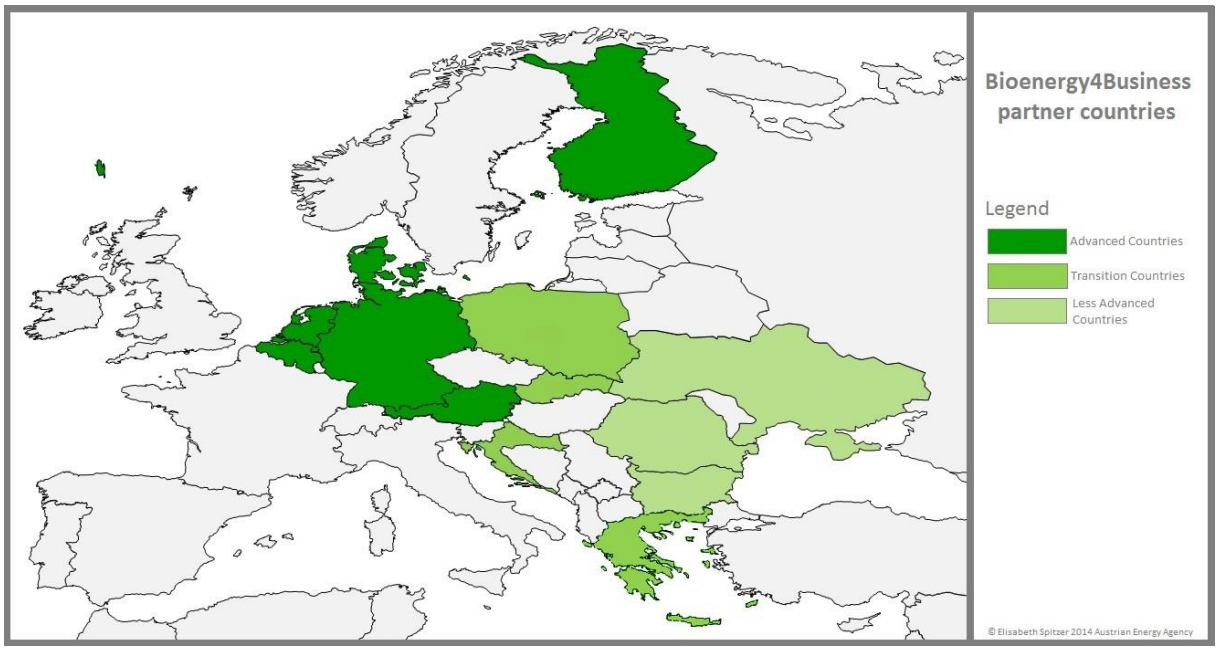


Figure 1: Countries where Bioenergy4Business is implemented and their actual biofuel market status.

Bioenergy4Business helps exploit the considerable economic and sustainable potential of European bioenergy sources for heating, which are locally available at reasonable prices. These can offer a viable alternative to vulnerable European businesses currently depending on fossil resources, which are often imported from politically unstable regions.

Bioenergy4Business makes new market segments for solid biomass usage accessible and enhances the use of both more solid biomass sources and so far not used ones (e.g. pellets, straw etc.) in European heat markets.

The website of the project is www.bioenergy4business.eu.

Introduction to this report

This report (D5.10)[2] was written within the frame of task 5.4 „Assessment of the economic pre-feasibility of bioenergy heating systems" of the project Bioenergy4Business. The objectives of this report is

- to provide a 1st model feasibility study for an in-house bio-heating system based on an existing best practice example.
- to demonstrate the usage of an Excel-tool developed in task 5.4 – the „B4B BioHeat Cost Calculator". The Tool allows a comparison of the economic efficiency (pre-feasibility level) of mid-scale, solid biomass and fossil fuel fired (district & in-house) heat-only plants (0.1 to 20 MW nominal plant heat load).

The „B4B BioHeat Cost Calculator" enables users to assess and compare the economic efficiency of a bioheat with a fossil fuelled reference (district & in-house) heat-only plant by a profitability calculation using the discounted cash-flow method – for both systems.

The 1st model feasibility study is modelled after the Austrian best practice example hotel Tulbingerkogel in Mauerbach, close to Vienna (see next chapter).

A 2nd model feasibility study (D5.11 of Bioenergy4Business) is dedicated to a district bio-heating system based on an existing best practice example.

[2] D … Deliverable

2. Best practice example – Hotel Tulbingerkogel

This feasibility study is based on a realized fuel-switch from fuel oil for wood-chips. The fuel-switch was realized in 2014 at the hotel Tulbingerkogel near Vienna. The following photos show the hotel and the realized wood chip boiler.

Figure 2: Hotel Tulbingerkogel (*www.**tulbingerkogel**.at)*.

Figure 3: Heating room with wood-chip boiler and buffer storage (Source: Frank Bläuel, Hotel Tulbingerkogel).

The wood-chip boiler has a nominal capacity of 500 kW and was installed together with two 5,000 liter hot water buffer storages. The existing oil boiler remained as a back-up / stand-by unit.

Both, the heating room and the fuel storage room were added to the hotel as underground facilities. A new street was built for accessing the fuel storage room. Ash is automatically vacuumed to a ground-based, mobile ash container for disposal.

As investment at this site was beyond the average and somewhat over-dimensioned model case assumptions for a 400 kW wood-chip boiler with two 5,000 litre buffer storages are given in the following chapter. The data are shown as screenshots of the "B4B BioHeat Cost Calculator" used for assessing the fuel switch. Every sub-chapter equals an Excel-sheet of the tool (for more details of the tools see chapter 4).

3. Overview of Assumptions

3.1 General

In this Excel-sheet

- the language to be used for the tool (line 1012, see table below, 9 languages are available),
- in line 1013 the country the project is realized in (and for which country-specific reference values are loaded; data of 12 countries are available),
- in line 1016 the project start year,
- in line 1017 the start of plant operation is fixed.
- Furthermore the fuels for the bioheat system (line 1018 and 1019) and the fuel of the fossil fuelled system (line 1020) can be chosen.

In line 2021 the annual price increase rate for reference investment values for plant equipment and building related investment (based on 2015 price-figures) contained in the tool can be varied. The investment reference values are increased from 2015 to the chosen project start year, after 2015, by entering a positive price increase rate.

Table 1: General project information

1010	GENERAL PROJECT INFORMATION		
Help	Parameter	Input Value	Reference Value
1012	Language to be used for the tool	English	
1013	loaded)	AT	
1014	National Currency	*EUR*	
1015	Exchange Rate (1 EUR = X national currency units)	1	1.00
1016	Project Start (Year), 1 year before operation starts	2016	
1017	Start of Operation	*2017*	
1018	Biomass Fuel Type	Wood Chips	
1019	Fossil fuel used for the biomass heat plant (for the peak/back-up boiler)	Fuel Oil	
1020	Fossil fuelled reference system: Fuel type	Fuel Oil	
1021	Annual price increase rate for reference investment values used for all plant components (price-base: 2015)	1.50%	1.50%

3.2 Technical

Table 2: Technical details of the biomass heat system.

Help	Biomass Heat System Parameter	Unit	Input Value	Reference Value
2016	**Heat Demand**			
2017	Thermal energy delivered/sold to end consumers	MWh/yr	**737**	
2018	Total consumer nominal connection capacity	MW	0.399	
2019	Number of connected consumers	#	1	
2020	Simultaneity factor of the heating plant	%	100%	100%
2022	**Heat Grid Expansion plan**			
2023	Grid Trass/Trench length incl. trasses to households (at 100% grid expansion)	m	-	
2024	Grid Expansion Year 1 (start of operation)	%	0%	= 0 m
2025	Grid Expansion Year 2	%	0%	= 0 m
2026	Grid Expansion Year 3	%	0%	= 0 m
	Grid Expansion after Year 3: 100%			
2029	**Grid related Heat Losses**			
2030	Old (existing), new or no district heating grid		No Heat Grid	
2031	Heat grid consumer structure (Category A, B or C - See Manual)		B	
2032	Grid related Heat Losses	%		0%
2034	**Biomass Heating Plant**			
2035	Total thermal capacity of the heating plant (max. peak load to be covered)	MW	***0.40***	
2037	**Biomass Boiler(s)**			
2038	1. Biomass boiler nominal heat generation capacity	MW	0.40	0.28
2039	2. Biomass boiler nominal capacity (if applicable)	MW		-
2040	3. Biomass boiler nominal capacity (if applicable)	MW		-
2041	Total nominal biomass boiler capacity	MW	*0.40*	0.28
2042	Average annual energy use efficiency biomass boiler(s)	%	**85.0%**	82%
2044	**Fossil fuelled Stand-by / Peak Load Boiler**		Fossil fuelled stand-by boiler	
2045	Fossil fuelled Stand-by/Peak Load boiler, nominal capacity (if applicable)	MW	0.40	0.40
2046	Actually installed total thermal capacity of the heating plant (must be >= cell value	MW	*0.80*	
2047	Old (existing) or new fossil fuel boiler (if applicable)		Old	
2048	Average annual energy use efficiency Fossil fuel Boiler (if applicable)	%	**85%**	79%
2049	Heat fraction generated with fossil fuels	%	**2.0%**	< 10 %
2050	Heat fraction generated with Biomass	%	*98.0%*	
2053	**Biomass Fuel Storage**			
2054	Fuel Storage Capacity (equivalent to x days of full load operation)	d	30.0	10.0
2055	Fuel Storage Size	m^3	*469*	
2057	**Electricity Consumption**			
2058	Specific Electricity Consumption heat grid	kWh_{el}/MWh_{th}		6.00
2059	Specific electricity consumption biomass boiler(s)	kWh_{el}/MWh_{th}	**11.00**	11.00
2060	Specific electricity consumption fossil fuel boiler	kWh_{el}/MWh_{th}	**4.00**	4.00

Table 3: Overview of technical performance data – biomass heat system.

2064	**Calculated energy flow Parameters**		
2065	Thermal energy delivered/sold to end consumers	Mwh_{sold}	*737*
2066	Total heat produced by plant(, injected into the heat grid)	$MWh_{generated}$	*737*
2067	Fuel Heat Input Biomass (net calorific value, NCV)	$MWh_{fuel,BM}$	*850*
2068	Fuel Heat Input Fossil Fuel (NCV)	$MWh_{fuel,fossil}$	*17*
2069	Total fuel heat input (NCV)	MWh_{fuel}	*867*
2070	**Electricity:**		
2071	Annual Electricity Consumption heat grid (100% heat delivery)	MWh_el	*0*
2072	Annual Electricity Consumption biomass boiler	MWh_el	*8*
2073	Annual Electricity Consumption fossil fuel boiler	MWh_el	*0*
2074	Annual Electricity Consumption plant (100% heat delivery)	MWh_el	*8*
2076	**Performance benchmarks of the biomass heating plant**		
2077	Network heat utilization ratio	kwh/(m*a)	***#DIV/0!***
2078	Network utilization ratio	kw/m	***#DIV/0!***
2079	Average annual full-load operating hours of installed biomass boilers	h/a	***1,806***
2080	Average annual full-load operating hours of connected consumers	h/a	***1,850***
2081	Annual energy use efficiency of the biomass boilers	%	***85%***
2082	Annual energy use efficiency of the heating grid	%	***100%***
2083	Annual energy use efficiency of the heating plant	%	***85%***

Table 4: Technical details of the fossil fuelled reference system.

2087	**Fossil Fuelled Reference System**			
	Parameter	**Unit**	**Input Value**	**Reference Value**
2089	This section determines the parameters of the alternative fossil fuelled heating system for comparison with the biomass heating system (characterized by the technical parameters above).			
2090	Nominal heat capacity fossil fuelled boiler 1	MW	0.40	0.4
2091	Nominal heat capacity fossil fuelled boiler 2	MW		0.4
2092	Nominal heat capacity fossil fuelled boiler 3	MW		
2093	Fossil fuelled boilers' total installed nominal heat capacity	MW	*0.40*	
2094	Specific Electricity consumption fossil fuel boiler(s)	kWh_{el}/MWh_{th}	4	4.0
2096	Average annual energy use efficiency of fossil boilers	%	88.0%	88%
2097	Total Fuel Heat Input (net calorific value)	$MWh_{produced+Fos}$	*838*	

3.3 Investment

Table 5: Investment figures of the biomass heat system.

	Biomass Heating System			
Help	**Parameter**	**Unit**	**Input Value**	**Reference Value**
3008	**Heat grid investment (100% grid expansion)**			
3009	**Heat Network Design:**			
3010	Grid Trass/Trench length incl. trasses to households (at 100% grid expansion)	m	-	
3011	% sealed surface	%		
3012	% free land	%	100.00%	
3013	% DN 20 or 25	%		
3014	% DN 50	%		
3015	% DN 100	%		
3016	% DN 200	%	100.00%	
3017	**Pipe and Earthwork**	**EUR**	**0**	-
3018	**Energy Transfer Stations (ETS)**			
3019	ETS - Average investment per MWh/a sold (depending on plant size)	EUR/MWh		71.05
3024	Energy Transfer Stations Investment	EUR		52,381
3025	**Total heat grid related investment**	**EUR**	-	

3027	**Boiler investment, incl. furnace, fuel feeding, measuring and control technology as well as flue gas cleaning equipment (the latter if required).**			
3028	Biomass Boiler 1	EUR	110,000	110,400
3029	Biomass Boiler 2	EUR		-
3030	Biomass Boiler 3	EUR		-
3031	Fossil fuelled Back-up/Peak Load Boiler	EUR		-
3032	**Total Boiler Investment of Biomass heating plant**	**EUR**	***110,000***	
3034	**Construction & development investment (assumed are stand-alone, new buildings)**			
3035	Boiler house (incl. area development and outdoor related investment)	EUR	15,000	110,851
3036	Boiler related electric, hydraulic and steelwork installations	EUR	50,000	49,400
3037	Fuel Storage (incl. area development and outdoor related investment)	EUR	45,000	33,138
	Sum of building cost	**EUR**	***110,000***	
3040	**Other initial Investment**			
3041	Other Investment	EUR	10,000	
3043	**Sub-Sum: Physical investment (Hardware)**	**EUR**	***230,000***	
3045	**Planning & Approval Cost**			
3046	Planning and Approval (fraction of physical investment)	%	4.0%	10.0%
3047	Planning and Approval (absolute number)	EUR	***9,200***	

The investment of the boiler house (see line number 3035, above) is much lower than the reference value given (see last column in that line). The reference value refers to a boiler house erected as a detached facility. In this case the existing boiler house can be adopted. The fuel storage is realized not detached but connected to the hotel. This decreases investment, nevertheless the new street for fuel delivery increases total investment cost.

The two buffer storage tanks are listed under other investment (line 3040).

The next table gives an overview of the assumed investment for the bioheat system.

3078	**Overview of investment by time of payment date (nominal values)**		
3079	Total initial investment (year 0-3)	EUR	*239,200*
3080	Total investment year 0	EUR	*239,200*
3081	Total investment year 1	EUR	-
3082	Total investment year 2	EUR	-
3083	Total investment year 3	EUR	-
3084	Total investment year 3 to 25 (incl. Re-investments according to VDI guideline 2065)	EUR	-
3086	**Overview of initial investment by category (without reinvestments)**		
3087	Heat grid Investment	EUR	-
3088	Boiler + fuel feeding system Investment	EUR	*110,000*
3089	Boiler house, fuel storage and boiler related electric, hydraulic and steelwork installations	EUR	*110,000*
3090	Other initial Investment	EUR	*10,000*
3091	Planning and Approval Cost	EUR	*9,200*

It is assumed that the fossil reference system does not need a re-investment of the fuel storage facilities. 15,000 EUR are assumed for maintaining and adopting the fuel storage and the heating room. The boiler related electric and hydraulic investment is lower than that for the bioheat system.

Table 6: Investment figures of the fossil fuelled reference system

	Parameter	Unit	Input Value	Reference Value
3095	**Fossil fuelled Reference System**			
3098	Grid investment (100% grid expansion)	EUR	-	
3100	**Boiler Investment**	**Fueltype:**	**Fuel Oil**	
3101	Fossil fuelled Boiler 1	EUR	**30,000**	28,516
3102	Fossil fuelled Boiler 2	EUR	**-**	-
3103	Fossil fuelled Boiler 3	EUR	**-**	-
	Total Boiler investment of fossil fuel Reference System		*30,000*	
3106	**Boiler house, fuel storage and boiler related supplementary installations Investment**			
3107	Boiler house (incl. area development and outdoor related investment)	EUR	**15,000**	36,950
3108	Boiler related electric and hydraulic installations	EUR	**42,500**	42,500
3109	Fuel oil Storage tank volume (equivalent to x days of full load operation)	d	**-**	10
3110	Oil storage tank volume (if Applicable)	l	-	
3111	Investment for fuel oil storage tank	EUR	**-**	-
3113	**Other initial investments (e.g. coal storage facility investment)**	EUR	**10,000**	
3115	**Planning and Approval Cost**	EUR	**3,900**	3,900
3145	**Overview of investment by time of payment (nominal values)**			
3146	Total investment that must be covered in year 0-3	EUR	*101,400*	
3147	Total investment year 0	EUR	*101,400*	
3148	Total investment year 1	EUR	-	
3149	Total investment year 2	EUR	-	
3150	Total investment year 3	EUR	-	
3151	Total investment year 3 to 25 (incl. VDI guideline 2065 Re-investments)	EUR	-	
3153	**Overview of initial investment by category (without reinvestments)**			
3154	Heat Grid Investment	EUR	-	
3155	Boiler Investment	EUR	*30,000*	
3156	Boiler house, fuel storage and electric and hydraulic boiler-related installations	EUR	*57,500*	
3157	Other initial Investment	EUR	*10,000*	
3159	Planning and Approval Cost	EUR	*3,900*	

3.4 Receipts

Table 7: Receipts of the biomass heat system.

	Parameter	Unit	Input Value	Reference Value
4005	**Biomass Heat System**			
4009	**Heat Sales Development**			
4010	Heat-sales - based on grid expansion in year 1	%		0%
4011	Heat-sales - based on grid expansion in year 2	%		0%
4012	Heat-sales - based on grid expansion in year 3	%		0%
4013	Heat-sales - based on grid expansion after year 3	%	*100%*	
4015	**Heat Price**			
4016	Average net heat sales price (excl. VAT), in year 1	EUR/MWh	**78.64**	95.00
4017	Heat-price escalation rate	% p.a.	**2.0%**	2.00%

The average net heat sales price (see line 4016, above), this are the revenues per MWh of the bioheat system, is set to be as high as the heat generation cost of the fossil system (opportunity cost).

The calculatory heat generation cost of the fossil system are 78.86 EUR/MWh (without VAT) at a discounted payback time of 25 years, equally to service life assumed for both systems. The net present value of the fossil fuel reference system is 0 under this assumption (see line 7032 of Table 13, below).

Table 8: Receipts of the fossil fuelled reference system.

	Parameter	Unit	Input Value	Reference Value
4049	**Fossil Fuelled Reference System**			
	All values not explicitly defined for the fossil reference system in this section are assumed to be similar to the parameter values of the biomass heat system (e.g. grid related data).			
4053	**Heat Price**			
4054	Average net heat sales price (excl. VAT) in year 1	EUR/MWh	78.64	78.64
4055	Heat-price escalation rate	% p.a.	2.0%	2.00%

3.5 Runningcost

Table 9: Regular payments of the biomass heat system.

	Parameter	Unit	Input Value	Reference Value
5005	**Biomass Heat System**			
5008	**Biomass Fuel Cost**			
5009	Selected fuel type:		Wood Chips	
5010	Biomass fuel price	EUR/MWh	27.00	18 - 28
5011	Biomass price escalation rate	% p.a.	2.00%	2.00%
5012	Annual biomass cost (theoretically; in year 1, at 100% grid expansion)	EUR/a	*22,950*	
5014	**Fossil Fuel Cost**			
5015	Selected system		Fossil fuelled stand-by boiler / Fuel Oil	
5016	Fossil fuel price	EUR/MWh	62.50	40 - 54
5017	Fossil fuel price escalation rate	% p.a.	2.00%	2.00%
5018	Annual fossil fuel cost (theoretically; in year 1, at 100% grid expansion)	EUR/a	*1,084*	
5020	**Electricity Cost**			
5021	Electricity purchase price	EUR/MWh	100.00	45 - 130
5022	Electricity price escalation rate	% p.a.	2.00%	2.00%
5023	Annual electricity cost (theoretically; in year 1, at 100% grid expansion)	EUR/a	*801*	
5025	**Staff Cost (excl. R&M)**			
5026	Weighted annual salary of staff categories required (year 1)	EUR/a	35,000	43,000
5027	Total person years of staff required	person years	0.10	0.10
5028	Staff cost - escalation rate	% p.a.	2.00%	2.00%
5029	Annual Staff Cost (in year 1)	EUR	*3,500*	
5031	**Repair- and Maintenance Cost (R&M)**			
5032	Annual R&M cost in % of total investment	%	1.80%	1.80%
5033	Repair- & Maintenance cost (year 1)	EUR/a	*4,200*	
5034	Repair- & Maintenance cost - annual increase	% p.a.	2.00%	2.00%
5036	**Property Cost**			
5037	Annual property cost / rent / lease	EUR/a		
5038	Annual property cost increase	% p.a.	1.50%	
5041	**Other annual cost**			
5042	Other annual cost (e.g. Insurance, ash disposal, wheel loader operation (excl. driver), etc.) considered as fraction of the total investment	%	0.25%	0.75%
5043	Annual other cost (year 1)	EUR/a	*583*	1,749
5044	Other cost - annual increase	% p.a.	2.00%	2.00%

The fossil fuel price (line 5016, above) is higher than in the table below (line 5054) as the annual fuel volume is much lower. The reference value for the R&M cost (line 5032, above) are calculated according to VDI Guideline 2067. Other annual cost (line 5042, above) are set lower as the reference value as no wheel loader operation is required.

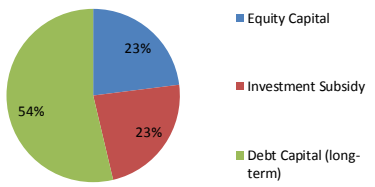
Table 10: Regular payments of the fossil fuelled reference system.

	Fossil Fuelled Reference System			
	Parameter	Unit	Input Value	Reference Value
	This section summarizes parameters that are specific to the fossil fuelled reference system. (Most parameters are adopted from the biomass system section above, e.g. electricity-, staff and property cost parameters).			
5052	**Fossil fuelled reference systems' fuel cost**			
5053	Selected fuel type		Fuel Oil	
5054	Fossil fuel price	EUR/MWh	52.00	40 - 54
5055	Fossil fuel price escalation rate	% p.a.	2.00%	2.00%
5056	Annual fuel cost (theoretically; in year 1, at 100% grid expansion)	EUR/a	*45,102*	
5058	**Repair- and Maintenance Cost (R&M)**			
5059	Annual R&M cost in % of total investment	%	1.84%	1.84%
5060	Repair- & Maintenance cost (year 1)	EUR/a	1,900	1,900
5061	Repair- & Maintenance cost - annual increase	% p.a.	2.00%	2.00%
5063	**Other annual cost**			
5064	Other annual cost (e.g. Insurance, office related cost, etc.) considered as fraction of the total investment	%	0.25%	0.50%
5065	Annual other cost (year 1)	EUR/a	258	258
5066	Other cost - annual increase	% p.a.	2.00%	2.00%

3.6 Economics

Table 11: Financing of the bioheat system.

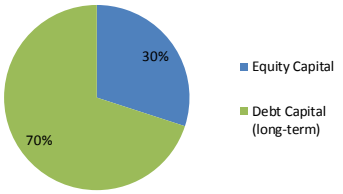
	Biomass Heat System			
	Parameter	Unit	Input Value	Reference Value
6008	**Investment Capital Structure**			
6009	Total calculatory investment (present value)	EUR	*243,984*	
6010	Total investment eligible for subsidy	EUR	227,240	239,200
6011	Investment subsidy share (of eligible investment) - if any subsidies are provided	%	25.0%	30.0%
6012	Equity Capital Share (equity capital related to calculatory investment minus investment subsidy)	%	30.0%	30.0%
6014	**Equity Capital**	**EUR**	56,152	56,152
6015	**Investment Subsidy**	**EUR**	*56,810*	
6016	**Debt Capital (long-term)**	**EUR**	*131,022*	
6018	**Terms of credit**			
6019	Long term Loan - interest rate	% p.a.	4.00%	3.00%
6020	Long term Loan - lent term	yr	10	10
6021	Long term Loan - annuity (interest + redemption)	EUR/a	*16,154*	
6024	Length of Construction Phase (max. 12 months)	Months	12	12
6025	Interest Payment for construction phase loan	EUR	*4,784*	
6027	**Equity Capital Conditions**			
6028	Cost of equity Capital (interest rate) - after tax	% p.a.	7.50%	7.50%
6029	Tax rate	% p.a.	25.00%	25.00%
6030	**Cost of Equity Capital (interest rate) - pre-tax**	**% p.a.**	10.00%	
6032	**WACC pre-tax**	**% p.a.**	6.73%	
6034	**Other Parameters**			
6035	Investment subsidy payment year	year	3	
6036	Inflation Rate	% p.a.	2.00%	2.00%



The calculatory investment (see line 6009, above and 6045 below) is higher than the initial physical investment (see line 3079, above and line 3146, above.) This is due to the long term credit which is redemption free during construction phase (1 year) and the investment subsidy granted in year 3 of operation (see line 6035, above). The interest for the construction phase and the later payment of the investment subsidy lead to a higher calculatory investment (at present value).

Table 12: Financing of the fossil fuelled reference system.

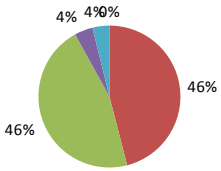
6044	**Capital Structure**			
6045	Total calculatory investment (present value)	EUR	***105,456***	
6046	Equity Capital Share (equity capital related to calculatory investment minus investment subsidy)	%	**30.00%**	30.00%
6047	Equity Capital	EUR	***31,637***	
6048	Debt Capital (long-term)	EUR	***73,819***	
6050	**Loan conditions**			
6051	Interest payments for short-term credit	EUR	***4,056***	4,056
6052	Loan - interest rate	% p.a.	**4.00%**	4.00%
6053	Loan - lent term	yr	**10**	10
6054	Loan - annuity (interest + redemption)	EUR/a	***9,101***	
6055	WACC pre-tax	%	*7.73%*	

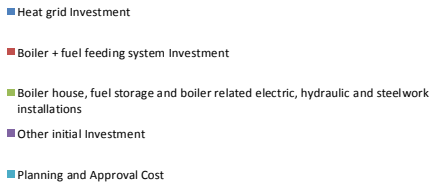


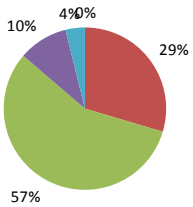
3.7 Results

Table 13: Profitability calculation – results for the bioheat and fossil fuelled reference system.

7004	**Economic efficiency - results of the profitability calculation using the discounted cash-flow method**					
	Biomass Heat System			**Fossil Fuelled Reference System**		
7006	Fuel type	Wood Chips & Fuel Oil		Fuel type	Fuel Oil	
7008	**Technical Parameters**					
7009	Total nominal biomass boiler capacity	0.4 MW		Total nominal fossil fuelled boiler capacity	0.4 MW	
7010	Fossil fuelled peak/back-up boiler capaci	0.4 MW				
7011	Heat Grid - Trass/trench length	0 m		Heat Grid - Trass/trench length	0 m	
7012	Annual heat sold/delivered	737 MWh/a		Annual heat sold/delivered	737 MWh/a	
	Investment					
	Total initial Investment (year 0-3)	239,200	EUR	Total initial Investment (year 0-3)	101,400	EUR
	Thereof Investment Subsidy (if any)	56,810	EUR			
7018	**Figure(s): Shares of initial investment components**					





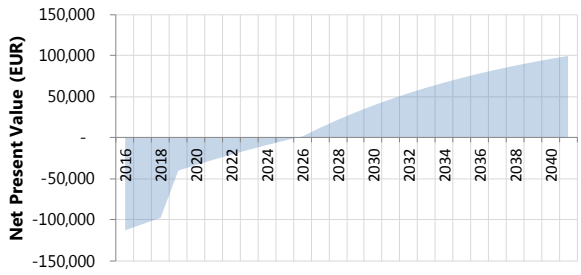


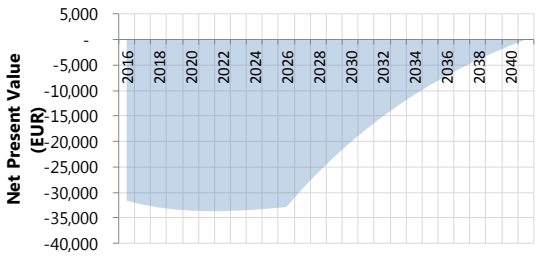
7028	**Discounted Cash-flow analysis (based on VDI Guideline 2067) - Assumptions overview**					
7029	Cost of equity capital (interest rate) - pre	10.00%		Cost of equity capital (interest rate) - pre-	10.00%	
7030	Loan interest rate	4.00%		Loan interest rate	4.00%	
7031	Tax rate	25.00%		Tax rate	25.00%	
7032	Heat sales price, excl. VAT (in year 1)	78.64	EUR/MWh	Heat sales price, excl. VAT (in year 1)	78.64	EUR/MWh
7033	Calculatory service life (t)	25	years	Calculatory service life (t)	25	years

7035 Discounted Cash-flow analysis (based on VDI Guideline 2067) - Results

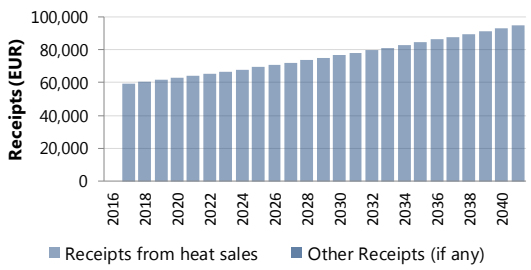
7036 Biomass Heat System		Fossil Fuelled Reference System	
7036 Discounted Payback Time	10.7 yrs	Discounted Payback Time	25.0 yrs
7037 Net Present Value (NPV, t=25 yrs.)	99,508 EUR	Net Present Value (NPV, t=25 yrs.)	3 EUR
7038 Internal Rate of Return (IRR, t=25 yrs.)	13.12%	Internal Rate of Return (IRR, t=25 yrs.)	7.92%
7039 Calculatory Heat Generation Cost	66.16 EUR/MWh	Calculatory Heat Generation Cost	78.64 EUR/MWh

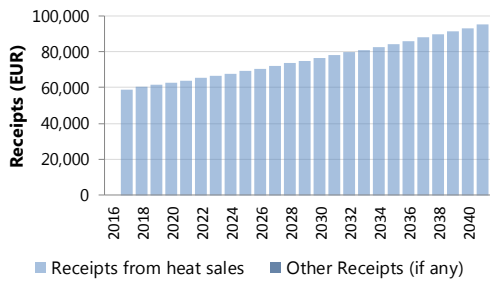
7041 Figure(s): Development of the NPV for a calculated service life of 25 years - visualization of the dynamic payback time.



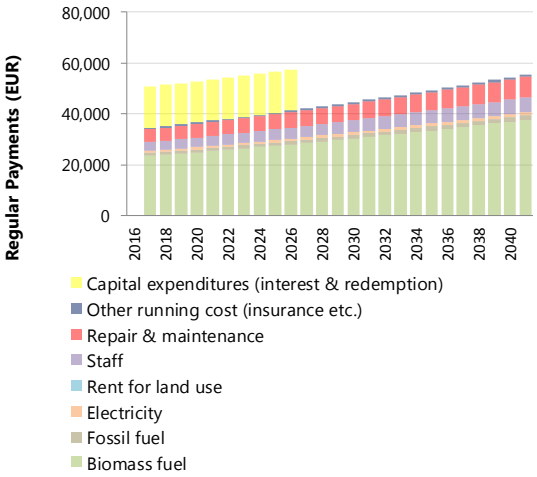


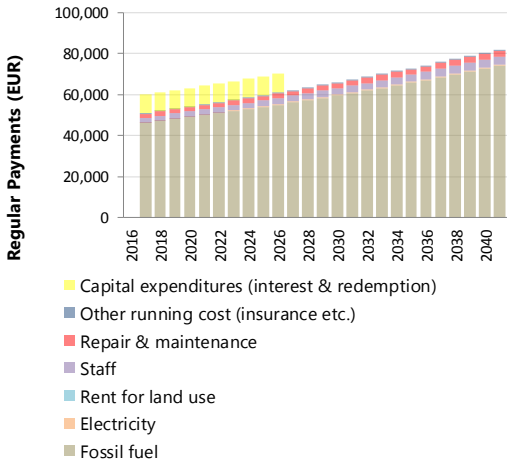
7054 Figure(s): Development of the receipts for a calculated service life of 25 years





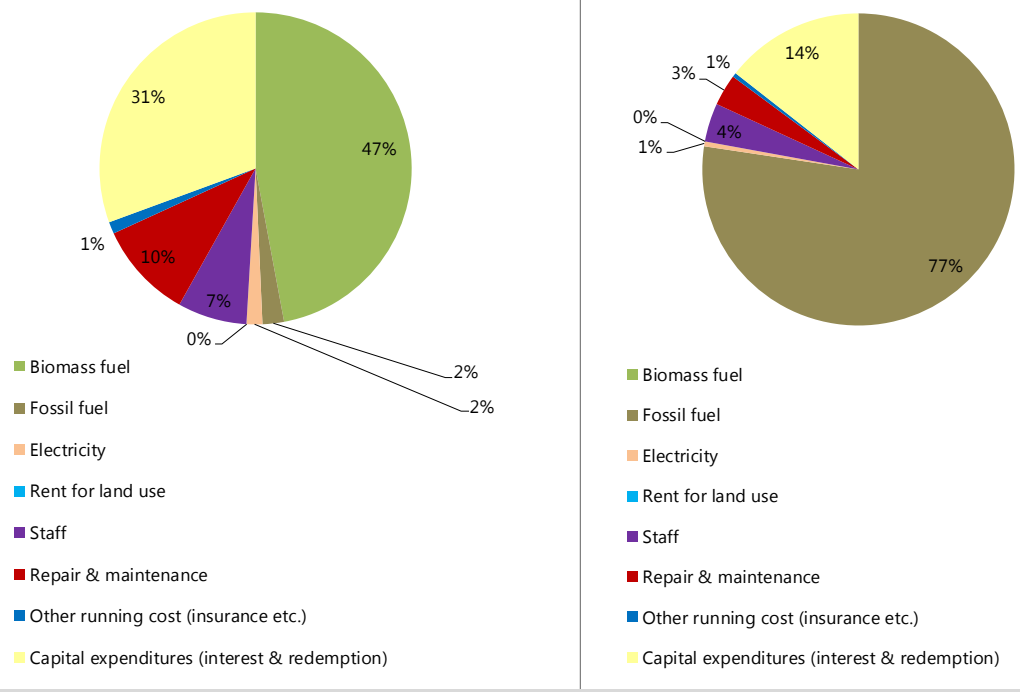
7067 Figure(s): Development of Payments (operating and capital expenditures) for a calculated service life of 25 years





The following figure shows the share of regular payments (operating and capital payments) in year 4 of operation (2020) for a calculated service life of 25 years.

Figure(s): Share of Payments (Opex and Capex) in year 4 (full capacity operation) for a calculated service life of 25 years



This table shows some further relevant calculation results.

	Biomass Heat System			Fossil Fuelled Reference System		
7006	Fuel type	Wood Chips & Fuel Oil		Fuel type	Fuel Oil	
	Fuel purchase price (NCV, year 1)	27.0	EUR/MWh	Fuel price (NCV, year 1)	52.0	EUR/MWh
	Fuel payment savings (year 4)	22,805	EUR/a	% of fossil RefSystem	46.7	
	Annual total payment savings (year 4)	10,321	EUR/a	% of fossil RefSystem	16.4	
	Fossil fuel subsituted by bioheat system	820	MWh/a	% of fossil RefSystem	97.9	
	Greenhouse gas savings	230.3	t CO_2-eq/a	% of fossil RefSystem	97.4	
	Saving of fuel input (NCV)	-30	MWh/a	% of fossil RefSystem	-3.5	

The last table shows, in the manner of a sensitivity analysis, the influence of a change of the calculated service life (see line 7090, here 15 years are assumed) on the Net Present Value (NPV), the Internal Rate of Return (IRR) and the Heat Generation Cost for both systems. In all tables above a calculated service life of 25 years was assumed.

7088	**Influence of the calculated service life on the results**					
	Biomass Heat System			**Fossil Fuelled Reference System**		
7090	**Calculated service life t (15-25 yrs)**	**15**	**yrs**	**Calculated service life t (15-25 yrs)**	**15**	**yrs**
7091	**Net Present Value (NPV)**	**46,936**	**EUR**	**Net Present Value (NPV)**	**-17,621**	**EUR**
7092	**Internal Rate of Return (IRR)**	**10.55%**		**Internal Rate of Return (IRR)**	**3.85%**	
7093	**Heat Generation Cost**	**71.27**	**EUR/MWh**	**Heat Generation Cost**	**81.41**	**EUR/MWh**

4. About the B4B BioHeat Cost Calculator

The **B4B BioHeat Cost Calculator** (Excel-Tool) will be downloadable from the www.bioheat4business.eu/services website by August 2016.

- The **B4B BioHeat Cost Calculator** can be used for a comparison of the economic efficiency (pre-feasibility level) of mid-scale, solid biomass and fossil fuel fired (district & in-house) heat-only plants (in 9 languages).
- By this Excel-Tool a bioheat and an alternative fossil fuelled reference system are assessed using a discounted Cash-flow analysis (based on VDI Guideline 2067).
- The Calculator contains country-specific reference values for investment (of various plant components) and running cost / revenue data (cost / price base 2015 of 12 countries). Scopes of this Excel-Tool are biomass heating plants with and without district heating networks, in a capacity range from 0.1 to 20 MW. Default values are given within this capacity bandwidth.

The Excel Tool consists of 6 data input sheets and 1 data output sheet (Results). To start the calculation procedure, fill in the Excel-Sheets from left to right in the given order. Input sheets are organized as lists, each parameter has one row. In the left column (next to the input parameter name) you will find a link to the corresponding manual entry. In the column "Input Value", you will find dark blue cells where the correct values for your project need to be typed in. To provide some guidance on plausible parameter values, you will find estimated reference values, or typical value ranges in the column "Reference Value". These values are based on a national survey conducted in the year 2015 by the Bioenergy4Business project partners. All cost related reference values are increased by means of the inflation rate set, only. This cost increase is calculated automatically, based on the year you chose to be the start year of your project (see below). In some cases you will also find reference values for capacities, technical parameters etc. Please note that all these reference values serve as rough first estimates for plausible input/parameter values only. The real values, which you should take as input/parameter values for your specific project can deviate substantially from the reference values, based on local conditions.

Please note that the tool and the related national survey for reference parameter values have been prepared with meticulous care and to the best of our knowledge. For the sake of convenience, calculations assumptions had to be agreed on which might result in (slight) deviations from precise results. Furthermore the results of this tool depend strongly on user inputs, such as heat demand assumptions and plant sizing parameters. Please note that an in depth heat demand inquiry is essential for the sizing of the plant components at optimal cost, and consequently has a strong impact on the feasibility of biomass heat projects.

This tool does not replace site specific planning by professionals and collecting several offers from manufacturing companies. Hence investment decisions cannot be based on the usage of this tool.

5. References

Verein Deutscher, Ingenieure. *VDI Guideline 2067 "Economic efficiency of building installations. Fundamentals and economic calculation.".* Berlin: Beuth Verlag GmbH, 2007.

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