Preparatory Study on

Eco-design of Boilers

Task 6 Report (FINAL)

Design Options

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CONTENTS

page

1 INTRODUCTION

1.1 Introduction

The scope of Task 6 of the preparatory Eco-design study on Central Heating Boilers is the identification of the short-term target design options, their monetary consequences in terms of Life Cycle Costs for the consumer, their environmental costs and benefits and pinpointing the solution with the least Life Cycle Costs (LLCC) and the Best Available Technology (BAT).

The assessment of monetary Life Cycle Costs is relevant to indicate whether design solutions might negatively or positively impact the total EU consumer's expenditure over the total product life (purchase, running costs, etc.). The distance between the LLCC and the BAT indicates – in a case a LLCC solution is set as a minimum target – the remaining space for product-differentiation (competition). The BAT indicates a medium-term target that would probably be more subject to promotion measures than restrictive actions. The BNAT (= Best Not yet Available Technologies (see subtask 6.5) indicates the long-term possibilities and helps to define the exact scope and nature of possible measures.

VHK has made all calculations based on the ECOBOILER model version 5a, which is added separately as an Excel file.

1.2 Approach

The BaseCase New Individual and Collective Boilers - as defined in Task 5 - will serve as the reference for the evaluation of the design options. These Base-cases define a complete heating system (incl. the heat generator, temperature controllers and valve controllers) in combination with its EU-average heat load. Because of reasons explained earlier, the proposed design options not only related to the boiler appliance itself, but also to other auxiliary system components that help improving the efficiency of the boiler and reducing the energy consumption for space heating. These auxiliary components are items like temperature controllers, valve controllers, renewable generator components that are commonly offered and sold together with the boiler appliance).

For each Design-option, the increase in consumer price (VAT included) will be estimated on the bases of:

- the data that was gathered and presented in the Task 2 Report, chapter 4 and 5
- data gathered for the Task 4 Report
- hands-on experience with engineering and production in the heating industry
- product list prices and prices collected from web-shops

The energy savings related to each individual design option will be calculated using the Integrated Boiler Model, version 5a. The consequences of each design-option for environmental impact and Life-Cycle costs will be determined on the bases of the EuP EcoDesign Model (version 5), where the input for the energy consumption in the use-phase is the output "CH Energy Total" from the Integrated Boiler Model.

The parameters that are used for calculating the life-cycle running costs are based on the results of the task 2 Report chapter 4, being:

Table 1.1

Product-life [yr]	17	Electricity rate per kWhe	0,15 €/kWh	Electr. rate increase / yr.	1,5%
Discount rate	2%	Gas rate per kWh	0,047 €/kWh	Gas rate increase / yr.	5,6%
Repair& maint /yr	€180	Oil rate per kWh	0,061 €/kWh	Oil rate increase / yr.	8,2%

1.3 Design Options & Costs

1.3.1 Costs Reference Boiler

The Base-Case New Individual Medium sized Boiler will serve as the first reference for the design options for the individual boiler, due to its market share of around 52%. Pursuant to Task 5, the table below gives a compact summary of this reference case for the evaluation of the design options..

Table 1-2. Reference system for evaluation of design options

INPUTS CH			PRODUCT PRICE BREAK DOWN	
CH-power class	**4 -M (Medium)**			
	1 –av. existing			
boiler characteristics			**OEM Subass.Costs** (Task 2, Ch5)	Euro/ system
power input in kW*	**22**	kW	Heat exchanger group	**90**
turndown ratio	**33%**		El. controls group	**50**
standby heat loss (% of Pnom)	**1,0**	%	Burner group	**20**
steady st. efficiency %	**5 -80/80/80/80**		Fuel controls group	**35**
fuel (dew point)	**1-gas**		CH-return group	**40**
air-fuel mix control	**1 -pneumatic**		CH-supply group	**10**
circ. Pump power	**6 -95W**		Fan group	**30**
fan power	**3 -P=9..40W**		Casing	**30**
CPU power sb/on	**4 -P=10/12W**		Condensate collect	**8**
controls power sb/on	**2 -P=0/10W**		Hot water group	21
comb. air intake	**1 -room sealed**		Packaging etc.	**10**
boiler mass (empty), kg	**45**	kg	Extra oil-fired (*0,12)	**65**
water content in kg	**4,0**	kg	**Subtotal OEM**	**409**
envelope volume in m³	**0,15**	m³		
noise level in dB-A	**43**	dB-A	Labour **(30% of Subtotal OEM)**	123
controllers			Overhead **(70% of Subtotal OEM)**	286
auto-timer control	**yes**		**total MSP**	**818**
valve control	**2 -RTV 2K**			
boiler temp control	**6 -on/off RT**		Ex wholesale **(1,3 * total MSP)**	1.063
electronic optimiser	**no**		Ex inst.excl.VAT **(1,55 * tot. MSP)**	1.268
auto set weather control	**N/A**		**BOILER cons.str price incl.VAT**	**1.509**

Reference System features

The Reference system is a system with a predefined “EU-average” heat load, that consists of a wall hung room-sealed modulating LT-boiler (η on GCV = 80/80/80/80 %) 0f 22 kW and a turn-down ratio of 33%. The boiler is equipped with standard average electric auxiliary components (pump, fan, cpu). The temperature is controlled with an on/off room thermostat with timer control in the living zone (zone 1) and at least 4 TRV’s for the other rooms (bedrooms and bathroom).

Reference System Price

Product Costs

The costs for this reference product-system are based on the OEM material costs for an non-condensing, open, heating only boiler (Table 5.5 Task 2 Report) on one hand, and the

average boiler street price (VAT incl.) of ca. € 1500 ,- (Table 4.1 , Task 2 Report) on the other hand. The OEM material-costs for the subassemblies/components op the reference boiler are adjusted according to the table below.

Table 1-3. Explanation Cost build up Base-case "M" size boiler

	(Task 2, Chapter 5)	Corrected for ref. boiler
OEM Subass. Costs (Euro/ system)	**Non cond./ atmospheric / solo**	**LT / room-sealed / combi**
1. Heat exchanger group	**80**	**90**
2, El. controls group	**50**	**50**
3. Burner group	**20**	**20**
4. Fuel controls group	**35**	**35**
5. CH-return group	**40**	**40**
6. CH-supply group	**10**	**10**
7. Fan group	**.**	**30**
8. Casing	**30**	**30**
9. Condensate collect	**.**	**8**
10. Hot water group		21
11. Packaging etc.	**10**	**10**
12. Extra oil-fired		**65**
Subtotal OEM	**275**	**409**
Labour **(30% of Subtotal OEM)**	83	123
Overhead **(70% of Subtotal OEM)**	192	286
total MSP	**550**	**818**
Ex wholesale **(1,3 * total MSP)**	715	1.063
Ex installer excl. VAT **(1,55 * total MSP)**	853	1.268
BOILER consumer street price incl. VAT (* 1,19)	**1014**	**1.509**

Because the reference boiler is room sealed (closed compartment for combustion chamber and heat exchanger) **€10,-** is added to the OEM price for the HE-group, to compensate for the materials used to close the combustion/he-compartment. Furthermore the reference boiler is fan-assisted, for which reason **€30,-** is added for a simple fan including fan controls and the necessary additional internal duct work. Since approximately 25% of the new sales are condensing boilers, 25% of the costs for a condensate collector is added. According to Table 5.5 of the Task 2 Report these costs are estimated at **€ 8,-**. Since around 58% of the new boilers sold in 2004 are combi boilers, an additional **€ 21,-** is added to value the share of combi boilers with additional hot water components.

Finally an additional figure needs to be added to correct for the percentage of oil fired boilers in the "M" (Medium) range of new sold boilers. Pursuant to table 4.1 of the Task 2 Report, this percentage is set at 1,5 * 1,45 * 0,09 = 19,6 % (factor for oil * factor for floor standing * 9% share of oil boiler in unit sales (see table 3.11 of the Task 5 report)). For the reference boiler system this equals an extra cost of **€ 65,-.** The consumer street price of the Reference Boiler System thus becomes € 1.509,-.

For collective boilers a higher share of oil fired appliances is applicable, namely 40% as average. For collective boilers (XL to 4XL) this percentage therefore becomes 1,5 * 1,45 * 0,4 = 87 %.

Product costs and boiler size

The impact on product costs for varying the nominal boiler output is mainly related to material costs for the heat exchanger, (burner), casing and packaging (together responsible for appr. 30% of subtotal OEM). In a certain range (in casu the range with a nominal output between 10 – 30 kW) these costs and the costs for the other components (fan, pump, control unit, piping) are very similar. Above this range there will be a bigger effect in price because of the different production series of those boilers and their OEM components. Based on list prices and on the calculation principle illustrated in the previous tables, the following numerical relation between nominal output and OEM price is assumed:

For the smaller boilers (XXS, XS, and M) the OEM-costs for the subassemblies 1.HE-group, 8.Casing and 11.packaging are reduced by 15% for each step smaller than size "M"; costs for the other subassembly groups remain the same.

For the bigger boilers (L, XL, XXL, 3XL and 4XL) the costs for these three subassembly groups is increased with 15% for size "L" , and for the size "XL" and "XXL" a multiplier of 2 respectively 3 is used. For the last two size-classes the costs for all other subassembly groups is increased with 25% per step upwards. Costs for the 3XL boilers are determined by multiplying all XXL-subassembly costs with a multiplier of 2. Costs for the 4XL boiler are determined by multiplying all 3XL subassembly costs with 4.

This approach leads to the following table on prices for boilers with basecase features.

Table 1.4. Cost build-up different size categories basecase boilers (related to size-category "M")

		1	2	3	4	5	6	7	8	9
		XXS	XS	S	M	L	XL	XXL	XXXL	XXXXL
	Pnom in kW	*10*	*14*	*19*	*22*	*29*	*60*	*115*	*250*	*750*
Nr.	*OEM Subass.Costs (Task 2,Ch.5)*									
1	Heat exchanger group	55	65	77	90	104	180	270	540	1620
2	El. controls group	50	50	50	50	50	63	78	156	469
3	Burner group	12	14	17	20	23	29	36	72	216
4	Fuel controls group	35	35	35	35	35	44	55	109	328
5	CH-return group	40	40	40	40	40	80	100	200	600
6	CH-supply group	10	10	10	10	10	13	16	31	94
7	Fan group	30	30	30	30	30	60	75	150	450
8	Casing	18	22	26	30	35	60	90	180	540
9	Condensate collect	8	8	8	8	8	16	20	40	120
10	Hot water group	21	21	21	21	21	21	21	21	21
11	Packaging etc.	6	7	9	10	12	20	30	60	180
	Extra oil-fired (*0,11)	54	57	61	65	69	491	664	1310	3895
	Subtotal OEM	**340**	**360**	**382**	**409**	**436**	**1075**	**1454**	**2870**	**8533**
	Labour	102	108	115	123	131	323	436	861	2560
	Overhead	238	252	268	286	305	753	1018	2009	5973
	total MSP	**680**	**719**	**765**	**818**	**872**	**2151**	**2909**	**5740**	**17065**
	Ex wholesale	885	935	994	1063	1133	2796	3781	7462	22185
	Ex installer excl. VAT	1055	1115	1185	1268	1351	3334	4508	8897	26451
	BOILER consumer street price incl. VAT	**1255**	**1326**	**1410**	**1509**	**1608**	**3967**	**5365**	**10587**	**31477**

Installation Costs

The installation costs are based on the data presented in table 4.2 of the Task 2 Report, where the average installation costs for the base-case new gas boilers is €1195,- and for oil boilers € 1737,-. Incorporated in these figures is a share of 40% of the installations that need new or renewed chimneys, electric connections and or condensate drains (due to first time installation and/or condensing boilers). Per size category the installation costs are weighted for their share of oil and gas. For instance in the "M" category there are around 9% oil boilers and 91% gas boilers, resulting in a total installation costs of (1195*0,91 + 1737*0,09 = € 1244,-). For collective boilers (XL to $XL) the installation costs are calculated with the adjusted formula "1195*0,6 + 1737*0,4" due to the higher share of oil boilers. In addition to this weighting for fuel, a multiplier is used to compensate for the installation costs related to the size of the boiler, according to the following table:

Size	XXS	XS	S	M	L	XL	XXL	3XL	4XL
Multiplier	0,80	0,85	0,90	1	1,1	2	3	4	7

This leads to the following assumptions on installation costs.

Table 1.5. Installation costs different size categories basecase boilers

	XXS	XS	S	M	L	XL	XXL	XXXL	XXXXL
Pnom in kW	*10*	*14*	*19*	*22*	*29*	*60*	*115*	*250*	*750*
INSTALLATION (Labour, materials, VAT)	972	1033	1094	1215	1337	2572	3857	5143	9001

Controller Costs

Concerning controllers, the reference for the size "M" and the smaller boiler sizes, is the on/off room thermostat with auto timer control, situated in the central part of the house (living) in combination with at least 4 TRV's (2K). Reference prices for these standard TRV's are set at euro 15,- per TRV (consumer price, VAT included) and for the on/off room thermostat with auto timer control: euro 90,-

Reference for collective boiler is the control system with a fixed boiler feed temperature.

A summary table for an overview of all the basecase design inputs is given in table 3.4 of the Task 5 Report.

1.3.2 Cost Assessment Design Options

All costs mentioned in this paragraph relate to size-category "M" and represent the increase in costs for a specific design option compared to the basecase product.

a. Steady-state efficiency

The increase of the steady-state efficiency from 80/80/80/80 to the various condensing modes, involves several of the subassembly groups, listed in the OEM cost build-up. The table below gives the price-increase for the various steps in improving the steady-state efficiency and is based on Table 5.5 of the Task 2 Report, that summarizes the OEM materials costs indications for gas-fired wall hung boilers.

Table 1-6. Price increase OEM subassembly groups related to steady-state efficiency

OEM Subass. Groups		84/84	85/91	87/95	89/97	96/97
Nr.	Steady-state eff. Option nr.	4	3	2	1	9
1	Heat exchanger group	15	25	30	35	60
2	El. controls group		20	30	40	40
3	Burner group				5	5
4	Fuel controls group					*
5	CH-return group		10	15	20	20
6	CH-supply group					
7	Fan group		5	5	5	5
8	Casing					
9	Condensate collector		27	27	27	27
10	Hot water group					
11	Packaging etc.					

** for 96/97% a type of λ-control is requested*

For the design-option "tertiary heat exchanger" that is represented with a steady-state efficiency figure of "96/97" (option 9), the additional OEM costs of €25,- for the 'heat exchanger group' related to a plastic heat exchanger that is added to the air-supply and exhaust channel of the boiler. If this design option is selected, it is necessary to also improve the air-fuel mix control with at least an ionisation based λ-control system to properly benefit from the preheated combustion air in the combustion process.

The expected steady-state efficiency for the tertiary heat exchanger is safely limited to 96 and 97% GCV (96% at 80/60 °C and 97% at 50/30 °C), and not 99% (as already claimed by some boiler manufacturers for boilers without tertiary heat exchanger at the 50/30 regime), because the technology of the tertiary heat exchanger partly still has to prove

itself, and some losses are expected due to an increased power consumption of the fan and due to a more complex dynamic behaviour during on/off cycling of the boiler.

b. Power input

If the heat load of the house is selected, the power input of the boiler normally is selected according to the same power class. The maximum power input of the boiler however, is mainly related to the requested domestic hot water production (combi appliances) and to a lesser extend to the heat load of the house. For heating only purposes it is therefore possible to select a power input class that is below the heat load class of the house. The table below gives the minimal required output power of the boiler for each "house heat load category".

Table 1-7. Load profiles: Net heat load, average power, peak output power required in normal and extreme circumstances

Cat.	Model	Extreme peak power [-10 °C] Phextr.	Temperature & heat-up correction factor EN 12831 #	MINIMUM REQUIRED OUTPUT POWER kW	est. input power BaseCase (incl. eff + oversize) kW
XXS	apartment new	2,60	1,38	**3,6**	10
XS	average new	3,70	1,38	**5,1**	14
S	apartment existing*	5,00	1,38	**6,9**	19
M	average existing	5,60	1,38	**7,7**	22
L	house existing	7,60	1,38	**10,5**	29
XL	new building (8 apartments)	22,20	1,38	**30,6**	60
XXL	existing building (8 ap.)	33,60	1,38	**46,4**	115

Selecting a boiler with a reduced power input will not only effect the product purchase price and with it the lifecycle costs, but also the annual energy consumption. Depending on the type of boiler controls and room temperature controls, the energy savings can vary between 0 and 4 %.

The influence on the product costs related to varying the maximal power rating of the reference boiler is illustrated in table 1-4.

c. Turndown Ratio

The costs for increasing the turn-down ratio of a boiler to 10% of the nominal boiler output, largely relates to the principle that is used to accomplish this feature and the reference boiler that is taken as starting point. If an extra diaphragm is used to increase the available air pressure of the traditional pneumatic control unit through which a higher measuring resolution is achieved (see Task 4 Report, paragraph 6.2) the extra OEM costs will be limited to around **15 - 20** € for an additional diaphragm and some fine tuning in the controls. If the increased turn down ratio is achieved with an adjusted mix- and control unit, using two valves that are both controlled by a motor, the cost increase will probably be higher. The following OEM cost increase for the "fuel control group" will be used for evaluation of the design options:

Table 1-8. OEM cost increase for the "fuel control group"

Turndown ratio	OEM cost increase for fuel control group
≥ 30%	0 euro
≤ 30% AND ≥ 20	10 euro (fixed amount)
≤ 20% AND ≥ 10	15 – 25 € (lineair function)

* Please note that these extra costs only relate to a boiler that is already optimised for condensing purposes and outfitted with variable speed fans and appropriate burners. If this is not the case cost increase will be double of the here mentioned figures.

d. Standby heat loss

Reducti0n of stand by heat losses can be achieved by reducing the radiation and convection losses of the appliance. Radiation and convection losses of the casing can be reduced by improving the insulation of the hottest spots of the boiler (burner and heat-exchanger) and by improving the insulation of the casing using (improved) insulation material with a reflective coating. Convection losses through the chimney can be reduced by using either a flue valve or some other kind of device or lay-out (heat trap) that prohibits the supply air from passing through the heat exchanger into the chimney.

Improving the insulation of the heat exchanger and casing is not very usefull when the heat can still escape through the flue-duct or chimney. Priority should be to first minimize these convection losses through the exhaust and then start improving on the boiler insulation. The following OEM cost increase will be used for evaluation of the design options:

Table 1-9. OEM cost increase will be used for evaluation of the design options

Standby heat loss	OEM cost increase
< 1% of nominal power	€ 5,- to be added to subassembly "fan group" (for adjusted construction (heat trap) or additional flue valve)
≤ 0,5% of nominal power	€ 10,- to be added to the subassembly "casing" (costs for appr. 1,5 m² insulation material)
	Please note that below 0,5% both OEM price increases are applicable

e. Air-fuel ratio control

The "M"-size reference boiler uses a standard pneumatic air-fuel ratio control. As explained in the Task 4 Report, this type of λ-control can be further improved with Ionisation based technology of next generation O2 and CO sensors. The following OEM cost-increase for improvement of the λ-control technology will be used for evaluation of the design options:

Table 1-10. OEM cost-increase for improvement of the λ-control technology

λ-control technology	OEM cost increase
Ionisation based	€20,-
Next generation O2 en CO	€ 30,-

f. Circulation Pump

The circulation pump that is assumed as the standard product for the reference boilers, is the single speed pump (single speed may selectable out of three). There is an A-G energy label for circulators, but this applies only to standalone products and cannot be applied to integrated circulation pumps. An alternative classification for the latter could be[1]:

a) Standard pumps, manual speed selection or remote speed selection (one up to three speed)

b) Electronic pumps, PWM or BUS controled remote speed selection (more than 20 different speeds)

c) High efficiency pumps, PWM or BUS controled remote speed selection (more than 20 different speeds)

[1] Pers. comm.. Armin Marko, 2007

The power consumption of pumps (see also Task 6- table 2.2), according to the differentiation above, and with comparable pressure head ("6-7m pump") is estimated by industry sources at:

a) 80-95W

b) 30-95W

c) 5-70W

For room temperature control systems (pump running mainly on max design speed, e.g. 1000l/h) the median values are expected to be 95, 80 and 45 W.

For outdoor temperature control systems (pump running a lot in part load < 1000l/h) the typical values are 80, 45 and 25 W.

In any case, these values are relevant for modelling. For legal measures we propose that validated and measured power consumption values should be used.

The same also goes for circulators that are used in solar systems and or in heat pump systems..

The OEM costs for a standard pump are integrated in subassembly group 5: “CH-return-group”, with reference costs of €40,- for the medium boiler. The following OEM cost-increase will be used for evaluation of the design options (pursuant discussions with pump manufacturers):

Table 1-11. OEM costs for a standard pump

Energy class circulator	OEM cost increase
Class B	€ 22,-
Class A	€ 50,-

g. Fan

The fan of the reference "M" boiler is a variable speed fan with an energy consumption 0f 9 to 40 watts maximum. This energy consumption of this component can be further reduced by improving motor and impeller efficiency. The following OEM cost-increase for improvement of the fan will be used for evaluation of the design options:

Table 1-12. OEM cost-increase for improvement of the fan

Energy consumption fans	OEM cost increase
6 – 30 watts	€ 5,-
3 – 18 watts	€ 10,-

h. CPU & controls

The power consumption of the CPU with its controls mainly depend on the type off power supply that is used and on the how intelligently the CPU is designed (optimised for minimal consumption or not). The CPU of the reference "M" boiler is an average unit with a power consumption of 10 – 12 watts. The following OEM cost-increase for improvement of the CPU-power consumption will be used for evaluation of the design options:

Table 1-13. OEM cost-increase for improvement of the CPU-power consumption

Energy consumption CPU	OEM cost increase
6 – 8 watts	€ 4,-
4 – 6 watts	€ 6,-
2 – 3 watts	€ 10,-

i. Boiler temperature control

The basecase boiler temperature control system is the on/off room thermostat controlled system, with auto timer control (clock based night setback). This reference control system can be improved by applying a modulating thermostat or a time proportional room thermostat. The extra costs for these design options are not based on OEM costs but on the price differences that can be derived from street prices for these products. Apart from that there will in the replacement market also be some extra costs for replacing the existing room thermostat. The following difference in street prices for improved room thermostats will be used for evaluation of the related design options:

Table 1-14. difference in street prices for improved room thermostats

Type of room thermostat	Increase purchase price (VAT included)	Additional installation costs
Modulating room thermostat	€ 30,-	€ 25,-
Time proportional RT	€ 50,-	€ 25,-

In case a weather dependent control system is selected the extra costs for this option relates to extra controller components (outdoor sensor and improved boiler control options). From energy perspective the weather dependent control system can not be seen as a design option because it consumes more energy that the basecase on/off room

thermostat. Weather dependent control systems are selected because they offer heating comfort in all habitable rooms. Compared to a fixed boiler temperature controlled system however, the weather dependent control system does offer energy savings and can in that sense be seen as design option.

The following difference in street prices for a weather dependent system (compared to a fixed boiler temp controlled system) will be used for evaluation of the related design options:

Table 1-15. difference in street prices for a weather dependent system

Type of boiler temp. control	Increase purchase price (VAT included)	Additional installation costs
Weather dependent	€ 100,-	€ 80,-

j. Valve control

The reference valve is a Thermostatic Radiator Valve (TRV) with a 2k band. Envisaged improvements of this control feature involves:

- the use of 1k TRV,s
- use of motor valves with a PID loop
- use of motor valves with a cpu

The added costs related to these improvements not only affect the systems purchase price, but also the installation costs (old valves need to be replaced by the new ones). The following cost increase figures will be used for evaluation of the related design options:

Table 1-16. cost increase figures

Type of boiler temp. control	Increase purchase price (VAT included)	Additional installation costs
TRV 1k	-	€ 60,- *(hydraulic balancing)*
Motor valve + PID loop	€ 60,- per valve	€15,- / valve
Motor valve + CPU	€ 85,- per valve	€ 15,- / valve

k. Electronic optimiser

The additional costs for an electric optimiser is related to the extra software that needs to added and most probably to some additional costs for the CPU-components (more expensive processor, etc.). The additional costs for the consumer for this design option is set at € 25,-

l. Autoset weather control

A control system that automatically sets optimal boiler feed temperature based on outdoor temperatures and on information on the difference of the actual and desired temperature in each individual room, is a system that has temperature sensors in each room and preferably uses motor valves in each habitable room. Data is wireless transmitted to a CPU that continuously calculates and adjusts the optimal boiler feed temperature.

The following cost increase figures will be used for evaluation of the related design options:

Table 1-17. cost increase figures autoset weather control

Components for autoset of boiler feed temperature	Increase purchase price (VAT included)	Additional installation costs
Motor valves + RF	€ 85,- per valve	€ 15,- per valve
Centralized control unit + RF	€ 250,-	€ 75,-

m. Solar collector

Based on list prices of manufacturers, the following costs will be used for evaluation of the related design options:

Table 1-18. costs solar collector

Type of collector	Unglazed	Glazed	Vacutube
Fixed material costs	€ 500,-	€ 500,-	€ 500,-
Material costs per m²	€ 200,-	€ 300,-	€ 400,-
Fixed Installation costs	€ 350,-	€ 350,-	€ 350,-
Installation costs per m²	€ 150,-	€ 150,-	€ 150,-

n. Electric Heat Pump

Based on list prices of manufacturers, the following costs will be used for evaluation of the related design options:

Table 1-19. costs electric heat pump

Type of heat pump	Air / water	Brine / water	Water / water
Fixed material costs	€ 750,-	€ 1000,-	€ 1000,-
Material costs per kW	€ 600,-	€ 1000,-	€ 1000,-
Fixed Installation costs	€ 500,-	€ 1000,-	€ 1000,-
Installation costs per kW	€ 300,-	€ 600,-	€ 600,-

For gas fired heat pumps the same price increase is assumed for the various types (air/water, brine/water and water/water).

2 DESIGN OPTIONS

The ECOBOILER model contains 31 main variables that each have – as an average- around 4 options to choose from. Theoretically this means that there are around 4^{31} possible combinations. This comes down to 4600 quadrillion design options (4600 * 10^{15}) for each size category. Since it is impossible to analytically cover all possible options, the best we can do is pick out some characteristic design options – possibly as heterogeneous as possible – and give an overview of their energy and Life Cycle Costs results.

We will limit the amount of options to 9 per size class.

Clearly, the presented options must not be considered by the reader as the only possible ones.

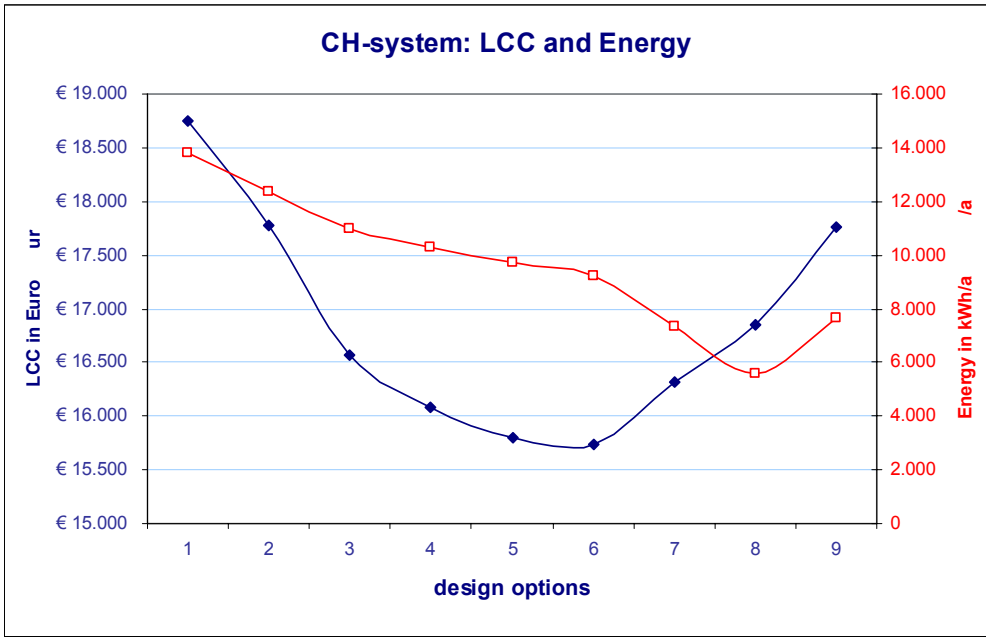
2.1 Design options and Impact size category "M" (Medium)

The following design options have been elaborated for this size class "M" (Medium).

Explanation design options:

1. Reference (see table 1-2 and first column table 2-2)
2. Improvement steady-state efficiency from 80/80 to **87/95**
3. Improvement steady-state efficiency to **89/97** and replacement of on/off room thermostat with a **modulating room thermostat** with **electronic optimiser**.
4. Option 3, extended with energy **class "B" variable speed pump**.
5. Option 4, extended with an improved **turndown ratio of 20%**, a reduction of the **standby heat loss to 0,5%**, a not over dimensioned **high efficient fan**, a **CPU with minimal standby power** consumption (2/3 watts), and the use of **1K TRV's** (which in fact is a hydraulic balancing of the system).
6. Option 5, extended with an improved **turndown ratio of 10%**; an improved steady-state efficiency through the application of a **tertiary heat exchanger with λ-control**, an energy **class "A" variable speed pump**.
7. Option 6, extended with a **2 kW electric air/water heat pump** with a nominal COP of **2,5** (at 7/50); (CH fraction served = 100%).
8. Option 6, extended with a **2 kW electric brine/water heat pump** with a nominal COP of **3,1** (at 0/50); (CH fraction served = 100%).
9. Option 6, extended with a **5 m² vacutube type solar collector** (CH fraction served = 100%).

Figure 2-1.
Design options, lifecycle costs and annual energy consumption category "M"



The average annual primary energy consumption for the BaseCase "M" sized boilers amounts to 13.827 kWh (net heating efficiency is 54%), with a total lifecycle costs of € 18.750,-

This annual primary energy consumption can be reduced with approximately 4090 kWh (= **30%**) to 9735 kWh/a with the existing and proven technology that is selected for Design Option 5. The net heating efficiency with this option is improved to 78%. The related lifecycle costs are reduced to € 15.797,-.

With Design Option nr. 6, the net heating efficiency is further improved to 82% (annual primary energy consumption: 9250 kWh), with similar lifecycle costs. The technology of the tertiary heat exchanger used in this design option however is not fully matured yet. For this reason we propose to use an **LLCC target** that is related to design option 5 and corresponds with a net efficiency of **78 %**

The BAT level is best represented with Design Option 8, that combines a state-of the art condensing boiler (incl. tertiary he) with a 2 kW brine water heat pump with a nominal COP of 3,1 (at 0/50° C). With this option the net heating efficiency rises to 136% giving a annual primary energy consumption of 5591 kWh. **BAT level is therefore set at 130 – 140%.** Related lifecycle costs are € 16.859,- and as such lower than the basecase lifecycle costs, but still € 1.062,- higher than the LLCC-level.

Design Options number 7 (combination with state-of-the art condensing boiler with an electric air/water heat pump) and options number 9 (combination with vacutube solar collector) are viable options with a net heating efficiency of around 100% and lifecycle costs of respectively € 16.323,- and € 17.755,-

Please note that BAT-levels can be further increased to net heating efficiency levels above 160% when water-to-water heat pumps are used.

The impact of the Design Options are summarized in the tables on the next four pages:

Table 2-2: Input Design Options in EcoBoiler Integrated Model for size category "M"

Table 2-3: Prices and Installation costs PER UNIT for Design Options size category "M"

Table 2-4: Life Cycle Costs and Annual Expenditure PER UNIT for size category "M"

Table 2-5: Environmental Impact PER UNIT over lifetime for size category "M"

Table 2-2. Input Design Options in EcoBoiler Integrated Model for size category "M"

DESIGN OPTIONS	1 BaseCase	2	3	4	5	6	7	8	9
INPUTS CH									
CH-power class	4 -M (Medium)	4 -M (Medium)	4 -M (Medium)	4 -M (Medium)	4 -M (Medium)	4 -M (Medium)	4 -M (Medium)	4 -M (Medium)	4 -M (Medium)
	1 -average existing	*1 -average existing*	*1 -average existing*	*1 -average existing*	*1 -average existing*	*1 -average existing*	*1 -average existing*	*1 -average existing*	*1 -average existing*
boiler characteristics									
power input in kW*	22 kW	22 kW	22 kW	22 kW	22 kW	22 kW	22 kW	22 kW	22 kW
turndown ratio	33%	33%	33%	33%	20%	10%	10%	10%	10%
standby heat loss (% of Pnom)	1,0%	1,0%	1,0%	1,0%	0,5%	0,5%	0,5%	0,5%	0,5%
steady st. efficiency %	5 -80/80/80/80	2 -87/87/95/95	1 -89/89/97/97	1 -89/89/97/97	1 -89/89/97/97	9 -ideal 96/96/97/97	9 -ideal 96/96/97/97	9 -ideal 96/96/97/97	9 -ideal 96/96/97/97
fuel (dewpoint)	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas
air-fuel mix control	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	3 -ionisation	3 -ionisation	3 -ionisation	3 -ionisation
circ. pump power	6 -95W	6 -95W	6 -95W	3 -25..(45)..65 W	3 -25..(45)..65 W	1 -5..(15)..25W + sb	1 -5..(15)..25W + sb	1 -5..(15)..25W + sb	1 -5..(15)..25W + sb
fan power	3 -P=9..40W	3 -P=9..40W	3 -P=9..40W	3 -P=9..40W	1 -P=3..18W	1 -P=3..18W	1 -P=3..18W	1 -P=3..18W	1 -P=3..18W
CPU power sb/on	4 -P=10/12W	4 -P=10/12W	4 -P=10/12W	4 -P=10/12W	1 -P=2/3W	1 -P=2/3W	1 -P=2/3W	1 -P=2/3W	1 -P=2/3W
controls power sb/on	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W
comb. air intake	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed
boiler mass (empty), kg	45 kg	45 kg	45 kg	45 kg	45 kg	45 kg	45 kg	45 kg	45 kg
water content in kg	4,0 kg	4,0 kg	4,0 kg	4,0 kg	4,0 kg	4,0 kg	4,0 kg	4,0 kg	4,0 kg
envelope volume in m3	0.15 m3	0.15 m3	0.15 m3	0.15 m3	0.15 m3	0.15 m3	0.15 m3	0.15 m3	0.15 m3
noise level in dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A
controllers									
auto-timer control	yes	yes	yes	yes	yes	yes	yes	yes	yes
valve control	2 -RTV 2K	2 -RTV 2K	2 -RTV 2K	2 -RTV 2K	3 -RTV 1K	3 -RTV 1K	3 -RTV 1K	3 -RTV 1K	3 -RTV 1K
boiler temp control	6 -on/off RT	6 -on/off RT	7 -modulating RT	7 -modulating RT	7 -modulating RT	7 -modulating RT	7 -modulating RT	7 -modulating RT	7 -modulating RT
electronic optimiser	no	no	yes	yes	yes	yes	yes	yes	yes
autoset weather control	N/A	N/A	no	N/A	N/A	N/A	no	no	no
solar (for combi only)									
collector type	N/A	1 -glazed	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube
collector surface m2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	5,0
tank position	N/A	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors
CH-fraction served	0%	100%	0%	0%	0%	0%	0%	0%	100%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
heat pump (HP)									
Reference type	1 -El. brine/ water 0/5	3 -El. air/ water 7/5(	3 -El. air/ water 7/50	3 -El. air/ water 7/5(	3 -El. air/ water 7/5(	3 -El. air/ water 7/50	3 -El. air/ water 7/50	1 -El. brine/ water 0/50	2 -El. water/ water 10/5(
Power nominal in kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	2,0 kW	2,0 kW	0,0 kW
COP nominal 0/50	0,00	0,00	0,00	2,50	0,00	3,50	2,50	3,10	3,80
Ratio CH : DHW	100%	80%	80%	80%	80%	80%	80%	80%	80%
CH-fraction served	100%	0%	100%	100%	100%	50%	100%	100%	0%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
MAIN ENERGY OUTPUTS									
Net heating efficiency	54%	61%	69%	74%	78%	82%	103%	136%	100%
Primary energy consumption	13827 kWh/a	12352 kWh/a	10987 kWh/a	10300 kWh/a	9735 kWh/a	9251 kWh/a	7368 kWh/a	5591 kWh/a	7642 kWh/a
-of which fuel (primary kWh GCV)	13247 kWh/a	11776 kWh/a	9890 kWh/a	9890 kWh/a	9454 kWh/a	9166 kWh/a	2154 kWh/a	1397 kWh/a	7520 kWh/a
-of which electricity (primary kWh)	580 kWh/a	576 kWh/a	1.097 kWh/a	410 kWh/a	281 kWh/a	85 kWh/a	5.214 kWh/a	4.195 kWh/a	123 kWh/a
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 2.724	€ 3.194	€ 3.383	€ 3.480	€ 3.737	€ 4.123	€ 7.173	€ 9.323	€ 7.723
Lifetime Running costs (NPV)	€ 16.025	€ 14.584	€ 13.185	€ 12.597	€ 12.060	€ 11.609	€ 9.150	€ 7.536	€ 10.032
Life Cycle Costs LCC	€ 18.750	€ 17.777	€ 16.569	€ 16.076	€ 15.797	€ 15.732	€ 16.323	€ 16.859	€ 17.755
Simple Payback Period PBB	reference yrs	6,6 yrs	5,0 yrs	4,4 yrs	5,1 yrs	6,2 yrs	17,4 yrs	18,7 yrs	16,5 yrs

Table 2-3. Prices and Installation costs per unit for Design Options size category "M"

DESIGN OPTIONS	1		2		3		4		5		6		7		8		9	
	4 -M (Medium)		4 -M (Medium)		4 -M (Medium)		4 -M (Medium)		4 -M (Medium)		4 -M (Medium)		4 -M (Medium)		4 -M (Medium)		4 -M (Medium)	
PRODUCT PRICE break down																		
OEM Subass. Costs (Task 2, Ch. 5)	Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system	
Heat exchanger group	90		120		125		125		125		150		150		150		150	
El. controls group	50		80		90		90		100		100		100		100		100	
Burner group	20		20		25		25		25		25		25		25		25	
Fuel controls group	35		35		35		35		45		80		80		80		80	
CH-return group	40		55		60		82		82		110		110		110		110	
CH-supply group	10		10		10		10		10		10		10		10		10	
Fan group	30		35		35		35		50		50		50		50		50	
Casing	30		30		30		30		40		40		40		40		40	
Condensate collect	8		35		35		35		35		35		35		35		35	
Hot water group	21		21		21		21		21		21		21		21		21	
Packaging etc.	10		10		10		10		10		10		10		10		10	
Extra oil-fired (*0,11)	65		85		90		94		103		119		119		119		119	
Subtotal OEM		**409**		**536**		**566**		**592**		**646**		**750**		**750**		**750**		**750**
Labour		123		161		170		178		194		225		225		225		225
Overhead		286		375		396		414		452		525		525		525		525
total MSP		**818**		**1.072**		**1.132**		**1.184**		**1.291**		**1.501**		**1.501**		**1.501**		**1.501**
Ex wholesale		1.063		1.394		1.472		1.540		1.679		1.951		1.951		1.951		1.951
Ex installer excl. VAT		1.268		1.662		1.754		1.836		2.001		2.326		2.326		2.326		2.326
BOILER consumer street price incl. VAT		**1.509**		**1.978**		**2.088**		**2.184**		**2.382**		**2.768**		**2.768**		**2.768**		**2.768**
CONTROLLERS incl. VAT		0		0		55		55		55		55		55		55		55
INSTALLATION (Labour, materials, VAT)		1.215		1.215		1.240		1.240		1.300		1.300		1.300		1.300		1.300
subtotal Boiler (all in)		**2.724**		**3.194**		**3.383**		**3.480**		**3.737**		**4.123**		**4.123**		**4.123**		**4.123**
SOLAR materials incl. VAT		0		0		0		0		0		0		0		0		2.500
SOLAR installation incl. VAT		0		0		0		0		0		0		0		0		1.100
HEAT PUMP materials incl. VAT		0		0		0		0		0		0		1.950		3.000		0
HEAT PUMP installation incl. VAT		0		0		0		0		0		0		1.100		2.200		0
TOTAL PURCHASE		**2.724**		**3.194**		**3.383**		**3.480**		**3.737**		**4.123**		**7.173**		**9.323**		**7.723**
Country Rprice corrected		**2.724**		**3.194**		**3.383**		**3.480**		**3.737**		**4.123**		**7.173**		**9.323**		**7.723**

Table 2-4. Life Cycle Costs and Annual Expenditure PER UNIT for size category "M"

DESIGN OPTIONS	1	2	3	4	5	6	7	8	9
	4 -M (Medium)	4 -M (Medium)	4 -M (Medium)	4 -M (Medium)	4 -M (Medium)	4 -M (Medium)	4 -M (Medium)	4 -M (Medium)	4 -M (Medium)
LCC break down									
Product Price	€ 1.509	€ 1.978	€ 2.143	€ 2.239	€ 2.437	€ 2.823	€ 4.773	€ 5.823	€ 5.323
Installation	€ 1.215	€ 1.215	€ 1.240	€ 1.240	€ 1.300	€ 1.300	€ 2.400	€ 3.500	€ 2.400
Fuel energy (gas, oil)	€ 12.956	€ 11.517	€ 9.672	€ 9.672	€ 9.246	€ 8.964	€ 2.106	€ 1.366	€ 7.354
Electricity	€ 497	€ 494	€ 941	€ 352	€ 241	€ 73	€ 4.471	€ 3.597	€ 105
Repair & Maintenance	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573
TOTAL LCC	€ 18.750	€ 17.777	€ 16.569	€ 16.076	€ 15.797	€ 15.732	€ 16.323	€ 16.859	€ 17.755
Annual expenditure									
Product Price	€ 89	€ 116	€ 126	€ 132	€ 143	€ 166	€ 281	€ 343	€ 313
Installation	€ 71	€ 71	€ 73	€ 73	€ 76	€ 76	€ 141	€ 206	€ 141
Fuel energy (gas, oil)	€ 666	€ 595	€ 529	€ 496	€ 469	€ 445	€ 355	€ 269	€ 368
Electricity	€ 35	€ 35	€ 66	€ 25	€ 17	€ 5	€ 313	€ 252	€ 7
Repair & Maintenance	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180
TOTAL expenditure/a	€ 1.041	€ 997	€ 974	€ 905	€ 885	€ 873	€ 1.269	€ 1.249	€ 1.010
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 2.724	€ 3.194	€ 3.383	€ 3.480	€ 3.737	€ 4.123	€ 7.173	€ 9.323	€ 7.723
Lifetime Running costs (NPV)	€ 16.025	€ 14.584	€ 13.185	€ 12.597	€ 12.060	€ 11.609	€ 9.150	€ 7.536	€ 10.032
Life Cycle Costs LCC	€ 18.750	€ 17.777	€ 16.569	€ 16.076	€ 15.797	€ 15.732	€ 16.323	€ 16.859	€ 17.755
Simple Payback Period PBB	reference yrs	6,6 yrs	5,0 yrs	4,4 yrs	5,1 yrs	6,2 yrs	17,4 yrs	18,7 yrs	16,5 yrs

Table 2-5. Environmental Impact PER UNIT over lifetime for size category "M"

DESIGN OPTIONS		1		2		3		4		5		6		7		8		9	
		4 -M (Medium)		4 -M (Medium)		4 -M (Medium)		4 -M (Medium)		4 -M (Medium)		4 -M (Medium)		4 -M (Medium)		4 -M (Medium)		4 -M (Medium)	
ENVIRONMENTAL IMPACT PER UNIT OVER LIFE																			
MATERIALS		**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE
TOTAL	kg	**45,2**		**45,2**		**45,2**		**45,2**		**45,2**		**45,2**		**45,2**		**45,2**		**45,2**	
of which																			
Disposal	kg	**6,7**		**6,7**		**6,7**		**6,7**		**6,7**		**6,7**		**6,7**		**6,7**		**6,7**	
Recycled	kg	**38,5**		**38,5**		**38,5**		**38,5**		**38,5**		**38,5**		**38,5**		**38,5**		**38,5**	
OTHER RESOURCES																			
Total Energy (GER)	GJ	**831,1**	828,4	**743,5**	740,8	**668,7**	666,0	**620,3**	616,9	**585,5**	581,8	**556,3**	550,7	**509,0**	500,4	**387,2**	382,7	**465,4**	455,6
of which, electric(in primary	GJ	**42,0**	41,4	**41,8**	41,1	**78,9**	78,3	**30,0**	29,3	**20,8**	20,0	**7,2**	6,0	**373,8**	372,3	**300,5**	299,5	**10,6**	8,8
Water (process)	m3	**3,2**	2,8	**3,2**	2,7	**5,7**	5,2	**2,5**	2,0	**1,9**	1,3	**1,0**	0,4	**25,5**	24,8	**20,7**	20,0	**1,5**	0,6
Water (cooling)	m3	**110,8**	110,4	**110,1**	109,7	**209,2**	208,8	**78,6**	78,1	**53,9**	53,4	**16,9**	16,1	**993,9**	992,8	**799,5**	798,7	**25,0**	23,4
Waste, non-haz./ landfill	kg	**5,8**	1,0	**5,8**	0,9	**6,6**	1,8	**5,5**	0,7	**5,3**	0,5	**4,4**	0,1	**15,0**	8,6	**11,2**	6,9	**5,5**	0,2
Waste, hazardous/ incinera	kg	**119,3**	48,0	**119,0**	47,7	**162,1**	90,8	**132,8**	34,0	**135,9**	23,2	**140,4**	7,0	**628,7**	431,6	**466,4**	347,3	**244,4**	10,2
EMISSIONS TO AIR																			
GHG in GWP100	tCO2	**46,9**	46,8	**41,9**	41,8	**37,2**	37,0	**35,1**	34,8	**33,2**	33,0	**31,8**	31,4	**24,2**	23,6	**18,2**	17,8	**26,6**	25,9
AP Acidification	kgSOx	**29,3**	28,3	**27,3**	26,3	**34,4**	33,4	**22,0**	20,7	**19,2**	17,8	**15,4**	13,8	**101,0**	98,8	**80,5**	79,0	**15,0**	12,3
VOC Volatile Organic Com	kg	**0,6**	0,6	**0,5**	0,5	**0,5**	0,5	**0,5**	0,4	**0,4**	0,4	**0,4**	0,4	**0,3**	0,2	**0,2**	0,2	**0,4**	0,3
POP Persist.Organic Poll.	mg i-Teq	**1,0**	0,3	**1,0**	0,3	**1,2**	0,5	**1,2**	0,2	**1,3**	0,1	**2,0**	0,0	**5,4**	2,4	**3,5**	2,0	**3,6**	0,1
HMa Heavy Metals	mg Ni	**1,6**	0,8	**1,6**	0,8	**2,2**	1,4	**1,6**	0,6	**1,6**	0,4	**1,4**	0,2	**8,1**	6,4	**6,5**	5,2	**2,2**	0,2
PAHs	mg	**0,3**	0,2	**0,3**	0,2	**0,4**	0,2	**0,3**	0,1	**0,3**	0,1	**0,2**	0,1	**0,9**	0,8	**0,8**	0,6	**0,3**	0,1
PM Particulate Matter	kg	**2,4**	1,4	**2,4**	1,4	**2,6**	1,5	**2,6**	1,3	**2,5**	1,2	**5,0**	1,1	**10,2**	3,0	**4,6**	2,6	**8,7**	1,1
EMISSIONS TO WATER																			
HMw Heavy Metals	g Hg/20	**0,9**	0,3	**0,9**	0,3	**1,1**	0,5	**0,9**	0,2	**0,9**	0,1	**0,7**	0,0	**3,3**	2,4	**2,8**	1,9	**1,2**	0,1
EP Eutrophication	g PO4	**13,0**	1,3	**13,0**	1,3	**14,1**	2,4	**15,3**	0,9	**16,4**	0,6	**17,1**	0,2	**34,4**	11,4	**30,3**	9,2	**30,5**	0,3
ANNUAL SPACE HEAT ENERGY breakdown																			
TOTAL	kWh/a	**13827**	100%	**12352**	100%	**10987**	100%	**10300**	100%	**9735**	100%	**9251**	100%	**7368**	100%	**5591**	100%	**7642**	100%
Tset	kWh/a	**6056**	44%	**6056**	49%	**6056**	55%	**6056**	59%	**6056**	62%	**6056**	65%	**6056**	82%	**6056**	108%	**6056**	79%
Tmass	kWh/a	**1106**	8%	**1106**	9%	**1245**	11%	**1245**	12%	**1245**	13%	**1245**	13%	**1245**	17%	**1245**	22%	**1245**	16%
Tintrans	kWh/a	**318**	2%	**318**	3%	**307**	3%	**307**	3%	**307**	3%	**307**	3%	**307**	4%	**307**	5%	**307**	4%
Tfluct (cntrl)	kWh/a	**992**	7%	**992**	8%	**546**	5%	**546**	5%	**290**	3%	**238**	3%	**238**	3%	**238**	4%	**238**	3%
Tstrat(emit)	kWh/a	**629**	5%	**645**	5%	**518**	5%	**518**	5%	**489**	5%	**469**	5%	**469**	6%	**469**	8%	**469**	6%
Distr. loss	kWh/a	**1131**	8%	**1133**	9%	**591**	5%	**591**	6%	**585**	6%	**587**	6%	**587**	8%	**587**	11%	**587**	8%
Steady st.	kWh/a	**2633**	19%	**1142**	9%	**384**	3%	**384**	4%	**336**	3%	**189**	2%	**47**	1%	**32**	1%	**155**	2%
Start/stop	kWh/a	**44**	0%	**45**	0%	**110**	1%	**110**	1%	**88**	1%	**35**	0%	**1**	0%	**0**	0%	**19**	0%
Stby heat	kWh/a	**338**	2%	**340**	3%	**133**	1%	**133**	1%	**59**	1%	**40**	0%	**10**	0%	**7**	0%	**33**	0%
Electric	kWh/a	**580**	4%	**576**	5%	**1097**	10%	**410**	4%	**281**	3%	**85**	1%	**84**	1%	**84**	2%	**85**	1%
Credit solar	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**1551**	0%
Credit HP	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**1677**	0%	**3434**	0%	**0**	0%
Net heating efficiency	%	**54%**		**61%**		**69%**		**74%**		**78%**		**82%**		**103%**		**136%**		**100%**	
gross heat load	kWh/a	**8.929**		**8.960**		**9.107**		**9.107**		**9.107**		**9.142**		**9.142**		**9.142**		**9.142**	
net heat load	kWh/a	**7.480**		**7.480**		**7.608**		**7.608**		**7.608**		**7.608**		**7.608**		**7.608**		**7.608**	
net load per unit floor area	kWh/m2	**160**		**143**		**127**		**119**		**113**		**107**		**85**		**65**		**89**	
CH system efficiency	%	**62%**		**70%**		**80%**		**85%**		**90%**		**95%**		**119%**		**156%**		**114%**	

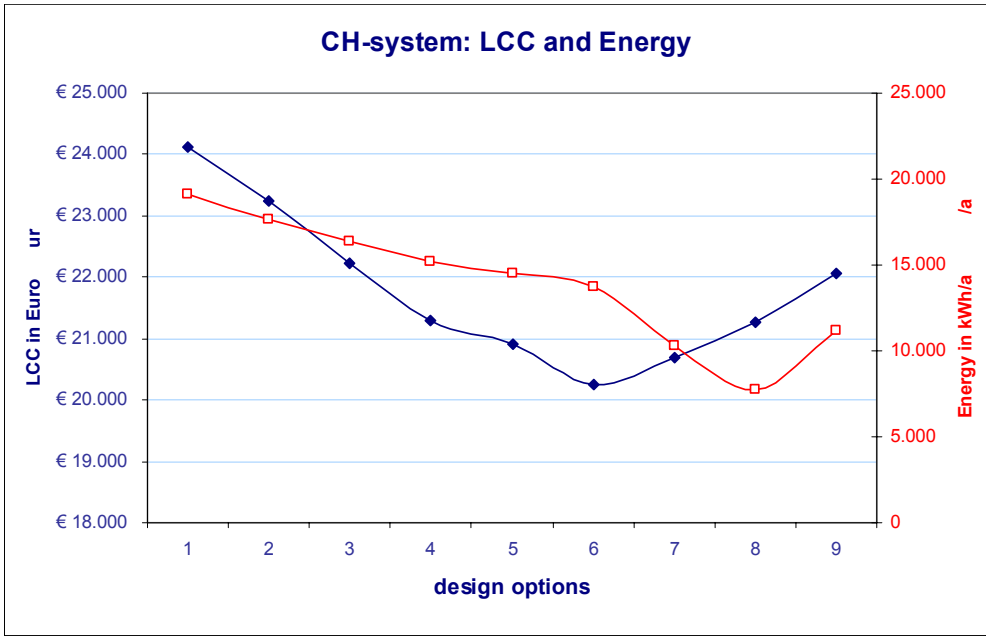
2.2 Design options and Impact size category “L” (Large)

The following design options have been elaborated for this size class “L” (Large).

Explanation design options

1. Reference (see first column table 2-7).
2. Improvement steady-state efficiency from 80/80 to **87/95** and the application of a **weather controlled boiler thermostat** instead of the on/off RT.
3. Improvement steady-state efficiency to **89/97**, the use of **1K TRV’s** (which in fact is a hydraulic balancing of the system).
4. Option 3, extended with energy **class “B” variable speed pump**, and an **electronic optimiser**.
5. Option 4, extended with **motorized valves with PID** loop (instead of 1k TRV), a not over dimensioned **high efficient fan**, and a reduction of the **standby heat loss to 0,5%**.
6. Option 5, extended with an improved **turndown ratio of 10%**.
7. Option 6, extended with a **tertiary heat exchanger**, and ionisation based **lambda control** system, **CPU controlled motor valves** and an a control system for **automatic optimisation of the boiler feed temperature**, also extended with a **3 kW electric air/water heat pump** with a nominal COP of **2,5** (at 7/50); (CH fraction served = 100%).
8. Option 7, but here the air/water heat pump is replaced by a **3 kW electric brine/water heat pump** with a nominal COP of **3,1** (at 0/50° C); (CH fraction served = 100%).
9. Option 7, but here the air/water heat pump is replaced by a **5 m² vacutube type solar collector** (CH fraction served = 100%).

Figure 2-6.
Design options, lifecycle costs and annual energy consumption category "L"



The average annual primary energy consumption for the BaseCase "L" sized boilers amounts to 19.095 kWh (net heating efficiency is 55%), with a total lifecycle costs of €24.119,-

This annual primary energy consumption can be reduced with approximately 5400 kWh (= **28%**) to 13.686 kWh with the existing and proven technology that is selected for Design Option 6. The net heating efficiency with this option is improved to **78%**. The related lifecycle costs are reduced to € 20.259,-.

With Design Option nr. 7, the net heating efficiency is further improved to 104% (annual primary energy consumption: 10.318 kWh), with similar lifecycle costs. The technology of the tertiary heat exchanger used in this design option - and to a lesser extend the control system for automatic optimisation of the boiler feed temperature - are not fully matured yet. For this reason we propose to use an **LLCC target** that is related to design option 6 and corresponds with a net efficiency of **78%.**

The BAT level is best represented with Design Option 8, that combines a state-of the art condensing boiler (incl. tertiary HE) with a 3 kW brine-to-water heat pump with a nominal COP of 3,1 (at 0/50° C). With this option the net heating efficiency rises to 137% giving a annual primary energy consumption of 7.789 kWh. **BAT level is therefore set at 130-140%.** Related lifecycle costs are € 21.262,- and as such lower than the basecase lifecycle costs, and around € 1000,- higher than the LLCC-level.

Please note that BAT-levels can be further increased to net heating efficiency levels above 160% when water-to-water heat pumps are used.

Design Options nr. 9 combines a state-of-the-art condensing boiler with 5 m^2 vacutube solar collectors, resulting in net heating efficiencies of around 96% with lifecycle costs of around € 22.000,-

The impact of the Design Options are summarized in the tables on the next four pages:

Table 2-7: Input Design Options in EcoBoiler Integrated Model for size category "L"

Table 2-8: Prices and Installation costs PER UNIT for Design Options size category "L"

Table 2-9: Life Cycle Costs and Annual Expenditure PER UNIT for size category "L"

Table 2-10: Environmental Impact PER UNIT over lifetime for size category "L"

Table 2-7. Input Design Options in EcoBoiler Integrated Model for size category "L"

DESIGN OPTIONS	1 BaseCase	2	3	4	5	6	7	8	9
INPUTS CH									
CH-power class	5 -L (Large)	5 -L (Large)	5 -L (Large)	5 -L (Large)	5 -L (Large)	5 -L (Large)	5 -L (Large)	5 -L (Large)	5 -L (Large)
	3 -house existing	*3 -house existing*	*3 -house existing*	*3 -house existing*	*3 -house existing*	*3 -house existing*	*3 -house existing*	*3 -house existing*	*3 -house existing*
boiler characteristics									
power input in kW*	29 kW	29 kW	29 kW	29 kW	29 kW	29 kW	29 kW	29 kW	29 kW
turndown ratio	33%	33%	33%	33%	33%	10%	10%	10%	10%
standby heat loss (% of Pnom)	1,0%	1,0%	1,0%	1,0%	0,5%	0,5%	0,5%	0,5%	0,5%
steady st. efficiency %	5 -80/80/80/80	2 -87/87/95/95	1 -89/89/97/97	1 -89/89/97/97	1 -89/89/97/97	1 -89/89/97/97	9 -ideal 96/96/97/97	9 -ideal 96/96/97/97	9 -ideal 96/96/97/97
fuel (dewpoint)	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas
air-fuel mix control	2-pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	3 -ionisation	3 -ionisation	3 -ionisation
circ. pump power	6 -95W	6 -95W	6 -95W	3 -25..(45)..65 W	3 -25..(45)..65 W	3 -25..(45)..65 W	3 -25..(45)..65 W	3 -25..(45)..65 W	3 -25..(45)..65 W
fan power	3 -P=9..40W	3 -P=9..40W	3 -P=9..40W	3 -P=9..40W	2 -P=6..30W	2 -P=6..30W	2 -P=6..30W	2 -P=6..30W	2 -P=6..30W
CPU power sb/on	4 -P=10/12W	4 -P=10/12W	4 -P=10/12W	4 -P=10/12W	4 -P=10/12W	4 -P=10/12W	1 -P=2/3W	1 -P=2/3W	1 -P=2/3W
controls power sb/on	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W
comb. air intake	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed
boiler mass (empty), kg	51 kg	51 kg	51 kg	51 kg	51 kg	51 kg	51 kg	51 kg	51 kg
water content in kg	6,0 kg	6,0 kg	6,0 kg	6,0 kg	6,0 kg	6,0 kg	6,0 kg	6,0 kg	6,0 kg
envelope volume in m3	0,17 m3	0,17 m3	0,17 m3	0,17 m3	0,17 m3	0,17 m3	0,17 m3	0,17 m3	0,17 m3
noise level in dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A
controllers									
auto-timer control	yes	yes	yes	yes	yes	yes	yes	yes	yes
valve control	2 -RTV 2K	2 -RTV 2K	3 -RTV 1K	3 -RTV 1K	4 -Motor + PID-loop	4 -Motor + PID-loop	5 -Motor + CPU	5 -Motor + CPU	5 -Motor + CPU
boiler temp control	6 -on/off RT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT
electronic optimiser	no	no	no	yes	yes	yes	yes	yes	yes
autoset weather control	N/A	N/A	no	N/A	N/A	N/A	yes	yes	yes
solar (for combi only)									
collector type	N/A	1 -glazed	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube
collector surface m2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	5,0
tank position	N/A	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors
CH-fraction served	0%	100%	0%	0%	0%	0%	0%	0%	100%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
heat pump (HP)									
Reference type	1 -El. brine/ water 0/5	3 -El. air/ water 7/5(	3 -El. air/ water 7/50	3 -El. air/ water 7/5(	3 -El. air/ water 7/5(	3 -El. air/ water 7/50	3 -El. air/ water 7/50	1 -El. brine/ water 0/50	2 -El. water/ water 10/5(
Power nominal in kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	3,0 kW	3,0 kW	0,0 kW
COP nominal 0/50	0,00	0,00	0,00	2,50	0,00	3,50	2,50	3,10	3,80
Ratio CH : DHW	100%	80%	80%	80%	80%	80%	80%	80%	80%
CH-fraction served	100%	0%	100%	100%	100%	50%	100%	100%	0%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
MAIN ENERGY OUTPUTS									
Net heating efficiency	55%	60%	64%	70%	74%	78%	104%	137%	96%
Primary energy consumption	19095 kWh/a	17611 kWh/a	16379 kWh/a	15208 kWh/a	14480 kWh/a	13686 kWh/a	10318 kWh/a	7789 kWh/a	11139 kWh/a
-of which fuel (primary kWh GCV)	18490 kWh/a	16310 kWh/a	15075 kWh/a	14702 kWh/a	13986 kWh/a	13243 kWh/a	2442 kWh/a	1433 kWh/a	10766 kWh/a
-of which electricity (primary kWh)	605 kWh/a	1.301 kWh/a	1.304 kWh/a	506 kWh/a	495 kWh/a	443 kWh/a	7.876 kWh/a	6.356 kWh/a	374 kWh/a
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 2.945	€ 3.614	€ 3.790	€ 3.911	€ 4.246	€ 4.355	€ 8.988	€ 11.838	€ 8.638
Lifetime Running costs (NPV)	€ 21.174	€ 19.639	€ 18.434	€ 17.385	€ 16.674	€ 15.904	€ 11.715	€ 9.424	€ 13.422
Life Cycle Costs LCC	€ 24.119	€ 23.253	€ 22.224	€ 21.296	€ 20.920	€ 20.259	€ 20.703	€ 21.262	€ 22.060
Simple Payback Period PBB	reference yrs	10,6 yrs	6,9 yrs	5,1 yrs	5,8 yrs	5,4 yrs	18,0 yrs	18,7 yrs	14,8 yrs

Table 2-8. Prices and Installati9on costs per unit for Design Options size category "L"

DESIGN OPTIONS	1		2		3		4		5		6		7		8		9	
	5 -L (Large)		5 -L (Large)		5 -L (Large)		5 -L (Large)		5 -L (Large)		5 -L (Large)		5 -L (Large)		5 -L (Large)		5 -L (Large)	
PRODUCT PRICE break down																		
OEM Subass. Costs (Task 2, Ch. 5)	Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system	
Heat exchanger group	104		138		144		144		144		144		173		173		173	
El. controls group	50		80		90		90		90		90		100		100		100	
Burner group	23		23		29		29		29		29		29		29		29	
Fuel controls group	35		35		35		35		35		60		80		80		80	
CH-return group	40		55		60		82		82		82		82		82		82	
CH-supply group	10		10		10		10		10		10		10		10		10	
Fan group	30		35		35		35		45		45		45		45		45	
Casing	35		35		35		35		46		46		46		46		46	
Condensate collect	8		35		35		35		35		35		35		35		35	
Hot water group	21		21		21		21		21		21		21		21		21	
Packaging etc.	12		12		12		12		12		12		12		12		12	
Extra oil-fired (*0,11)	69		90		95		100		104		108		119		119		119	
Subtotal OEM		**436**		**568**		**600**		**626**		**652**		**681**		**751**		**751**		**751**
Labour		131		171		180		188		195		204		225		225		225
Overhead		305		398		420		438		456		477		526		526		526
total MSP		**872**		**1.137**		**1.200**		**1.252**		**1.303**		**1.363**		**1.502**		**1.502**		**1.502**
Ex wholesale		1.133		1.478		1.560		1.628		1.694		1.771		1.953		1.953		1.953
Ex installer excl. VAT		1.351		1.762		1.860		1.941		2.020		2.112		2.329		2.329		2.329
BOILER consumer street price incl. VAT		**1.608**		**2.097**		**2.213**		**2.309**		**2.404**		**2.513**		**2.771**		**2.771**		**2.771**
CONTROLLERS incl. VAT		0		100		100		125		365		365		715		715		715
INSTALLATION (Labour, materials, VAT)		1.337		1.417		1.477		1.477		1.477		1.477		1.552		1.552		1.552
subtotal Boiler (all in)		**2.945**		**3.614**		**3.790**		**3.911**		**4.246**		**4.355**		**5.038**		**5.038**		**5.038**
SOLAR materials incl. VAT		0		0		0		0		0		0		0		0		2.500
SOLAR installation incl. VAT		0		0		0		0		0		0		0		0		1.100
HEAT PUMP materials incl. VAT		0		0		0		0		0		0		2.550		4.000		0
HEAT PUMP installation incl. VAT		0		0		0		0		0		0		1.400		2.800		0
TOTAL PURCHASE		**2.945**		**3.614**		**3.790**		**3.911**		**4.246**		**4.355**		**8.988**		**11.838**		**8.638**
Country Rprice corrected		**2.945**		**3.614**		**3.790**		**3.911**		**4.246**		**4.355**		**8.988**		**11.838**		**8.638**

Table 2-9. Life Cycle Costs and Annual Expenditure PER UNIT for size category "L"

DESIGN OPTIONS	1	2	3	4	5	6	7	8	9
	5 -L (Large)	5 -L (Large)	5 -L (Large)	5 -L (Large)	5 -L (Large)	5 -L (Large)	5 -L (Large)	5 -L (Large)	5 -L (Large)
LCC break down									
Product Price	€ 1.608	€ 2.197	€ 2.313	€ 2.434	€ 2.769	€ 2.878	€ 6.036	€ 7.486	€ 5.986
Installation	€ 1.337	€ 1.417	€ 1.477	€ 1.477	€ 1.477	€ 1.477	€ 2.952	€ 4.352	€ 2.652
Fuel energy (gas, oil)	€ 18.083	€ 15.951	€ 14.743	€ 14.379	€ 13.678	€ 12.952	€ 2.388	€ 1.402	€ 10.529
Electricity	€ 519	€ 1.116	€ 1.118	€ 433	€ 424	€ 380	€ 6.754	€ 5.450	€ 321
Repair & Maintenance	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573
TOTAL LCC	€ 24.119	€ 23.253	€ 22.224	€ 21.296	€ 20.920	€ 20.259	€ 20.703	€ 21.262	€ 22.060
Annual expenditure									
Product Price	€ 95	€ 129	€ 136	€ 143	€ 163	€ 169	€ 355	€ 440	€ 352
Installation	€ 79	€ 83	€ 87	€ 87	€ 87	€ 87	€ 174	€ 256	€ 156
Fuel energy (gas, oil)	€ 919	€ 848	€ 788	€ 732	€ 697	€ 659	€ 497	€ 375	€ 536
Electricity	€ 36	€ 78	€ 78	€ 30	€ 30	€ 27	€ 473	€ 381	€ 22
Repair & Maintenance	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180
TOTAL expenditure/a	€ 1.309	€ 1.318	€ 1.270	€ 1.172	€ 1.156	€ 1.122	€ 1.678	€ 1.633	€ 1.247

MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 2.945	€ 3.614	€ 3.790	€ 3.911	€ 4.246	€ 4.355	€ 8.988	€ 11.838	€ 8.638
Lifetime Running costs (NPV)	€ 21.174	€ 19.639	€ 18.434	€ 17.385	€ 16.674	€ 15.904	€ 11.715	€ 9.424	€ 13.422
Life Cycle Costs LCC	€ 24.119	€ 23.253	€ 22.224	€ 21.296	€ 20.920	€ 20.259	€ 20.703	€ 21.262	€ 22.060
Simple Payback Period PBB	reference yrs	10,6 yrs	6,9 yrs	5,1 yrs	5,8 yrs	5,4 yrs	18,0 yrs	18,7 yrs	14,8 yrs

Table 2-10. Environmental Impact PER UNIT over lifetime for size category "L"

DESIGN OPTIONS		1		2		3		4		5		6		7		8		9	
		5 -L (Large)		5 -L (Large)		5 -L (Large)		5 -L (Large)		5 -L (Large)		5 -L (Large)		5 -L (Large)		5 -L (Large)		5 -L (Large)	
ENVIRONMENTAL IMPACT PER UNIT OVER LIFE																			
MATERIALS		**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE
TOTAL	kg	**50,7**		**50,7**		**50,7**		**50,7**		**50,7**		**50,7**		**50,7**		**50,7**		**50,7**	
of which																			
Disposal	kg	**7,0**		**7,0**		**7,0**		**7,0**		**7,0**		**7,0**		**7,0**		**7,0**		**7,0**	
Recycled	kg	**43,8**		**43,8**		**43,8**		**43,8**		**43,8**		**43,8**		**43,8**		**43,8**		**43,8**	
OTHER RESOURCES																			
Total Energy (GER)	GJ	**1144,3**	1141,6	**1064,5**	1061,8	**991,4**	988,7	**912,9**	909,5	**869,9**	866,2	**824,1**	818,4	**716,2**	707,6	**543,7**	539,2	**676,2**	666,3
of which, electric(in primary	GJ	**43,8**	43,2	**93,5**	92,9	**93,7**	93,1	**36,8**	36,1	**36,1**	35,3	**32,7**	31,6	**563,9**	562,3	**454,8**	453,8	**28,5**	26,7
Water (process)	m3	**3,3**	2,9	**6,7**	6,2	**6,7**	6,2	**2,9**	2,4	**2,9**	2,4	**2,7**	2,1	**38,2**	37,5	**31,0**	30,3	**2,7**	1,8
Water (cooling)	m3	**115,6**	115,2	**248,2**	247,8	**248,6**	248,2	**96,7**	96,3	**94,7**	94,2	**85,0**	84,3	**1500,7**	1499,5	**1210,9**	1210,1	**72,8**	71,2
Waste, non-haz./ landfill	kg	**5,8**	1,0	**7,0**	2,1	**7,0**	2,1	**5,7**	0,8	**5,6**	0,8	**5,0**	0,7	**19,4**	13,0	**14,8**	10,5	**5,9**	0,6
Waste, hazardous/ incinera	kg	**121,4**	50,1	**179,1**	107,7	**179,3**	107,9	**140,7**	41,9	**153,6**	41,0	**170,0**	36,6	**849,0**	652,0	**645,3**	526,1	**265,2**	31,0
EMISSIONS TO AIR																			
GHG in GWP100	tCO2	**64,8**	64,6	**59,6**	59,4	**55,4**	55,2	**51,7**	51,5	**49,3**	49,0	**46,7**	46,3	**33,5**	32,8	**25,0**	24,7	**38,4**	37,7
AP Acidification	kgSOx	**36,8**	35,8	**46,7**	45,7	**45,1**	44,1	**30,2**	28,9	**29,1**	27,7	**27,4**	25,8	**150,4**	148,1	**120,3**	118,8	**23,9**	21,2
VOC Volatile Organic Com	kg	**0,8**	0,8	**0,8**	0,8	**0,7**	0,7	**0,7**	0,7	**0,6**	0,6	**0,6**	0,6	**0,4**	0,3	**0,3**	0,2	**0,6**	0,5
POP Persist.Organic Poll.	mg i-Teq	**1,0**	0,3	**1,3**	0,6	**1,3**	0,6	**1,2**	0,2	**1,4**	0,2	**2,2**	0,2	**6,7**	3,7	**4,5**	3,0	**3,7**	0,2
HMa Heavy Metals	mg Ni	**1,6**	0,8	**2,5**	1,6	**2,5**	1,6	**1,8**	0,7	**1,9**	0,7	**1,8**	0,6	**11,4**	9,7	**9,2**	7,8	**2,5**	0,5
PAHs	mg	**0,3**	0,2	**0,4**	0,3	**0,4**	0,3	**0,3**	0,1	**0,3**	0,1	**0,2**	0,1	**1,3**	1,2	**1,1**	0,9	**0,3**	0,1
PM Particulate Matter	kg	**2,5**	1,5	**2,8**	1,8	**2,8**	1,7	**2,7**	1,4	**2,7**	1,4	**5,2**	1,4	**11,2**	4,0	**5,4**	3,4	**8,8**	1,3
EMISSIONS TO WATER																			
HMw Heavy Metals	g Hg/20	**0,9**	0,3	**1,2**	0,6	**1,2**	0,6	**1,0**	0,2	**1,0**	0,2	**0,9**	0,2	**4,5**	3,6	**3,8**	2,9	**1,3**	0,2
EP Eutrophication	g PO4	**13,0**	1,3	**14,6**	2,9	**14,6**	2,9	**15,5**	1,1	**16,9**	1,1	**17,9**	1,0	**40,2**	17,3	**35,1**	14,0	**31,0**	0,8
ANNUAL SPACE HEAT ENERGY breakdown																			
TOTAL	kWh/a	**19095**	100%	**17611**	100%	**16379**	100%	**15208**	100%	**14480**	100%	**13686**	100%	**10318**	100%	**7789**	100%	**11139**	100%
Tset	kWh/a	**8660**	45%	**8660**	49%	**8660**	53%	**8660**	57%	**8660**	60%	**8660**	63%	**8660**	84%	**8660**	111%	**8660**	78%
Tmass	kWh/a	**1454**	8%	**1454**	8%	**1454**	9%	**1651**	11%	**1651**	11%	**1651**	12%	**1651**	16%	**1651**	21%	**1651**	15%
Tintrans	kWh/a	**401**	2%	**371**	2%	**371**	2%	**386**	3%	**386**	3%	**386**	3%	**386**	4%	**386**	5%	**386**	3%
Tfluct (cntrl)	kWh/a	**1359**	7%	**1359**	8%	**673**	4%	**670**	4%	**288**	2%	**205**	1%	**77**	1%	**77**	1%	**77**	1%
Tstrat(emit)	kWh/a	**918**	5%	**720**	4%	**713**	4%	**715**	5%	**711**	5%	**643**	5%	**642**	6%	**642**	8%	**642**	6%
Distr. loss	kWh/a	**1474**	8%	**1463**	8%	**1447**	9%	**1368**	9%	**1358**	9%	**1049**	8%	**774**	7%	**774**	10%	**774**	7%
Steady st.	kWh/a	**3674**	19%	**1593**	9%	**1071**	7%	**584**	4%	**506**	3%	**452**	3%	**50**	0%	**29**	0%	**217**	2%
Start/stop	kWh/a	**51**	0%	**105**	1%	**99**	1%	**100**	1%	**89**	1%	**47**	0%	**6**	0%	**3**	0%	**26**	0%
Stby heat	kWh/a	**499**	3%	**584**	3%	**587**	4%	**568**	4%	**337**	2%	**151**	1%	**14**	0%	**8**	0%	**59**	1%
Electric	kWh/a	**605**	3%	**1301**	7%	**1304**	8%	**506**	3%	**495**	3%	**443**	3%	**334**	3%	**334**	4%	**334**	3%
Credit solar	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**1687**	0%
Credit HP	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**2275**	0%	**4776**	0%	**0**	0%
Net heating efficiency	%	**55%**		**60%**		**64%**		**70%**		**74%**		**78%**		**104%**		**137%**		**96%**	
gross heat load	kWh/a	**12.292**		**12.302**		**12.314**		**12.533**		**12.533**		**12.533**		**12.579**		**12.579**		**12.579**	
net heat load	kWh/a	**10.515**		**10.486**		**10.486**		**10.697**		**10.697**		**10.697**		**10.697**		**10.697**		**10.697**	
net load per unit floor area	kWh/m2	**180**		**166**		**154**		**143**		**136**		**129**		**97**		**73**		**105**	
CH-system efficiency	%	**63%**		**68%**		**74%**		**81%**		**85%**		**90%**		**119%**		**158%**		**110%**	

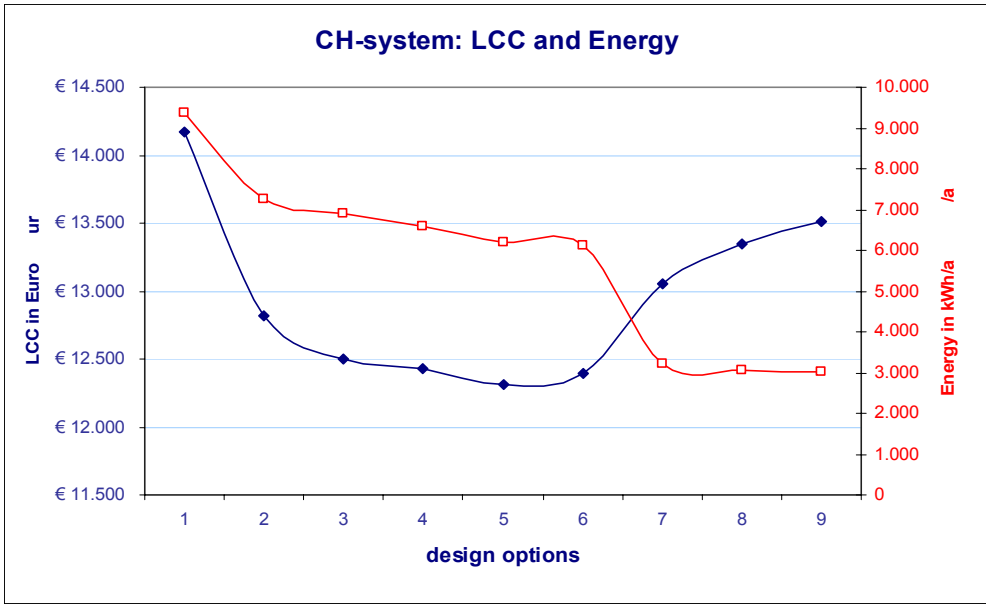
2.3 Design Options and Impact size category ”S” (Small)

The following design options have been elaborated for this size class “S” (Small).

Explanation design options

1. Reference (see first column table 2-12)
2. Improvement of **turndown ratio to 10%**, reduced **standby heat loss to 0,5%**, steady-state efficiency from 80/80 to **84/84**, in combination with **energy class “A” pump**, **high efficient fan** (3-18 watt), a **low stand by power for the CPU** (2/3 watts), **time-proportional room thermostat** with **electronic optimiser**.
3. Improvement steady-state efficiency to **89/97**, in combination with an **energy class “B” pump**, the **reference fan** (9 – 40 watts) and **reference CPU** and a **modulating room thermostat** with **electronic optimiser**.
4. Option 3, extended with energy **class “A” variable speed pump**, **low power fan** and a **CPU with low standby power** losses (2/3 watts).
5. Option 4, extended with an improved **turndown ratio of 10%**, application of **1k TRV’s** , a reduction of the **standby heat loss to 0,5%** .
6. Option 5, extended with a **tertiary heat exchanger** with an ionisation based **lambda control.**
7. Option **2**, extended with a **1,5 kW electric water-to-water heat pump** (collective system in case of apartment blocks), with a nominal **COP 0f 3,7** (at 10/50° C) and a CH fraction served of 100%).
8. Option **5**, extended with a **1,5 kW electric water-to-water heat pump** (collective system in case of apartment blocks), with a nominal **COP 0f 3,7** (at 10/50° C) and a CH fraction served of 100%).
9. Option **6**, extended with a **1,5 kW electric water-to-water heat pump** (collective system in case of apartment blocks), with a nominal **COP 0f 3,7** (at 10/50° C) and a CH fraction served of 100%).

Figure 2-11.
Design options, lifecycle costs and annual energy consumption category "S"



The average annual primary energy consumption for the BaseCase “S” sized boilers amounts to 9.368 kWh (net heating efficiency is 52%), with a total lifecycle costs of €14.172,-

This annual primary energy consumption can be reduced with approximately 3154 kWh (= **34%**) to 6.214 kWh with the existing and proven technology that is selected for Design Option 5. The net heating efficiency with this option is improved to 79%. The related lifecycle costs are reduced to € 12.313,-.

With Design Option nr. 6, the net heating efficiency is further improved to 81% (annual primary energy consumption: 6.109 kWh), with slightly higher lifecycle costs. The technology of the tertiary heat exchanger used in this design option is not fully matured yet. For this reason we propose to use an **LLCC target** that is related to design option 5 and corresponds with a net efficiency of **79%.**

The BAT level is best represented with Design Option 9, that combines a state-of the art condensing boiler (incl. tertiary he) with a 1,5 kW water to water heat pump with a nominal COP of 3,7 (at 10/50° C). With this option the net heating efficiency rises to 163% giving a annual primary energy consumption of 3024 kWh. **BAT level is therefore set at 160-170%.** Related lifecycle costs are € 13.512,- and as such lower than the basecase lifecycle costs, and only around € 1200,- higher than the LLCC-level.

Because this size category "S" is typical for existing apartments, design options 2 and 7 were elaborated. These two options explore the energy savings that can be achieved with state-of-the art LT boilers, mainly because this type of boiler could prevent the complex and expensive chimney renovation that often is necessary when non-condensing boilers are replaced by condensing boilers. The tables on the next pages show that a state-of-the art LT boiler - combined with a time proportional RT with optimiser - could improve the net heating efficiency from 52% to 68%. Combining the individual state-of-the-art LT-boilers with for example a collective water-to-water delivering 1,5 kW of heat per apartment, could boost the net heating efficiency to around 150%. Combined with state-of-the-art condensing boilers net heating efficiency rises to the earlier mentioned BAT-level of 163%

The impact of the Design Options are summarized in the tables on the next four pages:

Table 2-12: Input Design Options in EcoBoiler Integrated Model for size category "S"

Table 2-13: Prices and Installation costs PER UNIT for Design Options size category "S"

Table 2-14: Life Cycle Costs and Annual Expenditure PER UNIT for size category "S"

Table 2-15: Environmental Impact PER UNIT over lifetime for size category "S"

Table 2-12. Input Design Options in EcoBoiler Integrated Model for size category "S"

DESIGN OPTIONS	1 BaseCase	2	3	4	5	6	7	8	9
INPUTS CH									
CH-power class	3 -S (Small)	3 -S (Small)	3 -S (Small)	3 -S (Small)	3 -S (Small)	3 -S (Small)	3 -S (Small)	3 -S (Small)	3 -S (Small)
	5 -apartment existing	*5 -apartment existing*	*5 -apartment existing*	*5 -apartment existing*	*5 -apartment existing*	*5 -apartment existing*	*5 -apartment existing*	*5 -apartment existing*	*5 -apartment existing*
boiler characteristics									
power input in kW*	19 kW	19 kW	19 kW	19 kW	19 kW	19 kW	19 kW	19 kW	19 kW
turndown ratio	33%	10%	33%	33%	10%	10%	10%	10%	10%
standby heat loss (% of Pnom)	1,0%	0,5%	1,0%	1,0%	0,5%	0,5%	0,5%	0,5%	0,5%
steady st. efficiency %	5 -80/80/80/80	4 -84/84/84/84	1 -89/89/97/97	1 -89/89/97/97	1 -89/89/97/97	9 -ideal 96/96/97/97	4 -84/84/84/84	1 -89/89/97/97	9 -ideal 96/96/97/97
fuel (dewpoint)	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas
air-fuel mix control	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	3 -ionisation	2 -pneumatic	2 -pneumatic	3 -ionisation
circ. pump power	6 -95W	1 -5..(15)..25W + sb	3 -25..(45)..65 W	1 -5..(15)..25W + sb	1 -5..(15)..25W + sb	1 -5..(15)..25W + sb	1 -5..(15)..25W + sb	1 -5..(15)..25W + sb	1 -5..(15)..25W + sb
fan power	3 -P=9..40W	1 -P=3..18W	3 -P=9..40W	1 -P=3..18W	1 -P=3..18W	1 -P=3..18W	1 -P=3..18W	1 -P=3..18W	1 -P=3..18W
CPU power sb/on	4 -P=10/12W	1 -P=2/3W	4 -P=10/12W	1 -P=2/3W	1 -P=2/3W	1 -P=2/3W	1 -P=2/3W	1 -P=2/3W	1 -P=2/3W
controls power sb/on	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W
comb. air intake	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed
boiler mass (empty), kg	34 kg	34 kg	34 kg	34 kg	34 kg	34 kg	34 kg	34 kg	34 kg
water content in kg	2,0 kg	2,0 kg	2,0 kg	2,0 kg	2,0 kg	2,0 kg	2,0 kg	2,0 kg	2,0 kg
envelope volume in m3	0,12 m3	0,12 m3	0,12 m3	0,12 m3	0,12 m3	0,12 m3	0,12 m3	0,12 m3	0,12 m3
noise level in dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A
controllers									
auto-timer control	yes	yes	yes	yes	yes	yes	yes	yes	yes
valve control	2 -RTV 2K	3 -RTV 1K	2 -RTV 2K	2 -RTV 2K	3 -RTV 1K	3 -RTV 1K	3 -RTV 1K	3 -RTV 1K	3 -RTV 1K
boiler temp control	6 -on/off RT	8 -time-prop. RT	7 -modulating RT	7 -modulating RT	7 -modulating RT	7 -modulating RT	8 -time-prop. RT	7 -modulating RT	7 -modulating RT
electronic optimiser	no	yes	yes	yes	yes	yes	yes	yes	yes
autoset weather control	N/A	N/A	no	N/A	N/A	N/A	no	no	no
solar (for combi only)									
collector type	N/A	1 -glazed	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube
collector surface m2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
tank position	N/A	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors
CH-fraction served	0%	100%	0%	0%	0%	0%	0%	0%	0%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
heat pump (HP)									
Reference type	1 -El. brine/ water 0/5	3 -El. air/ water 7/5(	3 -El. air/ water 7/50	3 -El. air/ water 7/5(	3 -El. air/ water 7/5(	3 -El. air/ water 7/50	2 -El. water/ water 10/5(	2 -El. water/ water 10/5(	2 -El. water/ water 10/5(
Power nominal in kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	1,5 kW	1,5 kW	1,5 kW
COP nominal 0/50	0,00	0,00	0,00	2,50	0,00	3,50	3,70	3,70	3,70
Ratio CH : DHW	100%	80%	80%	80%	80%	80%	80%	80%	80%
CH-fraction served	100%	0%	100%	100%	100%	50%	100%	100%	100%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
MAIN ENERGY OUTPUTS									
Net heating efficiency	52%	68%	71%	75%	79%	81%	152%	162%	163%
Primary energy consumption	9368 kWh/a	7258 kWh/a	6894 kWh/a	6570 kWh/a	6214 kWh/a	6109 kWh/a	3234 kWh/a	3040 kWh/a	3024 kWh/a
-of which fuel (primary kWh GCV)	8814 kWh/a	7131 kWh/a	6495 kWh/a	6495 kWh/a	6136 kWh/a	6033 kWh/a	958 kWh/a	783 kWh/a	768 kWh/a
-of which electricity (primary kWh)	555 kWh/a	127 kWh/a	398 kWh/a	75 kWh/a	78 kWh/a	76 kWh/a	2.276 kWh/a	2.257 kWh/a	2.257 kWh/a
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 2.504	€ 3.159	€ 3.233	€ 3.444	€ 3.673	€ 3.854	€ 7.596	€ 8.073	€ 8.254
Lifetime Running costs (NPV)	€ 11.668	€ 9.655	€ 9.267	€ 8.989	€ 8.640	€ 8.538	€ 5.461	€ 5.274	€ 5.259
Life Cycle Costs LCC	€ 14.172	€ 12.814	€ 12.500	€ 12.433	€ 12.313	€ 12.391	€ 13.057	€ 13.347	€ 13.512
Simple Payback Period PBB	reference yrs	6,1 yrs	6,0 yrs	6,7 yrs	7,4 yrs	8,3 yrs	18,5 yrs	19,6 yrs	20,2 yrs

Table 2-13. Prices and Installation costs per unit for Design Options size category "S"

DESIGN OPTIONS	1		2		3		4		5		6		7		8		9	
	3 -S (Small)		3 -S (Small)		3 -S (Small)		3 -S (Small)		3 -S (Small)		3 -S (Small)		3 -S (Small)		3 -S (Small)		3 -S (Small)	
PRODUCT PRICE break down																		
OEM Subass. Costs (Task 2, Ch. 5)	Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system	
Heat exchanger group	77		89		106		106		106		128		89		106		128	
El. controls group	50		60		90		100		100		100		60		100		100	
Burner group	17		17		21		21		21		21		17		21		21	
Fuel controls group	35		60		35		35		60		80		60		60		80	
CH-return group	40		90		82		110		110		110		90		110		110	
CH-supply group	10		10		10		10		10		10		10		10		10	
Fan group	30		45		35		45		50		50		45		50		50	
Casing	26		26		26		26		34		34		34		34		34	
Condensate collect	8		8		35		35		35		35		8		35		35	
Hot water group	21		21		21		21		21		21		21		21		21	
Packaging etc.	9		9		9		9		9		9		9		9		9	
Extra oil-fired (*0,11)	61		82		89		98		105		113		84		105		113	
Subtotal OEM		**382**		**516**		**558**		**615**		**661**		**710**		**526**		**661**		**710**
Labour		115		155		167		185		198		213		158		198		213
Overhead		268		361		391		431		463		497		369		463		497
total MSP		**765**		**1.033**		**1.116**		**1.231**		**1.322**		**1.420**		**1.053**		**1.322**		**1.420**
Ex wholesale		994		1.342		1.451		1.600		1.719		1.846		1.369		1.719		1.846
Ex installer excl. VAT		1.185		1.601		1.731		1.907		2.049		2.201		1.632		2.049		2.201
BOILER consumer street price incl. VAT		**1.410**		**1.905**		**2.059**		**2.270**		**2.439**		**2.620**		**1.942**		**2.439**		**2.620**
CONTROLLERS incl. VAT		0		75		55		55		55		55		75		55		55
INSTALLATION (Labour, materials, VAT)		1.094		1.179		1.119		1.119		1.179		1.179		1.179		1.179		1.179
subtotal Boiler (all in)		**2.504**		**3.159**		**3.233**		**3.444**		**3.673**		**3.854**		**3.196**		**3.673**		**3.854**
SOLAR materials incl. VAT		0		0		0		0		0		0		0		0		0
SOLAR installation incl. VAT		0		0		0		0		0		0		0		0		0
HEAT PUMP materials incl. VAT		0		0		0		0		0		0		2.500		2.500		2.500
HEAT PUMP installation incl. VAT		0		0		0		0		0		0		1.900		1.900		1.900
TOTAL PURCHASE		**2.504**		**3.159**		**3.233**		**3.444**		**3.673**		**3.854**		**7.596**		**8.073**		**8.254**
Country Rprice corrected		**2.504**		**3.159**		**3.233**		**3.444**		**3.673**		**3.854**		**7.596**		**8.073**		**8.254**

Table 2-14. Life Cycle Costs and Annual Expenditure PER UNIT for size category "S"

DESIGN OPTIONS	1	2	3	4	5	6	7	8	9
	3 -S (Small)	3 -S (Small)	3 -S (Small)	3 -S (Small)	3 -S (Small)	3 -S (Small)	3 -S (Small)	3 -S (Small)	3 -S (Small)
LCC break down									
Product Price	€ 1.410	€ 1.980	€ 2.114	€ 2.325	€ 2.494	€ 2.675	€ 4.517	€ 4.994	€ 5.175
Installation	€ 1.094	€ 1.179	€ 1.119	€ 1.119	€ 1.179	€ 1.179	€ 3.079	€ 3.079	€ 3.079
Fuel energy (gas, oil)	€ 8.620	€ 6.974	€ 6.352	€ 6.352	€ 6.001	€ 5.900	€ 937	€ 766	€ 751
Electricity	€ 476	€ 109	€ 342	€ 64	€ 67	€ 65	€ 1.952	€ 1.936	€ 1.935
Repair & Maintenance	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573
TOTAL LCC	€ 14.172	€ 12.814	€ 12.500	€ 12.433	€ 12.313	€ 12.391	€ 13.057	€ 13.347	€ 13.512
Annual expenditure									
Product Price	€ 83	€ 116	€ 124	€ 137	€ 147	€ 157	€ 266	€ 294	€ 304
Installation	€ 64	€ 69	€ 66	€ 66	€ 69	€ 69	€ 181	€ 181	€ 181
Fuel energy (gas, oil)	€ 451	€ 349	€ 332	€ 316	€ 299	€ 294	€ 156	€ 146	€ 146
Electricity	€ 33	€ 8	€ 24	€ 4	€ 5	€ 5	€ 137	€ 135	€ 135
Repair & Maintenance	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180
TOTAL expenditure/a	€ 812	€ 723	€ 726	€ 703	€ 700	€ 705	€ 919	€ 937	€ 946
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 2.504	€ 3.159	€ 3.233	€ 3.444	€ 3.673	€ 3.854	€ 7.596	€ 8.073	€ 8.254
Lifetime Running costs (NPV)	€ 11.668	€ 9.655	€ 9.267	€ 8.989	€ 8.640	€ 8.538	€ 5.461	€ 5.274	€ 5.259
Life Cycle Costs LCC	€ 14.172	€ 12.814	€ 12.500	€ 12.433	€ 12.313	€ 12.391	€ 13.057	€ 13.347	€ 13.512
Simple Payback Period PBB	reference yrs	6,1 yrs	6,0 yrs	6,7 yrs	7,4 yrs	8,3 yrs	18,5 yrs	19,6 yrs	20,2 yrs

Table 2-15. Environmental Impact PER UNIT over lifetime for size category "S"

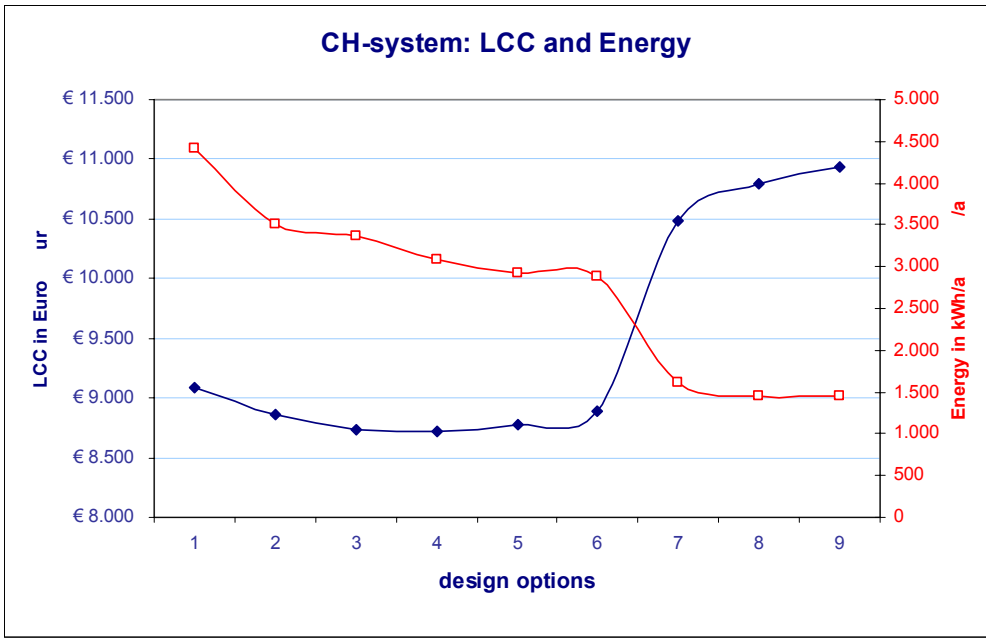
DESIGN OPTIONS		1		2		3		4		5		6		7		8		9	
		3 -S (Small)		3 -S (Small)		3 -S (Small)		3 -S (Small)		3 -S (Small)		3 -S (Small)		3 -S (Small)		3 -S (Small)		3 -S (Small)	
ENVIRONMENTAL IMPACT PER UNIT OVER LIFE																			
MATERIALS		**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE
TOTAL	kg	**34,1**		**34,1**		**34,1**		**34,1**		**34,1**		**34,1**		**34,1**		**34,1**		**34,1**	
of which																			
Disposal	kg	**6,1**		**6,1**		**6,1**		**6,1**		**6,1**		**6,1**		**6,1**		**6,1**		**6,1**	
Recycled	kg	**27,9**		**27,9**		**27,9**		**27,9**		**27,9**		**27,9**		**27,9**		**27,9**		**27,9**	
OTHER RESOURCES																			
Total Energy (GER)	GJ	**566,0**	563,3	**435,5**	432,8	**417,2**	414,5	**394,7**	391,4	**373,9**	370,2	**369,6**	364,0	**228,2**	219,7	**212,4**	207,9	**216,8**	207,0
of which, electric(in primary	GJ	**40,2**	39,6	**9,7**	9,1	**29,1**	28,4	**6,1**	5,3	**6,4**	5,6	**6,6**	5,4	**164,1**	162,5	**162,1**	161,2	**162,9**	161,1
Water (process)	m3	**3,1**	2,6	**1,1**	0,6	**2,4**	1,9	**0,9**	0,4	**0,9**	0,4	**0,9**	0,4	**11,6**	10,8	**11,5**	10,7	**11,7**	10,7
Water (cooling)	m3	**106,0**	105,6	**24,6**	24,2	**76,3**	75,9	**14,6**	14,2	**15,3**	14,8	**15,3**	14,5	**434,6**	433,4	**430,6**	429,8	**431,3**	429,7
Waste, non-haz./ landfill	kg	**5,7**	0,9	**5,0**	0,2	**5,5**	0,7	**4,9**	0,1	**4,9**	0,1	**4,4**	0,1	**10,2**	3,7	**8,0**	3,7	**9,0**	3,7
Waste, hazardous/ incinera	kg	**117,2**	45,9	**81,8**	10,5	**104,3**	33,0	**105,0**	6,2	**119,1**	6,4	**139,7**	6,3	**385,5**	188,5	**306,1**	186,9	**421,1**	186,8
EMISSIONS TO AIR																			
GHG in GWP100	tCO2	**31,8**	31,6	**24,8**	24,6	**23,5**	23,3	**22,5**	22,3	**21,3**	21,1	**21,1**	20,7	**11,0**	10,4	**10,0**	9,7	**10,4**	9,7
AP Acidification	kgSOx	**23,0**	22,0	**12,9**	11,9	**17,0**	16,0	**11,3**	10,0	**11,0**	9,6	**11,0**	9,5	**45,4**	43,1	**44,1**	42,6	**45,2**	42,5
VOC Volatile Organic Com	kg	**0,4**	0,4	**0,3**	0,3	**0,3**	0,3	**0,3**	0,3	**0,3**	0,3	**0,3**	0,3	**0,2**	0,1	**0,1**	0,1	**0,2**	0,1
POP Persist.Organic Poll.	mg i-Teq	**1,0**	0,3	**0,8**	0,1	**0,9**	0,2	**1,0**	0,0	**1,2**	0,0	**2,0**	0,0	**4,0**	1,1	**2,6**	1,1	**4,6**	1,1
HMa Heavy Metals	mg Ni	**1,6**	0,7	**1,0**	0,2	**1,4**	0,5	**1,2**	0,1	**1,4**	0,1	**1,4**	0,1	**4,5**	2,8	**4,2**	2,8	**4,8**	2,8
PAHs	mg	**0,3**	0,1	**0,2**	0,1	**0,3**	0,1	**0,2**	0,1	**0,2**	0,1	**0,2**	0,1	**0,5**	0,4	**0,5**	0,4	**0,6**	0,4
PM Particulate Matter	kg	**2,3**	1,3	**2,1**	1,1	**2,3**	1,2	**2,3**	1,1	**2,4**	1,1	**4,9**	1,0	**9,0**	1,8	**3,8**	1,8	**9,3**	1,8
EMISSIONS TO WATER																			
HMw Heavy Metals	g Hg/20	**0,8**	0,3	**0,6**	0,1	**0,8**	0,2	**0,8**	0,0	**0,9**	0,0	**0,7**	0,0	**1,9**	1,0	**1,9**	1,0	**2,2**	1,0
EP Eutrophication	g PO4	**12,9**	1,2	**12,0**	0,3	**12,6**	0,9	**14,6**	0,2	**16,0**	0,2	**17,1**	0,2	**27,9**	5,0	**26,1**	5,0	**35,2**	5,0
ANNUAL SPACE HEAT ENERGY breakdown																			
TOTAL	kWh/a	**9368**	100%	**7258**	100%	**6894**	100%	**6570**	100%	**6214**	100%	**6109**	100%	**3234**	100%	**3040**	100%	**3024**	100%
Tset	kWh/a	**3799**	41%	**3799**	52%	**3799**	55%	**3799**	58%	**3799**	61%	**3799**	62%	**3799**	117%	**3799**	125%	**3799**	126%
Tmass	kWh/a	**788**	8%	**875**	12%	**875**	13%	**875**	13%	**875**	14%	**875**	14%	**875**	27%	**875**	29%	**875**	29%
Tintrans	kWh/a	**263**	3%	**254**	3%	**254**	4%	**254**	4%	**254**	4%	**254**	4%	**254**	8%	**254**	8%	**254**	8%
Tfluct (cntrl)	kWh/a	**642**	7%	**122**	2%	**351**	5%	**351**	5%	**166**	3%	**168**	3%	**122**	4%	**166**	5%	**168**	6%
Tstrat(emit)	kWh/a	**415**	4%	**310**	4%	**343**	5%	**343**	5%	**312**	5%	**312**	5%	**310**	10%	**312**	10%	**312**	10%
Distr. loss	kWh/a	**846**	9%	**483**	7%	**435**	6%	**435**	7%	**432**	7%	**432**	7%	**483**	15%	**432**	14%	**432**	14%
Steady st.	kWh/a	**1752**	19%	**1139**	16%	**252**	4%	**252**	4%	**216**	3%	**125**	2%	**152**	5%	**35**	1%	**18**	1%
Start/stop	kWh/a	**43**	0%	**114**	2%	**76**	1%	**76**	1%	**43**	1%	**29**	0%	**15**	0%	**0**	0%	**0**	0%
Stby heat	kWh/a	**265**	3%	**35**	0%	**111**	2%	**111**	2%	**39**	1%	**39**	1%	**5**	0%	**6**	0%	**6**	0%
Electric	kWh/a	**555**	6%	**127**	2%	**398**	6%	**75**	1%	**78**	1%	**76**	1%	**127**	4%	**78**	3%	**76**	3%
Credit solar	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%
Credit HP	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**2908**	0%	**2917**	0%	**2915**	0%
Net heating efficiency	%	**52%**		**68%**		**71%**		**75%**		**79%**		**81%**		**152%**		**162%**		**163%**	
gross heat load	kWh/a	**6.052**		**6.149**		**6.168**		**6.168**		**6.168**		**6.198**		**6.149**		**6.168**		**6.198**	
net heat load	kWh/a	**4.850**		**4.928**		**4.928**		**4.928**		**4.928**		**4.928**		**4.928**		**4.928**		**4.928**	
net load per unit floor area	kWh/m2	**141**		**109**		**104**		**99**		**93**		**92**		**49**		**46**		**45**	
CH system efficiency	%	**60%**		**78%**		**82%**		**86%**		**91%**		**93%**		**175%**		**186%**		**187%**	

2.4 Design Options and Impact size category XS and XXS

Already for the size category “S” we saw a relatively small change in the lifecycle costs for the Design Options 2 to 6, due to the fact that improved efficiency brings less when annual energy consumption is limited. For the “XS” and “XXS” sized boilers this is even more so. The difference in lifecycle costs for a state-of-the-art LT boiler (option 2) versus the LLCC-level in the size class “XXS” is only around € 140,-. Pay-back periods for the proposed design options will therefore be longer.

Based on similar Design Options as described for the size-class “S” (Small) , the following graph can be constructed for size-class XXS:

Figure 2-16.
Design options, lifecycle costs and annual energy consumption category "XXS"



Similar to the previous size class “S”, we may conclude for these two sized classes “XS” and “XXS” that the **LLCC levels** have net heating efficiency values of around **77-78%**, to be achieved with state-of-the-art condensing boilers. However, given the longer payback periods and the chimney problem, the state-of-the art LT boiler - with a net system efficiency of around **68% -** could be a practical alternative, when combined with some form of renewable energy (solar or heat pump). A detailed economic analysis per project is advised.

Combined with collective heat pumps or (collective) solar collectors, the **BAT-levels** for these size classes (even with LT boilers) can be raised to above **160%.**

The impact of the Design Options are summarized in the tables on the next four pages:

Table 2-17: Input Design Options in EcoBoiler Integrated Model for size category “XXS”

Table 2-18: Prices & Installation costs PER UNIT for Design Options size category “XXS”

Table 2-19: Life Cycle Costs and Annual Expenditure PER UNIT for size category “XXS”

Table 2-20: Environmental Impact PER UNIT over lifetime for size category “XXS”

Table 2-17. Input Design Options in EcoBoiler Integrated Model for size category "XXS"

DESIGN OPTIONS	1 BaseCase	2	3	4	5	6	7	8	9
INPUTS CH									
CH-power class	1 -XXS (XX Small)	1 -XXS (XX Small)	1 -XXS (XX Small)	1 -XXS (XX Small)	1 -XXS (XX Small)	1 -XXS (XX Small)	1 -XXS (XX Small)	1 -XXS (XX Small)	1 -XXS (XX Small)
	6 -apartment new	*6 -apartment new*	*6 -apartment new*	*6 -apartment new*	*6 -apartment new*	*6 -apartment new*	*6 -apartment new*	*6 -apartment new*	*6 -apartment new*
boiler characteristics									
power input in kW*	10 kW	10 kW	10 kW	10 kW	10 kW	10 kW	10 kW	10 kW	10 kW
turndown ratio	33%	10%	33%	33%	10%	10%	10%	10%	10%
standby heat loss (% of Pnom)	1,0%	0,5%	1,0%	1,0%	0,5%	0,5%	0,5%	0,5%	0,5%
steady st. efficiency %	5 -80/80/80/80	4 -84/84/84/84	1 -89/89/97/97	1 -89/89/97/97	1 -89/89/97/97	9 -ideal 96/96/97/97	4 -84/84/84/84	1 -89/89/97/97	9 -ideal 96/96/97/97
fuel (dewpoint)	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas
air-fuel mix control	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	3 -ionisation	2 -pneumatic	2 -pneumatic	3 -ionisation
circ. pump power	5 -65W	1 -5..(15)..25W + sb	3 -25..(45)..65 W	1 -5..(15)..25W + sb	1 -5..(15)..25W + sb	1 -5..(15)..25W + sb	1 -5..(15)..25W + sb	1 -5..(15)..25W + sb	1 -5..(15)..25W + sb
fan power	2 -P=6..30W	1 -P=3..18W	3 -P=9..40W	1 -P=3..18W	1 -P=3..18W	1 -P=3..18W	1 -P=3..18W	1 -P=3..18W	1 -P=3..18W
CPU power sb/on	3 -P=6/8W	1 -P=2/3W	4 -P=10/12W	1 -P=2/3W	1 -P=2/3W	1 -P=2/3W	1 -P=2/3W	1 -P=2/3W	1 -P=2/3W
controls power sb/on	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W	1 -P=0/10W
comb. air intake	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed
boiler mass (empty), kg	34 kg	34 kg	34 kg	34 kg	34 kg	34 kg	34 kg	34 kg	34 kg
water content in kg	1,5 kg	1,5 kg	1,5 kg	1,5 kg	1,5 kg	1,5 kg	1,5 kg	1,5 kg	1,5 kg
envelope volume in m3	0,08 m3	0,08 m3	0,08 m3	0,08 m3	0,08 m3	0,08 m3	0,08 m3	0,08 m3	0,08 m3
noise level in dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A	43 dB-A
controllers									
auto-timer control	yes	yes	yes	yes	yes	yes	yes	yes	yes
valve control	2 -RTV 2K	3 -RTV 1K	2 -RTV 2K	2 -RTV 2K	3 -RTV 1K	3 -RTV 1K	3 -RTV 1K	3 -RTV 1K	3 -RTV 1K
boiler temp control	6 -on/off RT	8 -time-prop. RT	7 -modulating RT	7 -modulating RT	7 -modulating RT	7 -modulating RT	8 -time-prop. RT	7 -modulating RT	7 -modulating RT
electronic optimiser	no	yes	yes	yes	yes	yes	yes	yes	yes
autoset weather control	N/A	N/A	no	N/A	N/A	N/A	no	no	no
solar (for combi only)									
collector type	N/A	1 -glazed	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube
collector surface m2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
tank position	N/A	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors
CH-fraction served	0%	100%	0%	0%	0%	0%	0%	0%	0%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
heat pump (HP)									
Reference type	1 -El. brine/ water 0/5	3 -El. air/ water 7/50	3 -El. air/ water 7/50	3 -El. air/ water 7/50	3 -El. air/ water 7/50	3 -El. air/ water 7/50	2 -El. water/ water 10/50	2 -El. water/ water 10/50	2 -El. water/ water 10/50
Power nominal in kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	1,0 kW	1,0 kW	1,0 kW
COP nominal 0/50	0,00	0,00	0,00	2,50	0,00	3,50	3,70	3,70	3,70
Ratio CH : DHW	100%	80%	80%	80%	80%	80%	80%	80%	80%
CH-fraction served	100%	0%	100%	100%	100%	50%	100%	100%	100%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
MAIN ENERGY OUTPUTS									
Net heating efficiency	53%	68%	71%	77%	81%	83%	148%	164%	165%
Primary energy consumption	4422 kWh/a	3515 kWh/a	3366 kWh/a	3094 kWh/a	2933 kWh/a	2887 kWh/a	1609 kWh/a	1456 kWh/a	1447 kWh/a
-of which fuel (primary kWh GCV)	4100 kWh/a	3375 kWh/a	3027 kWh/a	3027 kWh/a	2868 kWh/a	2823 kWh/a	353 kWh/a	255 kWh/a	249 kWh/a
-of which electricity (primary kWh)	322 kWh/a	140 kWh/a	339 kWh/a	66 kWh/a	66 kWh/a	64 kWh/a	1.256 kWh/a	1.200 kWh/a	1.197 kWh/a
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 2.227	€ 2.866	€ 2.915	€ 3.126	€ 3.344	€ 3.499	€ 6.493	€ 6.944	€ 7.099
Lifetime Running costs (NPV)	€ 6.858	€ 5.993	€ 5.824	€ 5.590	€ 5.433	€ 5.389	€ 3.995	€ 3.852	€ 3.843
Life Cycle Costs LCC	€ 9.085	€ 8.859	€ 8.739	€ 8.716	€ 8.778	€ 8.888	€ 10.488	€ 10.796	€ 10.943
Simple Payback Period PBB	reference yrs	13,9 yrs	13,6 yrs	13,4 yrs	15,0 yrs	16,5 yrs	34,3 yrs	35,6 yrs	36,7 yrs

Table 2-18. Prices and Installation costs PER UNIT for Design Options size category "XXS"

DESIGN OPTIONS	1		2		3		4		5		6		7		8		9	
	1 -XXS (XX Small)		1 -XXS (XX Small)		1 -XXS (XX Small)		1 -XXS (XX Small)		1 -XXS (XX Small)		1 -XXS (XX Small)		1 -XXS (XX Small)		1 -XXS (XX Small)		1 -XXS (XX Small)	
PRODUCT PRICE break down																		
OEM Subass. Costs (Task 2, Ch. 5)	Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system	
Heat exchanger group	55		64		77		77		77		92		64		77		92	
El. controls group	50		60		90		100		100		100		60		100		100	
Burner group	12		12		15		15		15		15		12		15		15	
Fuel controls group	35		60		35		35		60		80		60		60		80	
CH-return group	40		90		82		110		110		110		90		110		110	
CH-supply group	10		10		10		10		10		10		10		10		10	
Fan group	30		45		35		45		50		50		45		50		50	
Casing	18		18		18		18		25		25		25		25		25	
Condensate collect	8		8		35		35		35		35		8		35		35	
Hot water group	21		21		21		21		21		21		21		21		21	
Packaging etc.	6		6		6		6		6		6		6		6		6	
Extra oil-fired (*0,11)	54		75		80		89		96		103		76		96		103	
Subtotal OEM		340		470		505		562		605		647		477		605		647
Labour		102		141		151		169		181		194		143		181		194
Overhead		238		329		353		393		423		453		334		423		453
total MSP		680		940		1.010		1.124		1.210		1.294		955		1.210		1.294
Ex wholesale		885		1.222		1.313		1.461		1.573		1.682		1.241		1.573		1.682
Ex installer excl. VAT		1.055		1.457		1.565		1.742		1.875		2.006		1.480		1.875		2.006
BOILER consumer street price incl. VAT		1.255		1.734		1.863		2.073		2.232		2.387		1.761		2.232		2.387
CONTROLLERS incl. VAT		0		75		55		55		55		55		75		55		55
INSTALLATION (Labour, materials, VAT)		972		1.057		997		997		1.057		1.057		1.057		1.057		1.057
subtotal Boiler (all in)		2.227		2.866		2.915		3.126		3.344		3.499		2.893		3.344		3.499
SOLAR materials incl. VAT		0		0		0		0		0		0		0		0		0
SOLAR installation incl. VAT		0		0		0		0		0		0		0		0		0
HEAT PUMP materials incl. VAT		0		0		0		0		0		0		2.000		2.000		2.000
HEAT PUMP installation incl. VAT		0		0		0		0		0		0		1.600		1.600		1.600
TOTAL PURCHASE		2.227		2.866		2.915		3.126		3.344		3.499		6.493		6.944		7.099
Country Rprice corrected		2.227		2.866		2.915		3.126		3.344		3.499		6.493		6.944		7.099

Table 2-19. Life Cycle Costs and Annual Expenditure PER UNIT for size category "XXS"

DESIGN OPTIONS	1 1 -XXS (XX Small)	2 1 -XXS (XX Small)	3 1 -XXS (XX Small)	4 1 -XXS (XX Small)	5 1 -XXS (XX Small)	6 1 -XXS (XX Small)	7 1 -XXS (XX Small)	8 1 -XXS (XX Small)	9 1 -XXS (XX Small)
LCC break down									
Product Price	€ 1.255	€ 1.809	€ 1.918	€ 2.128	€ 2.287	€ 2.442	€ 3.836	€ 4.287	€ 4.442
Installation	€ 972	€ 1.057	€ 997	€ 997	€ 1.057	€ 1.057	€ 2.657	€ 2.657	€ 2.657
Fuel energy (gas, oil)	€ 4.009	€ 3.300	€ 2.961	€ 2.961	€ 2.804	€ 2.761	€ 346	€ 250	€ 244
Electricity	€ 276	€ 120	€ 290	€ 57	€ 56	€ 55	€ 1.077	€ 1.029	€ 1.027
Repair & Maintenance	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573
TOTAL LCC	€ 9.085	€ 8.859	€ 8.739	€ 8.716	€ 8.778	€ 8.888	€ 10.488	€ 10.796	€ 10.943
Annual expenditure									
Product Price	€ 74	€ 106	€ 113	€ 125	€ 135	€ 144	€ 226	€ 252	€ 261
Installation	€ 57	€ 62	€ 59	€ 59	€ 62	€ 62	€ 156	€ 156	€ 156
Fuel energy (gas, oil)	€ 213	€ 169	€ 162	€ 149	€ 141	€ 139	€ 77	€ 70	€ 70
Electricity	€ 19	€ 8	€ 20	€ 4	€ 4	€ 4	€ 75	€ 72	€ 72
Repair & Maintenance	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180
TOTAL expenditure/a	€ 543	€ 526	€ 534	€ 517	€ 522	€ 529	€ 715	€ 731	€ 739
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 2.227	€ 2.866	€ 2.915	€ 3.126	€ 3.344	€ 3.499	€ 6.493	€ 6.944	€ 7.099
Lifetime Running costs (NPV)	€ 6.858	€ 5.993	€ 5.824	€ 5.590	€ 5.433	€ 5.389	€ 3.995	€ 3.852	€ 3.843
Life Cycle Costs LCC	€ 9.085	€ 8.859	€ 8.739	€ 8.716	€ 8.778	€ 8.888	€ 10.488	€ 10.796	€ 10.943
Simple Payback Period PBB	reference yrs	13,9 yrs	13,6 yrs	13,4 yrs	15,0 yrs	16,5 yrs	34,3 yrs	35,6 yrs	36,7 yrs

Table 2-20. Environmental Impact PER UNIT over lifetime for size category "XXS"

DESIGN OPTIONS		1		2		3		4		5		6		7		8		9	
		1 -XXS (XX Small)		1 -XXS (XX Small)		1 -XXS (XX Small)		1 -XXS (XX Small)		1 -XXS (XX Small)		1 -XXS (XX Small)		1 -XXS (XX Small)		1 -XXS (XX Small)		1 -XXS (XX Small)	
ENVIRONMENTAL IMPACT PER UNIT OVER LIFE																			
MATERIALS		**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE
TOTAL	kg	**34,1**		**34,1**		**34,1**		**34,1**		**34,1**		**34,1**		**34,1**		**34,1**		**34,1**	
of which																			
Disposal	kg	**6,1**		**6,1**		**6,1**		**6,1**		**6,1**		**6,1**		**6,1**		**6,1**		**6,1**	
Recycled	kg	**27,9**		**27,9**		**27,9**		**27,9**		**27,9**		**27,9**		**27,9**		**27,9**		**27,9**	
OTHER RESOURCES																			
Total Energy (GER)	GJ	**269,4**	266,7	**213,4**	210,7	**206,9**	204,2	**188,1**	184,8	**178,9**	175,2	**178,2**	172,5	**119,5**	110,9	**105,6**	101,1	**110,4**	100,6
of which, electric(in primary	GJ	**23,6**	23,0	**10,6**	10,0	**24,8**	24,2	**5,5**	4,7	**5,5**	4,7	**5,7**	4,6	**91,2**	89,7	**86,7**	85,7	**87,3**	85,5
Water (process)	m3	**2,0**	1,5	**1,1**	0,7	**2,1**	1,6	**0,8**	0,3	**0,9**	0,3	**0,9**	0,3	**6,7**	6,0	**6,4**	5,7	**6,6**	5,7
Water (cooling)	m3	**61,7**	61,3	**27,1**	26,7	**64,9**	64,5	**13,1**	12,6	**13,0**	12,5	**12,9**	12,2	**240,3**	239,1	**229,3**	228,5	**229,6**	228,0
Waste, non-haz./ landfill	kg	**5,3**	0,5	**5,0**	0,2	**5,4**	0,6	**4,9**	0,1	**4,9**	0,1	**4,4**	0,1	**8,5**	2,1	**6,3**	2,0	**7,3**	2,0
Waste, hazardous/ incinera	kg	**98,0**	26,7	**82,9**	11,6	**99,4**	28,0	**104,3**	5,5	**118,1**	5,4	**138,7**	5,3	**301,0**	104,0	**218,5**	99,4	**333,4**	99,1
EMISSIONS TO AIR																			
GHG in GWP100	tCO2	**15,1**	14,9	**12,1**	11,9	**11,5**	11,3	**10,7**	10,5	**10,2**	9,9	**10,2**	9,8	**5,8**	5,1	**5,0**	4,6	**5,3**	4,6
AP Acidification	kgSOx	**12,4**	11,4	**8,1**	7,1	**11,3**	10,3	**6,5**	5,3	**6,4**	5,0	**6,5**	5,0	**25,9**	23,6	**24,0**	22,4	**25,0**	22,4
VOC Volatile Organic Com	kg	**0,2**	0,2	**0,2**	0,2	**0,2**	0,1	**0,2**	0,1	**0,1**	0,1	**0,2**	0,1	**0,1**	0,1	**0,1**	0,0	**0,1**	0,0
POP Persist.Organic Poll.	mg i-Teq	**0,9**	0,2	**0,8**	0,1	**0,9**	0,2	**1,0**	0,0	**1,2**	0,0	**2,0**	0,0	**3,6**	0,6	**2,1**	0,6	**4,1**	0,6
HMa Heavy Metals	mg Ni	**1,3**	0,4	**1,1**	0,2	**1,3**	0,5	**1,2**	0,1	**1,3**	0,1	**1,3**	0,1	**3,3**	1,6	**2,9**	1,5	**3,5**	1,5
PAHs	mg	**0,2**	0,1	**0,2**	0,1	**0,2**	0,1	**0,2**	0,1	**0,2**	0,1	**0,2**	0,1	**0,3**	0,2	**0,4**	0,2	**0,4**	0,2
PM Particulate Matter	kg	**2,1**	1,1	**2,0**	1,0	**2,2**	1,1	**2,3**	1,0	**2,3**	1,0	**4,8**	1,0	**8,6**	1,4	**3,4**	1,4	**8,9**	1,4
EMISSIONS TO WATER																			
HMw Heavy Metals	g Hg/20	**0,7**	0,1	**0,7**	0,1	**0,7**	0,2	**0,8**	0,0	**0,9**	0,0	**0,7**	0,0	**1,5**	0,6	**1,5**	0,6	**1,7**	0,6
EP Eutrophication	g PO4	**12,4**	0,7	**12,0**	0,3	**12,4**	0,7	**14,6**	0,1	**15,9**	0,1	**17,1**	0,1	**25,7**	2,8	**23,7**	2,6	**32,8**	2,6
ANNUAL SPACE HEAT ENERGY breakdown																			
TOTAL	kWh/a	**4422**	100%	**3515**	100%	**3366**	100%	**3094**	100%	**2933**	100%	**2887**	100%	**1609**	100%	**1456**	100%	**1447**	100%
Tset	kWh/a	**1653**	37%	**1653**	47%	**1653**	49%	**1653**	53%	**1653**	56%	**1653**	57%	**1653**	103%	**1653**	114%	**1653**	114%
Tmass	kWh/a	**423**	10%	**470**	13%	**470**	14%	**470**	15%	**470**	16%	**470**	16%	**470**	29%	**470**	32%	**470**	32%
Tintrans	kWh/a	**277**	6%	**260**	7%	**260**	8%	**260**	8%	**260**	9%	**260**	9%	**260**	16%	**260**	18%	**260**	18%
Tfluct (cntrl)	kWh/a	**383**	9%	**65**	2%	**204**	6%	**204**	7%	**92**	3%	**92**	3%	**65**	4%	**92**	6%	**92**	6%
Tstrat(emit)	kWh/a	**241**	5%	**191**	5%	**212**	6%	**212**	7%	**194**	7%	**194**	7%	**191**	12%	**194**	13%	**194**	13%
Distr. loss	kWh/a	**394**	9%	**280**	8%	**231**	7%	**231**	7%	**234**	8%	**234**	8%	**280**	17%	**234**	16%	**234**	16%
Steady st.	kWh/a	**628**	14%	**388**	11%	**-64**	-2%	**-64**	-2%	**-60**	-2%	**-100**	-3%	**56**	3%	**12**	1%	**6**	0%
Start/stop	kWh/a	**21**	0%	**57**	2%	**24**	1%	**24**	1%	**12**	0%	**8**	0%	**6**	0%	**0**	0%	**0**	0%
Stby heat	kWh/a	**79**	2%	**12**	0%	**37**	1%	**37**	1%	**13**	0%	**13**	0%	**1**	0%	**1**	0%	**1**	0%
Electric	kWh/a	**322**	7%	**140**	4%	**339**	10%	**66**	2%	**66**	2%	**64**	2%	**140**	9%	**66**	5%	**64**	4%
Credit solar	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%
Credit HP	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**1511**	0%	**1526**	0%	**1527**	0%
Net heating efficiency	%	**53%**		**68%**		**71%**		**77%**		**81%**		**83%**		**148%**		**164%**		**165%**	
gross heat load	kWh/a	**2.965**		**3.005**		**3.015**		**3.015**		**3.015**		**3.031**		**3.005**		**3.015**		**3.031**	
net heat load	kWh/a	**2.354**		**2.382**		**2.382**		**2.382**		**2.382**		**2.382**		**2.382**		**2.382**		**2.382**	
net load per unit floor area	kWh/m2	**56**		**45**		**43**		**39**		**37**		**37**		**21**		**19**		**18**	
CH system efficiency	%	**61%**		**78%**		**81%**		**89%**		**93%**		**95%**		**170%**		**188%**		**189%**	

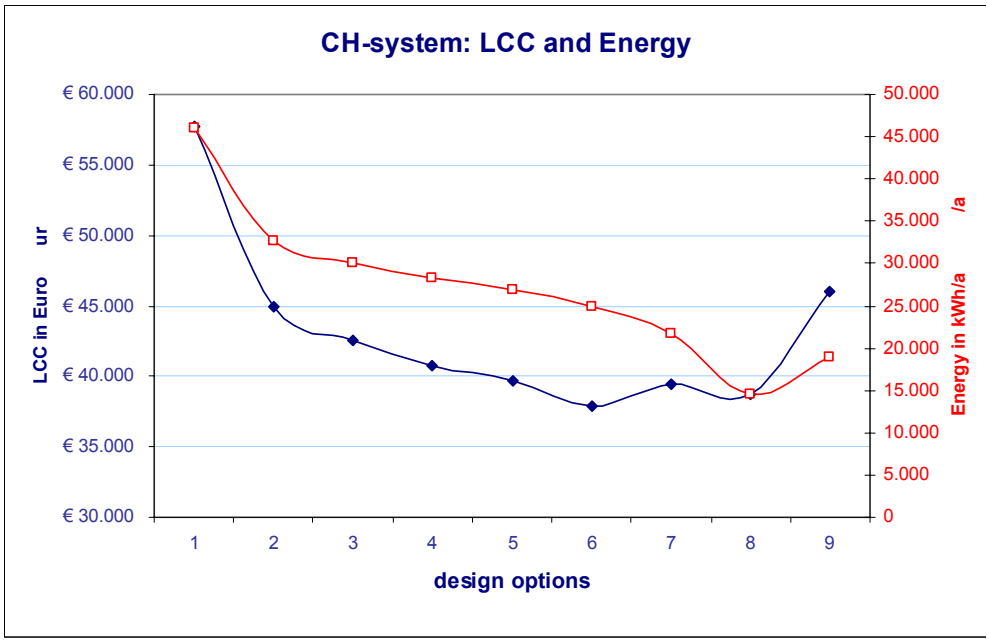
2.5 Design Options & Impact size category "XL"

The following design options have been elaborated for this size-class "XL" (Extra Large).

Explanation design options

1. Reference (see first column table 2-22)
2. Improvement steady-state efficiency from 80/80 to **87/95** and the application of a **weather controlled boiler thermostat with timer control** instead of the on/off RT.
3. Improvement steady-state efficiency to **89/97**, the use of **1K TRV's** (which in fact is a hydraulic balancing of the system).
4. Option 3, extended with a smaller **95 W pump**, an **electronic optimiser** and a more energy efficient **CPU (14/16 W)**
5. Option 4, extended with **motorized valves with PID** loop (instead of 1k TRV) and a reduction of the **standby heat loss to 0,5%**.
6. Option 5, extended with an improved **turndown ratio of 10%**, a minimization of the **CPU power consumption to 10/12 W**, and **CPU controlled motor valves**
7. Option 6, extended with a **tertiary heat exchanger**, and ionisation based **lambda control** system, also extended with a **7 kW electric air/water heat pump** with a nominal COP of **2,5** (at 7/50); (CH fraction served = 100%).
8. Option 7, but here the air/water heat pump is replaced by a **7 kW electric water/water heat pump** with a nominal COP of **3,8** (at 10/50° C); (CH fraction served = 100%).
9. Option 7, but here the air/water heat pump is replaced by a **24 m² vacutube type solar collector** (CH fraction served = 100%).

Figure 2-21.
Design options, lifecycle costs and annual energy consumption category "XL"



The average annual primary energy consumption for the BaseCase "XL" sized boilers amounts to 45.965 kWh (net heating efficiency is 44%), with a total lifecycle costs of €57.697,-

This annual primary energy consumption can be reduced with approximately 5400 kWh (= **46%**) to 24.806 kWh with the existing and proven technology that is selected for Design Option 6. The net heating efficiency with this option is improved to **77%**. The related lifecycle costs are reduced to € 37.851,-. This **77%** is also the **LLCC-level.**

With Design Option nr. 8 (in which a state-of-the-art condensing boiler (with tertiary heat exchanger and lambda-control) is combined with a 7 kW water-to-water heat pump), the net heating efficiency can be increased to a **BAT level of 132%** (annual consumption: 14507 kWh) with lifecycle costs that are only € 800,- higher than the LLCC-level.

If the power output of the heat pump in Design Option 8 is further increased to 12 kW, the neat heating efficiency rises to 157%, with an annual consumption of 12.159 kWh and lifecycle costs of € 43.659,-

The ultimate BAT level is best represented with a system that combines individual local state-of-the-art condensing boilers with a collective water-to-water heat pump. Net heating efficiencies can then be increased to levels above 140 % (see also BAT-options for XXS to S)

Design Options nr. 9 combines a state-of-the-art condensing boiler with 24 m² vacutube solar collectors, resulting in net heating efficiencies of around 101% with lifecycle costs of around € 46.000,-

The impact of the Design Options are summarized in the tables on the next four pages:

Table 2-22: Input Design Options in EcoBoiler Integrated Model for size category “XL”

Table 2-23: Prices and Installation costs PER UNIT for Design Options size category “XL”

Table 2-24: Life Cycle Costs and Annual Expenditure PER UNIT for size category “XL”

Table 2-25: Environmental Impact PER UNIT over lifetime for size category “XL”

Table 2-22. Input Design Options in EcoBoiler Integrated Model for size category "XL"

DESIGN OPTIONS	1 BaseCase	2	3	4	5	6	7	8	9
INPUTS CH									
CH-power class	6 -XL (Xtra Large)	6 -XL (Xtra Large)	6 -XL (Xtra Large)	6 -XL (Xtra Large)	6 -XL (Xtra Large)	6 -XL (Xtra Large)	6 -XL (Xtra Large)	6 -XL (Xtra Large)	6 -XL (Xtra Large)
	8 -new building (8 ap)	*8 -new building (8 ap)*	*8 -new building (8 ap)*	*8 -new building (8 ap)*	*8 -new building (8 ap)*	*8 -new building (8 ap)*	*8 -new building (8 ap)*	*8 -new building (8 ap)*	*8 -new building (8 ap)*
boiler characteristics									
power input in kW*	60 kW	60 kW	60 kW	60 kW	60 kW	60 kW	60 kW	60 kW	60 kW
turndown ratio	33%	33%	33%	33%	33%	10%	10%	10%	10%
standby heat loss (% of Pnom)	1,0%	1,0%	1,0%	1,0%	0,5%	0,5%	0,5%	0,5%	0,5%
steady st. efficiency %	5 -80/80/80/80	2 -87/87/95/95	1 -89/89/97/97	1 -89/89/97/97	1 -89/89/97/97	1 -89/89/97/97	9 -ideal 96/96/97/97	9 -ideal 96/96/97/97	9 -ideal 96/96/97/97
fuel (dewpoint)	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas
air-fuel mix control	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	3 -ionisation	3 -ionisation	3 -ionisation
circ. pump power	7 -200W	7 -200W	7 -200W	6 -95W	6 -95W	6 -95W	6 -95W	6 -95W	6 -95W
fan power	5 -P=60W	5 -P=60W	5 -P=60W	5 -P=60W	5 -P=60W	5 -P=60W	5 -P=60W	5 -P=60W	5 -P=60W
CPU power sb/on	7 -P=28/30W	7 -P=28/30W	7 -P=28/30W	5 -P=14/16W	5 -P=14/16W	4 -P=10/12W	4 -P=10/12W	4 -P=10/12W	4 -P=10/12W
controls power sb/on	3 -P=0/18W	3 -P=0/18W	3 -P=0/18W	3 -P=0/18W	3 -P=0/18W	3 -P=0/18W	3 -P=0/18W	3 -P=0/18W	3 -P=0/18W
comb. air intake	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed
boiler mass (empty), kg	110 kg	110 kg	110 kg	110 kg	110 kg	110 kg	110 kg	110 kg	110 kg
water content in kg	12,0 kg	12,0 kg	12,0 kg	12,0 kg	12,0 kg	12,0 kg	12,0 kg	12,0 kg	12,0 kg
envelope volume in m3	1,00 m3	1,00 m3	1,00 m3	1,00 m3	1,00 m3	1,00 m3	1,00 m3	1,00 m3	1,00 m3
noise level in dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A
controllers									
auto-timer control	no	yes	yes	yes	yes	yes	yes	yes	yes
valve control	2 -RTV 2K	2 -RTV 2K	3 -RTV 1K	3 -RTV 1K	4 -Motor + PID-loop	5 -Motor + CPU	5 -Motor + CPU	5 -Motor + CPU	5 -Motor + CPU
boiler temp control	4 -fixed BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT
	no	no	no	yes	yes	yes	yes	yes	yes
autoset weather control	N/A	N/A	no	N/A	N/A	N/A	no	no	no
solar (for combi only)									
collector type	N/A	1 -glazed	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube
collector surface m2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	24,0
tank position	N/A	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors
CH-fraction served	0%	100%	0%	0%	0%	0%	0%	0%	100%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
heat pump (HP)									
Reference type	1 -El. brine/ water 0/5	3 -El. air/ water 7/50	3 -El. air/ water 7/50	3 -El. air/ water 7/50	3 -El. air/ water 7/50	3 -El. air/ water 7/50	3 -El. air/ water 7/50	2 -El. water/ water 10/50	2 -El. water/ water 10/50
Power nominal in kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	7,0 kW	7,0 kW	0,0 kW
COP nominal 0/50	0,00	0,00	0,00	2,50	0,00	3,50	2,50	3,80	3,80
Ratio CH : DHW	100%	80%	80%	80%	80%	80%	80%	80%	80%
CH-fraction served	100%	0%	100%	100%	100%	50%	100%	100%	0%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
MAIN ENERGY OUTPUTS									
Net heating efficiency	44%	58%	62%	68%	71%	77%	88%	132%	101%
Primary energy consumption	45965 kWh/a	32672 kWh/a	30171 kWh/a	28283 kWh/a	26831 kWh/a	24806 kWh/a	21690 kWh/a	14507 kWh/a	18899 kWh/a
-of which fuel (primary kWh GCV)	43118 kWh/a	30560 kWh/a	28054 kWh/a	26989 kWh/a	25536 kWh/a	23670 kWh/a	5838 kWh/a	4662 kWh/a	17668 kWh/a
-of which electricity (primary kWh)	2.848 kWh/a	2.112 kWh/a	2.117 kWh/a	1.295 kWh/a	1.295 kWh/a	1.136 kWh/a	15.852 kWh/a	9.844 kWh/a	1.231 kWh/a
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 6.498	€ 7.841	€ 8.170	€ 8.195	€ 8.639	€ 8.951	€ 17.010	€ 22.660	€ 23.510
Lifetime Running costs (NPV)	€ 51.199	€ 37.117	€ 34.437	€ 32.591	€ 31.035	€ 28.901	€ 22.419	€ 16.008	€ 22.553
Life Cycle Costs LCC	€ 57.697	€ 44.958	€ 42.607	€ 40.786	€ 39.674	€ 37.851	€ 39.429	€ 38.668	€ 46.063
Simple Payback Period PBB	reference yrs	1,9 yrs	2,0 yrs	1,8 yrs	2,1 yrs	2,2 yrs	8,9 yrs	10,1 yrs	11,8 yrs

Table 2-23. Prices and Installation costs PER UNIT for Design Options size category "XL"

DESIGN OPTIONS	1		2		3		4		5		6		7		8		9	
	6 -XL (Xtra Large)		6 -XL (Xtra Large)		6 -XL (Xtra Large)		6 -XL (Xtra Large)		6 -XL (Xtra Large)		6 -XL (Xtra Large)		6 -XL (Xtra Large)		6 -XL (Xtra Large)		6 -XL (Xtra Large)	
PRODUCT PRICE break down																		
OEM Subass. Costs (Task 2, Ch. 5)	Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system	
Heat exchanger group	180		240		250		250		250		250		300		300		300	
El. controls group	63		100		113		113		113		113		113		113		113	
Burner group	29		29		36		36		36		36		36		36		36	
Fuel controls group	44		44		44		44		44		75		100		100		100	
CH-return group	80		110		120		120		120		120		120		120		120	
CH-supply group	13		13		13		13		13		13		13		13		13	
Fan group	60		70		70		70		80		80		80		80		80	
Casing	60		60		60		60		80		80		80		80		80	
Condensate collect	10		44		44		44		44		44		44		44		44	
Hot water group	21		21		21		21		21		21		21		21		21	
Packaging etc.	20		20		20		20		20		20		20		20		20	
Extra oil-fired (*0,11)	486		630		663		663		688		715		778		778		778	
Subtotal OEM		1.064		1.380		1.453		1.453		1.508		1.565		1.703		1.703		1.703
Labour		319		414		436		436		452		470		511		511		511
Overhead		745		966		1.017		1.017		1.055		1.096		1.192		1.192		1.192
total MSP		2.129		2.759		2.905		2.905		3.016		3.131		3.407		3.407		3.407
Ex wholesale		2.768		3.587		3.777		3.777		3.920		4.070		4.428		4.428		4.428
Ex installer excl. VAT		3.300		4.277		4.503		4.503		4.674		4.852		5.280		5.280		5.280
BOILER consumer street price incl. VAT		3.927		5.089		5.359		5.359		5.562		5.774		6.283		6.283		6.283
CONTROLLERS incl. VAT		0		100		100		125		365		465		465		465		465
INSTALLATION (Labour, materials, VAT)		2.572		2.652		2.712		2.712		2.712		2.712		2.712		2.712		2.712
subtotal Boiler (all in)		6.498		7.841		8.170		8.195		8.639		8.951		9.460		9.460		9.460
SOLAR materials incl. VAT		0		0		0		0		0		0		0		0		10.100
SOLAR installation incl. VAT		0		0		0		0		0		0		0		0		3.950
HEAT PUMP materials incl. VAT		0		0		0		0		0		0		4.950		8.000		0
HEAT PUMP installation incl. VAT		0		0		0		0		0		0		2.600		5.200		0
TOTAL PURCHASE		6.498		7.841		8.170		8.195		8.639		8.951		17.010		22.660		23.510
Country Rprice corrected		6.498		7.841		8.170		8.195		8.639		8.951		17.010		22.660		23.510

Table 2-24. Life Cycle Costs and Annual Expenditure PER UNIT for size category "XL"

DESIGN OPTIONS	1	2	3	4	5	6	7	8	9
	6 -XL (Xtra Large)	6 -XL (Xtra Large)	6 -XL (Xtra Large)	6 -XL (Xtra Large)	6 -XL (Xtra Large)	6 -XL (Xtra Large)	6 -XL (Xtra Large)	6 -XL (Xtra Large)	6 -XL (Xtra Large)
LCC break down									
Product Price	€ 3.927	€ 5.189	€ 5.459	€ 5.484	€ 5.927	€ 6.239	€ 11.698	€ 14.748	€ 16.848
Installation	€ 2.572	€ 2.652	€ 2.712	€ 2.712	€ 2.712	€ 2.712	€ 5.312	€ 7.912	€ 6.662
Fuel energy (gas, oil)	€ 46.185	€ 32.734	€ 30.049	€ 28.908	€ 27.353	€ 25.353	€ 6.253	€ 4.994	€ 18.925
Electricity	€ 2.442	€ 1.811	€ 1.815	€ 1.110	€ 1.110	€ 975	€ 13.594	€ 8.442	€ 1.056
Repair & Maintenance	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573
TOTAL LCC	€ 57.697	€ 44.958	€ 42.607	€ 40.786	€ 39.674	€ 37.851	€ 39.429	€ 38.668	€ 46.063
Annual expenditure									
Product Price	€ 231	€ 305	€ 321	€ 323	€ 349	€ 367	€ 688	€ 868	€ 991
Installation	€ 151	€ 156	€ 160	€ 160	€ 160	€ 160	€ 312	€ 465	€ 392
Fuel energy (gas, oil)	€ 2.423	€ 1.723	€ 1.591	€ 1.491	€ 1.415	€ 1.308	€ 1.144	€ 765	€ 996
Electricity	€ 171	€ 127	€ 127	€ 78	€ 78	€ 68	€ 951	€ 591	€ 74
Repair & Maintenance	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180
TOTAL expenditure/a	€ 3.157	€ 2.490	€ 2.378	€ 2.231	€ 2.180	€ 2.083	€ 3.275	€ 2.868	€ 2.633
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 6.498	€ 7.841	€ 8.170	€ 8.195	€ 8.639	€ 8.951	€ 17.010	€ 22.660	€ 23.510
Lifetime Running costs (NPV)	€ 51.199	€ 37.117	€ 34.437	€ 32.591	€ 31.035	€ 28.901	€ 22.419	€ 16.008	€ 22.553
Life Cycle Costs LCC	€ 57.697	€ 44.958	€ 42.607	€ 40.786	€ 39.674	€ 37.851	€ 39.429	€ 38.668	€ 46.063
Simple Payback Period PBB	reference yrs	1,9 yrs	2,0 yrs	1,8 yrs	2,1 yrs	2,2 yrs	8,9 yrs	10,1 yrs	11,8 yrs

Table 2-25. Environmental Impact PER UNIT over lifetime for size category "XL"

DESIGN OPTIONS		1		2		3		4		5		6		7		8		9	
		6 -XL (Xtra Large)		6 -XL (Xtra Large)		6 -XL (Xtra Large)		6 -XL (Xtra Large)		6 -XL (Xtra Large)		6 -XL (Xtra Large)		6 -XL (Xtra Large)		6 -XL (Xtra Large)		6 -XL (Xtra Large)	
ENVIRONMENTAL IMPACT PER UNIT OVER LIFE																			
MATERIALS		**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE
TOTAL	kg	**129,8**		**129,8**		**129,8**		**129,8**		**129,8**		**129,8**		**129,8**		**129,8**		**129,8**	
of which																			
Disposal	kg	**10,4**		**10,4**		**10,4**		**10,4**		**10,4**		**10,4**		**10,4**		**10,4**		**10,4**	
Recycled	kg	**119,4**		**119,4**		**119,4**		**119,4**		**119,4**		**119,4**		**119,4**		**119,4**		**119,4**	
OTHER RESOURCES																			
Total Energy (GER)	GJ	**2829,8**	2827,2	**2013,2**	2010,5	**1861,1**	1858,4	**1738,2**	1734,9	**1650,2**	1646,5	**1527,3**	1521,6	**1495,9**	1487,3	**991,3**	986,8	**1173,0**	1163,2
of which, electric(in primary	GJ	**204,0**	203,3	**151,4**	150,8	**151,8**	151,2	**93,2**	92,4	**93,3**	92,4	**82,3**	81,1	**1133,4**	1131,9	**703,9**	702,9	**89,7**	87,9
Water (process)	m3	**14,0**	13,6	**10,5**	10,1	**10,5**	10,1	**6,7**	6,2	**6,7**	6,2	**6,0**	5,4	**76,2**	75,5	**47,6**	46,9	**6,8**	5,9
Water (cooling)	m3	**542,6**	542,2	**402,5**	402,1	**403,5**	403,1	**247,0**	246,5	**247,0**	246,5	**217,2**	216,4	**3019,5**	3018,3	**1875,2**	1874,4	**236,0**	234,4
Waste, non-haz./ landfill	kg	**9,5**	4,7	**8,3**	3,5	**8,3**	3,5	**6,9**	2,1	**6,9**	2,1	**6,2**	1,9	**32,5**	26,1	**20,5**	16,2	**7,3**	2,0
Waste, hazardous/ incinera	kg	**307,1**	235,8	**246,2**	174,8	**246,6**	175,3	**206,1**	107,2	**219,8**	107,2	**227,5**	94,1	**1509,4**	1312,3	**934,2**	815,0	**336,1**	101,9
EMISSIONS TO AIR																			
GHG in GWP100	tCO2	**175,8**	175,6	**125,0**	124,8	**115,3**	115,1	**108,6**	108,4	**103,1**	102,8	**95,5**	95,1	**72,6**	72,0	**49,1**	48,7	**72,9**	72,2
AP Acidification	kgSOx	**180,9**	179,9	**130,2**	129,2	**122,9**	121,9	**104,9**	103,6	**100,7**	99,3	**92,5**	90,9	**311,0**	308,7	**196,3**	194,8	**77,6**	74,9
VOC Volatile Organic Com	kg	**2,6**	2,6	**1,8**	1,8	**1,7**	1,7	**1,6**	1,6	**1,5**	1,5	**1,4**	1,4	**0,8**	0,8	**0,6**	0,5	**1,1**	1,0
POP Persist.Organic Poll.	mg i-Teq	**2,1**	1,3	**1,7**	1,0	**1,7**	1,0	**1,6**	0,6	**1,8**	0,6	**2,5**	0,5	**10,4**	7,4	**6,1**	4,6	**4,1**	0,6
HMa Heavy Metals	mg Ni	**4,4**	3,5	**3,5**	2,6	**3,5**	2,6	**2,7**	1,6	**2,9**	1,6	**2,7**	1,4	**21,2**	19,5	**13,5**	12,1	**3,6**	1,6
PAHs	mg	**0,7**	0,5	**0,5**	0,4	**0,5**	0,4	**0,4**	0,3	**0,4**	0,3	**0,3**	0,2	**2,4**	2,3	**1,6**	1,4	**0,4**	0,3
PM Particulate Matter	kg	**5,1**	4,2	**4,3**	3,2	**4,2**	3,1	**4,0**	2,7	**4,0**	2,7	**6,4**	2,5	**14,6**	7,4	**7,0**	5,0	**9,8**	2,3
EMISSIONS TO WATER																			
HMw Heavy Metals	g Hg/20	**1,9**	1,3	**1,6**	1,0	**1,6**	1,0	**1,3**	0,6	**1,4**	0,6	**1,2**	0,5	**8,2**	7,3	**5,4**	4,5	**1,7**	0,6
EP Eutrophication	g PO4	**18,0**	6,3	**16,3**	4,6	**16,3**	4,6	**17,3**	2,8	**18,6**	2,8	**19,4**	2,5	**57,7**	34,8	**42,7**	21,6	**32,9**	2,7
ANNUAL SPACE HEAT ENERGY breakdown																			
TOTAL	kWh/a	**45965**	100%	**32672**	100%	**30171**	100%	**28283**	100%	**26831**	100%	**24806**	100%	**21690**	100%	**14507**	100%	**18899**	100%
Tset	kWh/a	**19949**	43%	**13222**	40%	**13222**	44%	**13222**	47%	**13222**	49%	**13222**	53%	**13222**	61%	**13222**	91%	**13222**	70%
Tmass	kWh/a	**335**	1%	**3394**	10%	**3394**	11%	**3763**	13%	**3763**	14%	**3763**	15%	**3763**	17%	**3763**	26%	**3763**	20%
Tintrans	kWh/a	**0**	0%	**2239**	7%	**2239**	7%	**2155**	8%	**2155**	8%	**2155**	9%	**2155**	10%	**2155**	15%	**2155**	11%
Tfluct (cntrl)	kWh/a	**3109**	7%	**2971**	9%	**1372**	5%	**1391**	5%	**570**	2%	**160**	1%	**159**	1%	**159**	1%	**159**	1%
Tstrat(emit)	kWh/a	**2507**	5%	**2291**	7%	**2194**	7%	**2248**	8%	**2151**	8%	**1711**	7%	**1714**	8%	**1714**	12%	**1714**	9%
Distr. loss	kWh/a	**6514**	14%	**3536**	11%	**3514**	12%	**3037**	11%	**3041**	11%	**2631**	11%	**2632**	12%	**2632**	18%	**2632**	14%
Steady st.	kWh/a	**8450**	18%	**1645**	5%	**858**	3%	**-24**	0%	**-89**	0%	**-255**	-1%	**119**	1%	**95**	1%	**351**	2%
Start/stop	kWh/a	**216**	0%	**126**	0%	**118**	0%	**117**	0%	**103**	0%	**49**	0%	**8**	0%	**6**	0%	**23**	0%
Stby heat	kWh/a	**2037**	4%	**1135**	3%	**1142**	4%	**1081**	4%	**620**	2%	**234**	1%	**56**	0%	**45**	0%	**168**	1%
Electric	kWh/a	**2848**	6%	**2112**	6%	**2117**	7%	**1295**	5%	**1295**	5%	**1136**	5%	**1135**	5%	**1135**	8%	**1135**	6%
Credit solar	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**6423**	0%
Credit HP	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**3273**	0%	**10419**	0%	**0**	0%
Net heating efficiency	%	**44%**		**58%**		**62%**		**68%**		**71%**		**77%**		**88%**		**132%**		**101%**	
gross heat load	kWh/a	**23.766**		**22.387**		**22.411**		**22.723**		**22.723**		**22.723**		**22.819**		**22.819**		**22.819**	
net heat load	kWh/a	**20.284**		**18.856**		**18.856**		**19.140**		**19.140**		**19.140**		**19.140**		**19.140**		**19.140**	
net load per unit floor area	kWh/m2	**73**		**52**		**48**		**45**		**43**		**40**		**35**		**23**		**30**	
CH-system efficiency	%	**51%**		**66%**		**72%**		**78%**		**82%**		**89%**		**101%**		**152%**		**116%**	

2.6 Design Options and Impact size category “XXL”

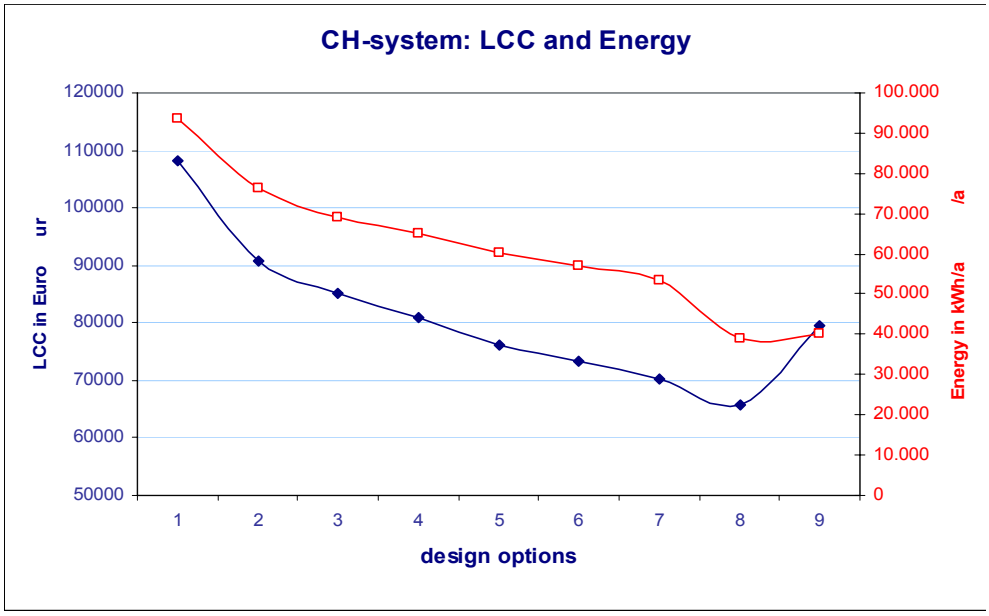
The XXL boiler is a product typically installed as collective boiler in apartment blocks, suited for heating in average 8 existing apartments, or a double number of new apartments.

The following design options have been elaborated for boiler systems in size class XXL.

Explanation Design Options

1. Reference (see first column table 2-18)
2. Improvement in boiler temperature control system; instead of a fixed BT a **weather controlled boiler temperature** with **auto timer control** is applied.
3. Option 2, extended with an improvement of the steady-state efficiency from **80/80 to 85/91** and an **electronic optimiser**.
4. Option 3, with an improvement of the steady-state efficiency from **85/91 tot 89/97** and a **reduced CPU power consumption to 28/30 watts.**
5. Option 4, extended with an improvement of the radiator valves **from 2K to 1K TRV’s** and a **reduction of the steady-state heat losses** from 1 **to 0,5 %.**
6. Option 5, extended with an improved **turndown ratio of 20%**, a further reduced power consumption of the CPU to 14/16 watts and **motorized radiator valves with a PID loop**.
7. Option 6, extended with an improved **turndown ratio of 10%**, improvement of the steady-state efficiency to **96/97 %** through a **tertiary heat exchanger** and **CPU controlled motorized radiator valves.**
8. Option 7, however with steady-state efficiency of **89/97%** and improved with an **electric 7 kW collective water-to-water heat pump** with a nominal COP of **3,8** (at 10/50 C), CH fraction served is 100%).
9. Option 7, extended with **40 m² of the vacutube-type solar collector** (tank position indoors) with a CH-fraction served of 100%.

Figure 2-26.
Design options, lifecycle costs and annual energy consumption category "XXL"



The average annual primary energy consumption for the BaseCase "XXL" sized boilers amounts to 93.407 kWh (net heating efficiency is 45%), with a total lifecycle costs of €108.111,-

The LLCC-option clearly is **Design Option 8**, that combines a state-of-the-art condensing boiler with a collective electric water-to-water heat pump and achieves a net heating efficiency of 101%. However, the initial investments needed are almost a factor 3 higher than the basecase option and since the investments and related profits (lower energy bill) are not always in the same hands, some kind of political and financial support is appropriate to facilitate the achievement of this **LLCC-level of 101%**.

With this LLCC-level the annual primary energy consumption is reduced from 93.407 (basecase) to 39.079 kWh, a reduction of 57%! The lifecycle costs are reduced from €108.111,- to € 65.623,- (reduction of 39% !).

The net heating efficiency of this Design Option 8 can be further improved by increasing the nominal load of the heat pump. If for instance a heat pump of 20 kW is used, the net heating efficiency rises up to **135%** and lifecycle costs increase to € 73.738,-. This can be seen as **BAT level for the collective boiler**.

Design Options nr. 9 combines a state-of-the-art condensing boiler with 40 m² vacutube solar collectors (5 m² for each apartment), resulting in net heating efficiencies of around 98% with lifecycle costs of around € 79.600,-. Considerably lower than the current basecase lifecycle costs but still around €14.000,- more than the LLCC level.

The ultimate BAT level is best represented with a system that combined individual local state-of-the-art condensing boilers with a collective water-to-water heat pump. Net heating efficiencies can then be increased to levels above 140 % (see also BAT-options for XXS to S)

The impact of the Design Options are summarized in the tables on the next four pages:

Table 2-27: Input Design Options in EcoBoiler Integrated Model for size category "XXL"

Table 2-28: Prices & Installation costs PER UNIT for Design Options size category "XXL"

Table 2-29: Life Cycle Costs and Annual Expenditure PER UNIT for size category "XXL"

Table 2-30: Environmental Impact PER UNIT over lifetime for size category "XXL"

Table 2-27. Input Design Options in EcoBoiler Integrated Model for size category "XXL"

DESIGN OPTIONS	1 BaseCase	2	3	4	5	6	7	8	9
INPUTS CH									
CH-power class	7 -XXL (XX Large)	7 -XXL (XX Large)	7 -XXL (XX Large)	7 -XXL (XX Large)	7 -XXL (XX Large)	7 -XXL (XX Large)	7 -XXL (XX Large)	7 -XXL (XX Large)	7 -XXL (XX Large)
	7 -exist. building (8 ap)	*7 -exist. building (8 ap)*	*7 -exist. building (8 ap)*	*7 -exist. building (8 ap)*	*7 -exist. building (8 ap)*	*7 -exist. building (8 ap)*	*7 -exist. building (8 ap)*	*7 -exist. building (8 ap)*	*7 -exist. building (8 ap)*
boiler characteristics									
power input in kW*	115 kW	115 kW	115 kW	115 kW	115 kW	115 kW	115 kW	115 kW	115 kW
turndown ratio	33%	33%	33%	33%	33%	20%	10%	10%	10%
standby heat loss (% of Pnom)	1,0%	1,0%	1,0%	1,0%	0,5%	0,5%	0,5%	0,5%	0,5%
steady st. efficiency %	5 -80/80/80/80	5 -80/80/80/80	3 -85/85/91/91	1 -89/89/97/97	1 -89/89/97/97	1 -89/89/97/97	9 -ideal 96/96/97/97	1 -89/89/97/97	9 -ideal 96/96/97/97
fuel (dewpoint)	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas
air-fuel mix control	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	3 -ionisation	2 -pneumatic	3 -ionisation
circ. pump power	7 -200W	7 -200W	7 -200W	7 -200W	7 -200W	7 -200W	7 -200W	7 -200W	7 -200W
fan power	6 -P=90W	6 -P=90W	6 -P=90W	6 -P=90W	6 -P=90W	6 -P=90W	6 -P=90W	6 -P=90W	6 -P=90W
CPU power sb/on	8 -P=56/60W	8 -P=56/60W	8 -P=56/60W	7 -P=28/30W	7 -P=28/30W	5 -P=14/16W	5 -P=14/16W	5 -P=14/16W	5 -P=14/16W
controls power sb/on	3 -P=0/18W	3 -P=0/18W	3 -P=0/18W	3 -P=0/18W	3 -P=0/18W	3 -P=0/18W	3 -P=0/18W	3 -P=0/18W	3 -P=0/18W
comb. air intake	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed
boiler mass (empty), kg	221 kg	221 kg	221 kg	221 kg	221 kg	221 kg	221 kg	221 kg	221 kg
water content in kg	20,0 kg	20,0 kg	20,0 kg	20,0 kg	20,0 kg	20,0 kg	20,0 kg	20,0 kg	20,0 kg
envelope volume in m3	1,00 m3	1,00 m3	1,00 m3	1,00 m3	1,00 m3	1,00 m3	1,00 m3	1,00 m3	1,00 m3
noise level in dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A
controllers									
auto-timer control	no	yes	yes	yes	yes	yes	yes	yes	yes
valve control	2 -RTV 2K	2 -RTV 2K	2 -RTV 2K	2 -RTV 2K	3 -RTV 1K	4 -Motor + PID-loop	5 -Motor + CPU	5 -Motor + CPU	5 -Motor + CPU
boiler temp control	4 -fixed BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT
	no	no	yes	yes	yes	yes	yes	yes	yes
autoset weather control	N/A	N/A	no	N/A	N/A	N/A	no	no	no
solar (for combi only)									
collector type	N/A	1 -glazed	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube
collector surface m2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	40,0
tank position	N/A	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors
CH-fraction served	0%	100%	0%	0%	0%	0%	0%	0%	100%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
heat pump (HP)									
Reference type	1 -El. brine/ water 0/5	3 -El. air/ water 7/50	3 -El. air/ water 7/50	3 -El. air/ water 7/5	3 -El. air/ water 7/5	3 -El. air/ water 7/50	2 -El. water/ water 10/5	2 -El. water/ water 10/5	2 -El. water/ water 10/5
Power nominal in kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	7,0 kW	0,0 kW
COP nominal 0/50	0,00	0,00	0,00	2,50	0,00	3,50	3,70	3,80	3,70
Ratio CH : DHW	100%	80%	80%	80%	80%	80%	80%	80%	80%
CH-fraction served	100%	0%	100%	100%	100%	50%	100%	100%	0%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
MAIN ENERGY OUTPUTS									
Net heating efficiency	45%	51%	57%	61%	66%	69%	74%	101%	98%
Primary energy consumption	93407 kWh/a	76361 kWh/a	69143 kWh/a	65041 kWh/a	60141 kWh/a	56981 kWh/a	53228 kWh/a	39079 kWh/a	40148 kWh/a
-of which fuel (primary kWh GCV)	89492 kWh/a	73292 kWh/a	65698 kWh/a	61924 kWh/a	57024 kWh/a	54148 kWh/a	50590 kWh/a	22558 kWh/a	37359 kWh/a
-of which electricity (primary kWh)	3.915 kWh/a	3.069 kWh/a	3.445 kWh/a	3.116 kWh/a	3.116 kWh/a	2.833 kWh/a	2.638 kWh/a	16.522 kWh/a	2.788 kWh/a
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 9.171	€ 9.351	€ 11.294	€ 11.285	€ 11.633	€ 11.979	€ 12.960	€ 25.439	€ 35.810
Lifetime Running costs (NPV)	€ 98.940	€ 81.377	€ 73.807	€ 69.603	€ 64.511	€ 61.279	€ 57.413	€ 40.185	€ 43.791
Life Cycle Costs LCC	€ 108.111	€ 90.729	€ 85.101	€ 80.888	€ 76.144	€ 73.258	€ 70.373	€ 65.623	€ 79.601
Simple Payback Period PBB	reference yrs	0,2 yrs	1,7 yrs	1,4 yrs	1,4 yrs	1,5 yrs	1,8 yrs	6,1 yrs	9,7 yrs

Table 2-28. Prices & Installation costs PER UNIT for Design Options size category "XXL"

DESIGN OPTIONS	1		2		3		4		5		6		7		8		9	
	7 -XXL (XX Large)		7 -XXL (XX Large)		7 -XXL (XX Large)		7 -XXL (XX Large)		7 -XXL (XX Large)		7 -XXL (XX Large)		7 -XXL (XX Large)		7 -XXL (XX Large)		7 -XXL (XX Large)	
PRODUCT PRICE break down																		
OEM Subass. Costs (Task 2, Ch. 5)	Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system	
Heat exchanger group	270		270		345		375		375		375		450		375		450	
El. controls group	78		78		131		141		141		141		141		141		141	
Burner group	36		36		43		45		45		45		45		45		45	
Fuel controls group	55		55		66		55		55		70		125		94		125	
CH-return group	100		100		150		150		150		150		150		150		150	
CH-supply group	16		16		19		16		16		16		16		16		16	
Fan group	75		75		105		88		100		100		100		100		100	
Casing	90		90		90		90		120		120		120		120		120	
Condensate collect	13		13		66		55		55		55		55		55		55	
Hot water group	21		21		21		21		21		21		21		21		21	
Packaging etc.	30		30		30		30		30		30		30		30		30	
Extra oil-fired (*0,11)	658		658		895		894		929		943		1.052		962		1.052	
Subtotal OEM		**1.440**		**1.440**		**1.960**		**1.958**		**2.036**		**2.065**		**2.303**		**2.108**		**2.303**
Labour		432		432		588		587		611		619		691		632		691
Overhead		1.008		1.008		1.372		1.370		1.425		1.445		1.612		1.476		1.612
total MSP		**2.881**		**2.881**		**3.921**		**3.916**		**4.072**		**4.130**		**4.607**		**4.216**		**4.607**
Ex wholesale		3.745		3.745		5.097		5.090		5.294		5.368		5.989		5.481		5.989
Ex installer excl. VAT		4.466		4.466		6.077		6.069		6.312		6.401		7.141		6.535		7.141
BOILER consumer street price incl. VAT		**5.314**		**5.314**		**7.232**		**7.222**		**7.511**		**7.617**		**8.497**		**7.776**		**8.497**
CONTROLLERS incl. VAT		0		100		125		125		125		365		465		465		465
INSTALLATION (Labour, materials, VAT)		3.857		3.937		3.937		3.937		3.997		3.997		3.997		3.997		3.997
subtotal Boiler (all in)		**9.171**		**9.351**		**11.294**		**11.285**		**11.633**		**11.979**		**12.960**		**12.239**		**12.960**
SOLAR materials incl. VAT		0		0		0		0		0		0		0		0		16.500
SOLAR installation incl. VAT		0		0		0		0		0		0		0		0		6.350
HEAT PUMP materials incl. VAT		0		0		0		0		0		0		0		8.000		0
HEAT PUMP installation incl. VAT		0		0		0		0		0		0		0		5.200		0
TOTAL PURCHASE		**9.171**		**9.351**		**11.294**		**11.285**		**11.633**		**11.979**		**12.960**		**25.439**		**35.810**
Country Rprice corrected		**9.171**		**9.351**		**11.294**		**11.285**		**11.633**		**11.979**		**12.960**		**25.439**		**35.810**

Table 2-29. Life Cycle Costs and Annual Expenditure PER UNIT for size category "XXL"

DESIGN OPTIONS	1 7 -XXL (XX Large)	2 7 -XXL (XX Large)	3 7 -XXL (XX Large)	4 7 -XXL (XX Large)	5 7 -XXL (XX Large)	6 7 -XXL (XX Large)	7 7 -XXL (XX Large)	8 7 -XXL (XX Large)	9 7 -XXL (XX Large)
LCC break down									
Product Price	€ 5.314	€ 5.414	€ 7.357	€ 7.347	€ 7.636	€ 7.982	€ 8.962	€ 16.241	€ 25.462
Installation	€ 3.857	€ 3.937	€ 3.937	€ 3.937	€ 3.997	€ 3.997	€ 3.997	€ 9.197	€ 10.347
Fuel energy (gas, oil)	€ 93.010	€ 76.173	€ 68.281	€ 64.359	€ 59.266	€ 56.276	€ 52.579	€ 23.444	€ 38.828
Electricity	€ 3.357	€ 2.632	€ 2.954	€ 2.672	€ 2.672	€ 2.430	€ 2.262	€ 14.168	€ 2.391
Repair & Maintenance	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573	€ 2.573
TOTAL LCC	€ 108.111	€ 90.729	€ 85.101	€ 80.888	€ 76.144	€ 73.258	€ 70.373	€ 65.623	€ 79.601
Annual expenditure									
Product Price	€ 313	€ 318	€ 433	€ 432	€ 449	€ 470	€ 527	€ 955	€ 1.498
Installation	€ 227	€ 232	€ 232	€ 232	€ 235	€ 235	€ 235	€ 541	€ 609
Fuel energy (gas, oil)	€ 4.778	€ 3.906	€ 3.537	€ 3.327	€ 3.077	€ 2.915	€ 2.723	€ 1.999	€ 2.054
Electricity	€ 235	€ 184	€ 207	€ 187	€ 187	€ 170	€ 158	€ 991	€ 167
Repair & Maintenance	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180	€ 180
TOTAL expenditure/a	€ 5.733	€ 4.821	€ 4.588	€ 4.358	€ 4.128	€ 3.970	€ 3.824	€ 4.667	€ 4.508
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 9.171	€ 9.351	€ 11.294	€ 11.285	€ 11.633	€ 11.979	€ 12.960	€ 25.439	€ 35.810
Lifetime Running costs (NPV)	€ 98.940	€ 81.377	€ 73.807	€ 69.603	€ 64.511	€ 61.279	€ 57.413	€ 40.185	€ 43.791
Life Cycle Costs LCC	€ 108.111	€ 90.729	€ 85.101	€ 80.888	€ 76.144	€ 73.258	€ 70.373	€ 65.623	€ 79.601
Simple Payback Period PBB	reference yrs	0,2 yrs	1,7 yrs	1,4 yrs	1,4 yrs	1,5 yrs	1,8 yrs	6,1 yrs	9,7 yrs

Table 2-30. Environmental Impact PER UNIT over lifetime for size category "XXL"

DESIGN OPTIONS		1		2		3		4		5		6		7		8		9	
		7 -XXL (XX Large)		7 -XXL (XX Large)		7 -XXL (XX Large)		7 -XXL (XX Large)		7 -XXL (XX Large)		7 -XXL (XX Large)		7 -XXL (XX Large)		7 -XXL (XX Large)		7 -XXL (XX Large)	
ENVIRONMENTAL IMPACT PER UNIT OVER LIFE																			
MATERIALS		**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE
TOTAL	kg	**221,2**		**221,2**		**221,2**		**221,2**		**221,2**		**221,2**		**221,2**		**221,2**		**221,2**	
of which																			
Disposal	kg	**17,0**		**17,0**		**17,0**		**17,0**		**17,0**		**17,0**		**17,0**		**17,0**		**17,0**	
Recycled	kg	**204,1**		**204,1**		**204,1**		**204,1**		**204,1**		**204,1**		**204,1**		**204,1**		**204,1**	
OTHER RESOURCES																			
Total Energy (GER)	GJ	**5683,4**	5680,7	**4645,3**	4642,6	**4213,8**	4211,1	**3963,3**	3959,9	**3667,9**	3664,2	**3476,1**	3470,4	**3250,3**	3241,7	**2545,8**	2541,3	**2463,8**	2454,0
of which, electric(in primary	GJ	**280,2**	279,5	**219,8**	219,1	**246,6**	246,0	**223,3**	222,5	**223,3**	222,5	**203,4**	202,3	**189,9**	188,3	**1180,6**	1179,7	**200,9**	199,1
Water (process)	m3	**19,1**	18,6	**15,1**	14,6	**16,9**	16,4	**15,4**	14,8	**15,4**	14,8	**14,1**	13,5	**13,3**	12,6	**79,4**	78,6	**14,2**	13,3
Water (cooling)	m3	**745,9**	745,5	**584,7**	584,3	**656,3**	655,9	**593,8**	593,4	**593,8**	593,4	**540,3**	539,5	**503,4**	502,3	**3146,6**	3145,8	**532,5**	530,9
Waste, non-haz./ landfill	kg	**11,3**	6,4	**9,9**	5,0	**10,5**	5,7	**9,9**	5,1	**9,9**	5,1	**8,9**	4,7	**10,8**	4,3	**31,5**	27,2	**9,9**	4,6
Waste, hazardous/ incinera	kg	**395,4**	324,1	**325,4**	254,1	**356,5**	285,2	**356,9**	258,0	**370,6**	258,0	**368,0**	234,6	**415,4**	218,4	**1486,9**	1367,8	**465,0**	230,8
EMISSIONS TO AIR																			
GHG in GWP100	tCO2	**343,9**	343,7	**281,3**	281,1	**254,3**	254,1	**239,4**	239,1	**221,2**	221,0	**209,9**	209,4	**196,3**	195,7	**135,4**	135,1	**147,8**	147,1
AP Acidification	kgSOx	**288,0**	286,9	**233,5**	232,5	**222,2**	221,2	**207,3**	206,0	**195,7**	194,3	**183,7**	182,2	**172,3**	170,0	**359,5**	358,0	**143,7**	141,0
VOC Volatile Organic Com	kg	**4,8**	4,8	**4,0**	3,9	**3,6**	3,6	**3,4**	3,4	**3,1**	3,1	**3,0**	2,9	**2,8**	2,7	**1,7**	1,6	**2,1**	2,0
POP Persist.Organic Poll.	mg i-Teq	**2,6**	1,8	**2,2**	1,4	**2,3**	1,6	**2,5**	1,5	**2,6**	1,5	**3,3**	1,3	**4,2**	1,2	**9,2**	7,7	**4,8**	1,3
HMa Heavy Metals	mg Ni	**5,7**	4,8	**4,6**	3,8	**5,1**	4,3	**5,0**	3,9	**5,1**	3,9	**4,7**	3,5	**5,0**	3,3	**21,6**	20,3	**5,5**	3,5
PAHs	mg	**0,9**	0,7	**0,7**	0,6	**0,8**	0,6	**0,7**	0,6	**0,7**	0,6	**0,6**	0,5	**0,6**	0,5	**2,6**	2,4	**0,7**	0,5
PM Particulate Matter	kg	**7,0**	6,1	**6,1**	5,1	**6,0**	4,9	**5,9**	4,6	**5,8**	4,4	**8,1**	4,2	**11,2**	4,0	**10,3**	8,3	**11,1**	3,5
EMISSIONS TO WATER																			
HMw Heavy Metals	g Hg/20	**2,4**	1,8	**2,0**	1,4	**2,2**	1,6	**2,2**	1,4	**2,3**	1,4	**2,0**	1,3	**2,1**	1,2	**8,5**	7,6	**2,4**	1,3
EP Eutrophication	g PO4	**20,3**	8,6	**18,4**	6,7	**19,3**	7,6	**21,3**	6,8	**22,6**	6,8	**23,1**	6,2	**28,7**	5,8	**57,4**	36,3	**36,3**	6,1
ANNUAL SPACE HEAT ENERGY breakdown																			
TOTAL	kWh/a	**93407**	100%	**76361**	100%	**69143**	100%	**65041**	100%	**60141**	100%	**56981**	100%	**53228**	100%	**39079**	100%	**40148**	100%
Tset	kWh/a	**41924**	45%	**30392**	40%	**30392**	44%	**30392**	47%	**30392**	51%	**30392**	53%	**30392**	57%	**30392**	78%	**30392**	76%
Tmass	kWh/a	**271**	0%	**6362**	8%	**7041**	10%	**7041**	11%	**7041**	12%	**7041**	12%	**7041**	13%	**7041**	18%	**7041**	18%
Tintrans	kWh/a	**0**	0%	**1984**	3%	**1990**	3%	**1990**	3%	**1990**	3%	**1990**	3%	**1990**	4%	**1990**	5%	**1990**	5%
Tfluct (cntrl)	kWh/a	**5262**	6%	**5082**	7%	**5129**	7%	**5138**	8%	**2517**	4%	**928**	2%	**282**	1%	**282**	1%	**282**	1%
Tstrat(emit)	kWh/a	**3888**	4%	**3758**	5%	**3790**	5%	**3790**	6%	**3668**	6%	**3502**	6%	**3116**	6%	**3108**	8%	**3116**	8%
Distr. loss	kWh/a	**14289**	15%	**7280**	10%	**6885**	10%	**6895**	11%	**6806**	11%	**6498**	11%	**5694**	11%	**5680**	15%	**5694**	14%
Steady st.	kWh/a	**17584**	19%	**14714**	19%	**6765**	10%	**2914**	4%	**2275**	4%	**1843**	3%	**1025**	2%	**822**	2%	**749**	2%
Start/stop	kWh/a	**604**	1%	**374**	0%	**385**	1%	**390**	1%	**332**	1%	**267**	0%	**111**	0%	**71**	0%	**80**	0%
Stby heat	kWh/a	**5669**	6%	**3346**	4%	**3321**	5%	**3375**	5%	**2002**	3%	**1686**	3%	**938**	2%	**405**	1%	**684**	2%
Electric	kWh/a	**3915**	4%	**3069**	4%	**3445**	5%	**3116**	5%	**3116**	5%	**2833**	5%	**2638**	5%	**2638**	7%	**2638**	7%
Credit solar	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**12520**	0%
Credit HP	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**13350**	0%	**0**	0%
Net heating efficiency	%	**45%**		**51%**		**57%**		**61%**		**66%**		**69%**		**74%**		**101%**		**98%**	
gross heat load	kWh/a	**48.638**		**45.129**		**45.953**		**46.045**		**46.045**		**46.045**		**46.229**		**46.045**		**46.229**	
net heat load	kWh/a	**42.195**		**38.738**		**39.423**		**39.423**		**39.423**		**39.423**		**39.423**		**39.423**		**39.423**	
net load per unit floor area	kWh/m2	**175**		**143**		**130**		**122**		**113**		**107**		**100**		**73**		**75**	
CH system efficiency	%	**52%**		**58%**		**66%**		**70%**		**75%**		**80%**		**85%**		**116%**		**113%**	

2.7 Design Options and Impact size category "3XL & 4XL"

During the last expert meeting, the commission indicated its interest in also the very large gas appliances, i.e. with limited production series. To accommodate this wish we have defined size-classes 3XL and 4XL. Typically this would be heating systems with – for a 3XL boiler - a net heat load of around 100.000 kWh/a and a Pnom somewhere between 150 and 350 kW for instance for apartment buildings (16 – 24 existing apt.) or buildings that combine shops - and offices. The 4XL boiler typically is a boiler with a nominal capacity above 350 kW, serving an average net heat load of over 300.000 kWh per annum (high-rise buildings with 60 apts., large office buildings, hospitals, shopping malls (in cascade configurations)).

A first Indication

Although this Preparatory Study mainly focuses on boilers with a heat output below a 100 kW, VHK did a preliminary assessment on the design options for these larger size-categories, mainly because the related energy consumption is substantial. Resulting figures must therefore be interpreted as indicative and preliminary.

The design options that have been elaborated for boiler systems in size class 3XL and 4XL are similar to the ones described in the previous paragraph that deals with the XXL/size.

Explanation Design Options

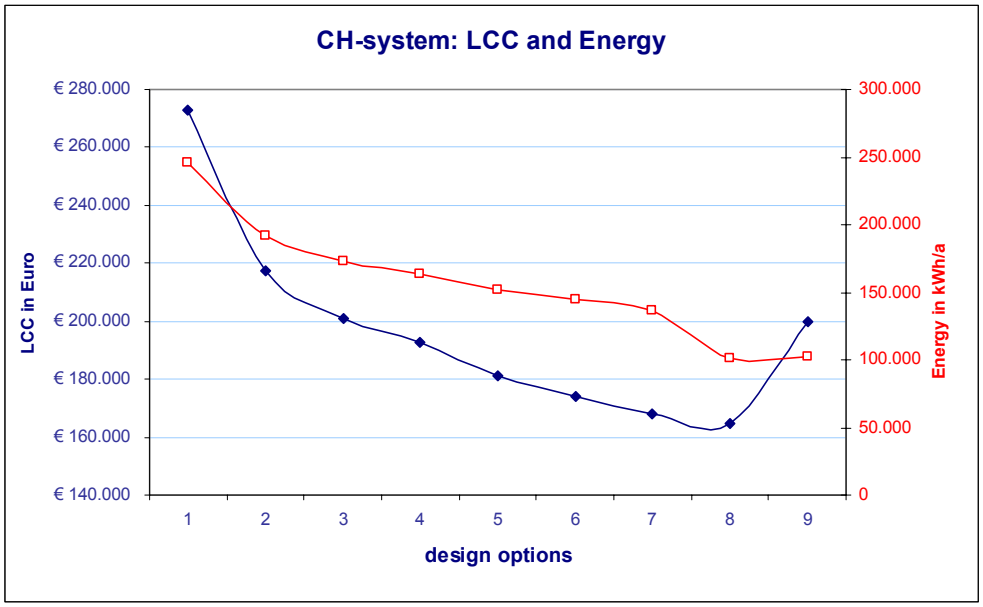
1. Reference (see first column table 2-32 and 2-37))
2. Improvement in boiler temperature control system; instead of a fixed BT a **weather controlled boiler temperature** with **auto timer control** is applied.
3. Option 2, extended with an improvement of the steady-state efficiency from **80/80 to 85/91** and an **electronic optimiser**.
4. Option 3, with an improvement of the steady-state efficiency from **85/91 tot 89/97.**
5. Option 4, extended with an improvement of the radiator valves **from 2K to 1K TRV's** and a **reduction of the steady-state heat losses** from 1 **to 0,5 %.**
6. Option 5, extended with an improved **turndown ratio of 20%** and **motorized radiator valves with a PID loop**.
7. Option 6, extended with an improved **turndown ratio of 10%**, improvement of the steady-state efficiency to **96/97 %** through a **tertiary heat exchanger, CPU controlled motorized radiator valves** and a **reduction of the CPU power consumption**
8. For 3XL : Option 7, extended with an **electric 25 kW collective water-to-water heat pump** with a nominal COP of **4,1** (at 10/50 C), CH fraction served is 100%).

   For 4XL: Option 7, extended with an **electric 70 kW collective water-to water heat pump** with a nominal COP of **4,3** (at 10/50 C), CH fraction served is 100%).
9. For 3XL: Option 7, extended with **120 m² of the vacutube-type solar collector** (6 m² per apartment, tank position indoors) with a CH-fraction served of 100%.

   For 4XL: Option 7, extended with **400 m² of the vacutube-type solar collector** (6,6 m² per apartment, tank position indoors) with a CH-fraction served of 100%.

2.7.1 Results size-class 3XL

Figure 2-31.
Design options, lifecycle costs and annual energy consumption category "3XL"



The average annual primary energy consumption for the BaseCase "3XL" sized boilers amounts to 246.159 kWh (net heating efficiency is 43%), with a total lifecycle costs of €272.770,-

The LLCC-option clearly is **Design Option 8**, that combines a state-of-the-art condensing boiler with a collective electric water-to-water heat pump and achieves a net heating efficiency of **98%**. With this **LLCC-level** the annual primary energy consumption is reduced from 246.159 (basecase) to 101.118 kWh, a reduction of 59%! The lifecycle costs are reduced from € 272.770,- to € 164.827,- (reduction of 40% !).

The net heating efficiency of this Design Option 8 can be further improved by increasing the nominal load of the heat pump. If for instance a heat pump of 54 kW is used, the net heating efficiency rises up to **115%** and lifecycle costs increase to € 190.187,-. This can be seen as **BAT level for the collective boiler**.

Design Options nr. 9 combines a state-of-the-art condensing boiler with 120 m² vacutube solar collectors (6 m² for each apartment), resulting in net heating efficiencies of around 97% with lifecycle costs of around € 199.739,-. Considerably lower than the current basecase lifecycle costs but still around €35.000,- more than the LLCC level.

The ultimate BAT level is best represented with a system that combined individual local state-of-the-art condensing boilers with a collective water-to-water heat pump. Net heating efficiencies can then be increased to levels above 140 % (see also BAT-options for XXS to S)

The impact of the Design Options are summarized in the tables on the next four pages:

Table 2-32: Input Design Options in EcoBoiler Integrated Model for size category "3XL"

Table 2-33: Prices & Installation costs PER UNIT for Design Options size category "3XL"

Table 2-34: Life Cycle Costs and Annual Expenditure PER UNIT for size category "3XL"

Table 2-35: Environmental Impact PER UNIT over lifetime for size category "3XL"

Table 2-32. Input Design Options in EcoBoiler Integrated Model for size category "3XL"

DESIGN OPTIONS	1 BaseCase	2	3	4	5	6	7	8	9
INPUTS CH									
CH-power class	8 -3XL	8 -3XL	8 -3XL	8 -3XL	8 -3XL	8 -3XL	8 -3XL	8 -3XL	8 -3XL
	9 -high-rise avg. (20 ap)	*9 -high-rise avg. (20 ap)*	*9 -high-rise avg. (20 ap)*	*9 -high-rise avg. (20 ap)*	*9 -high-rise avg. (20 ap)*	*9 -high-rise avg. (20 ap)*	*9 -high-rise avg. (20 ap)*	*9 -high-rise avg. (20 ap)*	*9 -high-rise avg. (20 ap)*
boiler characteristics									
power input in kW*	250 kW	250 kW	250 kW	250 kW	250 kW	250 kW	250 kW	250 kW	250 kW
turndown ratio	33%	33%	33%	33%	33%	20%	10%	10%	10%
standby heat loss (% of Pnom)	1,0%	1,0%	1,0%	1,0%	0,5%	0,5%	0,5%	0,5%	0,5%
steady st. efficiency %	5 -80/80/80/80	5 -80/80/80/80	3 -85/85/91/91	1 -89/89/97/97	1 -89/89/97/97	1 -89/89/97/97	9 -ideal 96/96/97/97	9 -ideal 96/96/97/97	9 -ideal 96/96/97/97
fuel (dewpoint)	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas
air-fuel mix control	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	3 -ionisation	3 -ionisation	3 -ionisation
circ. pump power	8 -600W	8 -600W	8 -600W	8 -600W	8 -600W	8 -600W	8 -600W	8 -600W	8 -600W
fan power	7 -P=150W	7 -P=150W	7 -P=150W	7 -P=150W	7 -P=150W	7 -P=150W	7 -P=150W	7 -P=150W	7 -P=150W
CPU power sb/on	9 -P=72/80W	9 -P=72/80W	9 -P=72/80W	9 -P=72/80W	9 -P=72/80W	9 -P=72/80W	8 -P=56/60W	8 -P=56/60W	8 -P=56/60W
controls power sb/on	4 -P=0/36W	4 -P=0/36W	4 -P=0/36W	4 -P=0/36W	4 -P=0/36W	4 -P=0/36W	4 -P=0/36W	4 -P=0/36W	4 -P=0/36W
comb. air intake	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed
boiler mass (empty), kg	650 kg	650 kg	650 kg	650 kg	650 kg	650 kg	650 kg	650 kg	650 kg
water content in kg	60,0 kg	60,0 kg	60,0 kg	60,0 kg	60,0 kg	60,0 kg	60,0 kg	60,0 kg	60,0 kg
envelope volume in m3	2,00 m3	2,00 m3	2,00 m3	2,00 m3	2,00 m3	2,00 m3	2,00 m3	2,00 m3	2,00 m3
noise level in dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A
controllers									
auto-timer control	no	yes	yes	yes	yes	yes	yes	yes	yes
valve control	2 -RTV 2K	2 -RTV 2K	2 -RTV 2K	2 -RTV 2K	3 -RTV 1K	4 -Motor + PID-loop	5 -Motor + CPU	5 -Motor + CPU	5 -Motor + CPU
boiler temp control	4 -fixed BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT
	no	no	yes	yes	yes	yes	yes	yes	yes
autoset weather control	N/A	N/A	no	N/A	N/A	N/A	no	no	no
solar (for combi only)									
collector type	N/A	1 -glazed	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube
collector surface m2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	120,0
tank position	N/A	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors
CH-fraction served	0%	100%	0%	0%	0%	0%	0%	0%	100%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
heat pump (HP)									
Reference type	1 -El. brine/ water 0/50	3 -El. air/ water 7/5	3 -El. air/ water 7/50	3 -El. air/ water 7/50	3 -El. air/ water 7/50	3 -El. air/ water 7/50	2 -El. water/ water 10/	2 -El. water/ water 10/5	2 -El. water/ water 10/5
Power nominal in kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	25,0 kW	0,0 kW
COP nominal 0/50	0,00	0,00	0,00	2,50	0,00	3,50	3,70	4,10	3,80
Ratio CH : DHW	100%	80%	80%	80%	80%	80%	80%	80%	80%
CH-fraction served	100%	0%	100%	100%	100%	50%	100%	100%	0%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
MAIN ENERGY OUTPUTS									
Net heating efficiency	43%	51%	57%	61%	65%	69%	73%	98%	97%
Primary energy consumption	246159 kWh/a	191530 kWh/a	173312 kWh/a	164060 kWh/a	152105 kWh/a	144722 kWh/a	136977 kWh/a	101118 kWh/a	102729 kWh/a
-of which fuel (primary kWh GCV)	236126 kWh/a	183971 kWh/a	164671 kWh/a	155367 kWh/a	143412 kWh/a	136560 kWh/a	129678 kWh/a	43166 kWh/a	95029 kWh/a
-of which electricity (primary kWh)	10.033 kWh/a	7.560 kWh/a	8.641 kWh/a	8.693 kWh/a	8.693 kWh/a	8.162 kWh/a	7.299 kWh/a	57.952 kWh/a	7.700 kWh/a
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 15.730	€ 15.729	€ 18.278	€ 19.571	€ 20.148	€ 20.600	€ 22.460	€ 64.460	€ 89.310
Lifetime Running costs (NPV)	€ 257.040	€ 201.465	€ 182.612	€ 173.121	€ 160.869	€ 153.391	€ 145.597	€ 100.367	€ 110.429
Life Cycle Costs LCC	€ 272.770	€ 217.194	€ 200.890	€ 192.692	€ 181.016	€ 173.991	€ 168.057	€ 164.827	€ 199.739
Simple Payback Period PBB	reference yrs	0,0 yrs	0,7 yrs	0,9 yrs	1,0 yrs	1,0 yrs	1,2 yrs	7,4 yrs	10,4 yrs

Table 2-33. Prices & Installation costs PER UNIT for Design Options size category "3XL"

DESIGN OPTIONS	1		2		3		4		5		6		7		8		9	
	8 -3XL		8 -3XL		8 -3XL		8 -3XL		8 -3XL		8 -3XL		8 -3XL		8 -3XL		8 -3XL	
PRODUCT PRICE break down																		
OEM Subass. Costs (Task 2, Ch. 5	Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system	
Heat exchanger group	540		540		690		750		750		750		900		900		900	
El. controls group	156		156		219		281		281		281		281		281		281	
Burner group	72		72		72		90		90		90		90		90		90	
Fuel controls group	109		109		109		109		109		141		250		250		250	
CH-return group	200		200		250		300		300		300		300		300		300	
CH-supply group	31		31		31		31		31		31		31		31		31	
Fan group	150		150		175		175		200		200		200		200		200	
Casing	180		180		180		180		240		240		240		240		240	
Condensate collect	40		25		109		109		109		109		109		109		109	
Hot water group	21		21		21		21		21		21		21		21		21	
Packaging etc.	60		60		60		60		60		60		60		60		60	
Extra oil-fired (*0,11)	1.310		1.298		1.610		1.770		1.841		1.868		2.085		2.085		2.085	
Subtotal OEM		**2.870**		**2.842**		**3.527**		**3.877**		**4.033**		**4.091**		**4.568**		**4.568**		**4.568**
Labour		861		853		1.058		1.163		1.210		1.227		1.370		1.370		1.370
Overhead		2.009		1.990		2.469		2.714		2.823		2.864		3.198		3.198		3.198
total MSP		**5.740**		**5.685**		**7.053**		**7.754**		**8.067**		**8.182**		**9.136**		**9.136**		**9.136**
Ex wholesale		7.462		7.390		9.169		10.080		10.487		10.636		11.877		11.877		11.877
Ex installer excl. VAT		8.897		8.811		10.932		12.019		12.504		12.682		14.161		14.161		14.161
BOILER consumer street price incl. VAT		**10.587**		**10.485**		**13.010**		**14.302**		**14.879**		**15.092**		**16.852**		**16.852**		**16.852**
CONTROLLERS incl. VAT		0		100		125		125		125		365		465		465		465
INSTALLATION (Labour, materials, VAT)		5.143		5.143		5.143		5.143		5.143		5.143		5.143		5.143		5.143
subtotal Boiler (all in)		**15.730**		**15.729**		**18.278**		**19.571**		**20.148**		**20.600**		**22.460**		**22.460**		**22.460**
SOLAR materials incl. VAT		0		0		0		0		0		0		0		0		48.500
SOLAR installation incl. VAT		0		0		0		0		0		0		0		0		18.350
HEAT PUMP materials incl. VAT		0		0		0		0		0		0		0		26.000		0
HEAT PUMP installation incl. VAT		0		0		0		0		0		0		0		16.000		0
TOTAL PURCHASE		**15.730**		**15.729**		**18.278**		**19.571**		**20.148**		**20.600**		**22.460**		**64.460**		**89.310**

Table 2-34. Life Cycle Costs and Annual Expenditure PER UNIT for size category "3XL"

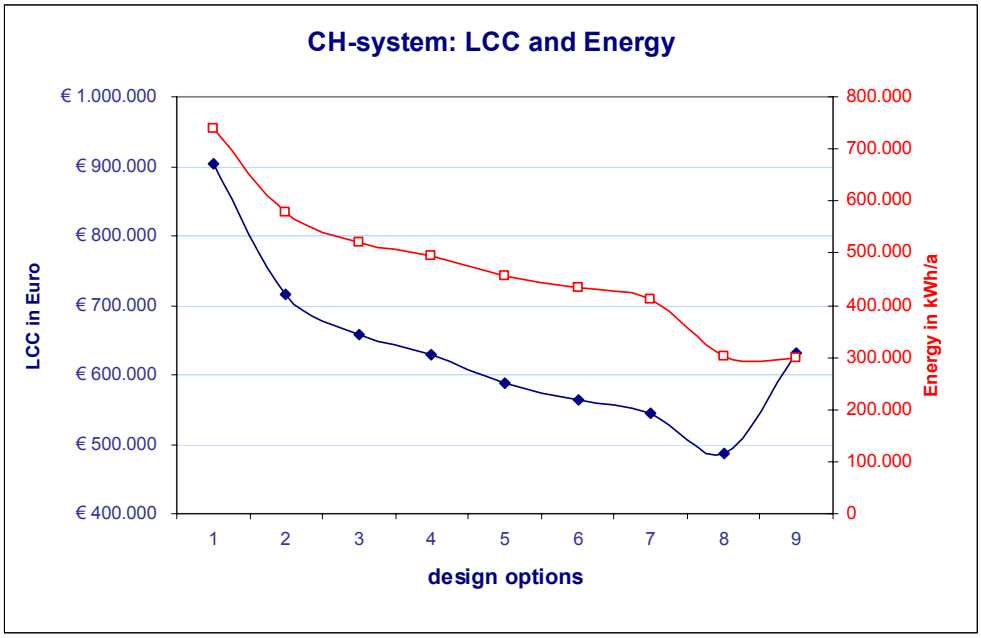
DESIGN OPTIONS	1	2	3	4	5	6	7	8	9
	8 -3XL	8 -3XL	8 -3XL	8 -3XL	8 -3XL	8 -3XL	8 -3XL	8 -3XL	8 -3XL
LCC break down									
Product Price	€ 10.587	€ 10.585	€ 13.135	€ 14.427	€ 15.004	€ 15.457	€ 17.317	€ 43.317	€ 65.817
Installation	€ 5.143	€ 5.143	€ 5.143	€ 5.143	€ 5.143	€ 5.143	€ 5.143	€ 21.143	€ 23.493
Fuel energy (gas, oil)	€ 242.005	€ 188.551	€ 168.771	€ 159.235	€ 146.983	€ 139.961	€ 132.907	€ 44.241	€ 97.395
Electricity	€ 8.603	€ 6.482	€ 7.410	€ 7.455	€ 7.455	€ 6.999	€ 6.259	€ 49.695	€ 6.603
Repair & Maintenance	€ 6.431	€ 6.431	€ 6.431	€ 6.431	€ 6.431	€ 6.431	€ 6.431	€ 6.431	€ 6.431
TOTAL LCC	€ 272.770	€ 217.194	€ 200.890	€ 192.692	€ 181.016	€ 173.991	€ 168.057	€ 164.827	€ 199.739
Annual expenditure									
Product Price	€ 623	€ 623	€ 773	€ 849	€ 883	€ 909	€ 1.019	€ 2.548	€ 3.872
Installation	€ 303	€ 303	€ 303	€ 303	€ 303	€ 303	€ 303	€ 1.244	€ 1.382
Fuel energy (gas, oil)	€ 12.109	€ 9.422	€ 8.525	€ 8.070	€ 7.482	€ 7.119	€ 6.738	€ 4.974	€ 5.053
Electricity	€ 602	€ 454	€ 518	€ 522	€ 522	€ 490	€ 438	€ 3.477	€ 462
Repair & Maintenance	€ 450	€ 450	€ 450	€ 450	€ 450	€ 450	€ 450	€ 450	€ 450
TOTAL expenditure/a	€ 14.086	€ 11.250	€ 10.569	€ 10.193	€ 9.639	€ 9.271	€ 8.947	€ 12.693	€ 11.219
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 15.730	€ 15.729	€ 18.278	€ 19.571	€ 20.148	€ 20.600	€ 22.460	€ 64.460	€ 89.310
Lifetime Running costs (NPV)	€ 257.040	€ 201.465	€ 182.612	€ 173.121	€ 160.869	€ 153.391	€ 145.597	€ 100.367	€ 110.429
Life Cycle Costs LCC	€ 272.770	€ 217.194	€ 200.890	€ 192.692	€ 181.016	€ 173.991	€ 168.057	€ 164.827	€ 199.739
Simple Payback Period PBB	reference yrs	0,0 yrs	0,7 yrs	0,9 yrs	1,0 yrs	1,0 yrs	1,2 yrs	7,4 yrs	10,4 yrs

Table 2-35. Environmental Impact PER UNIT over lifetime for size category "3XL"

DESIGN OPTIONS		1		2		3		4		5		6		7		8		9	
		8 -3XL		8 -3XL		8 -3XL		8 -3XL		8 -3XL		8 -3XL		8 -3XL		8 -3XL		8 -3XL	
ENVIRONMENTAL IMPACT PER UNIT OVER LIFE																			
MATERIALS		**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE
TOTAL	kg	**649,3**		**649,3**		**649,3**		**649,3**		**649,3**		**649,3**		**649,3**		**649,3**		**649,3**	
of which																			
Disposal	kg	**17,0**		**17,0**		**17,0**		**17,0**		**17,0**		**17,0**		**17,0**		**49,6**		**49,6**	
Recycled	kg	**204,1**		**204,1**		**204,1**		**204,1**		**204,1**		**204,1**		**204,1**		**599,7**		**599,7**	
OTHER RESOURCES																			
Total Energy (GER)	GJ	**14822,5**	14819,8	**11530,8**	11528,1	**10455,3**	10452,6	**9904,0**	9900,6	**9190,3**	9186,6	**8745,1**	8739,4	**8275,3**	8266,8	**6739,7**	6716,2	**6297,6**	6225,9
of which, electric(in primary	GJ	**717,0**	716,3	**540,4**	539,8	**617,6**	617,0	**621,4**	620,7	**621,5**	620,7	**583,9**	582,8	**522,7**	521,2	**4141,9**	4137,8	**562,4**	549,8
Water (process)	m3	**48,2**	47,8	**36,4**	36,0	**41,6**	41,1	**41,9**	41,4	**41,9**	41,4	**39,4**	38,9	**35,5**	34,7	**277,6**	275,9	**42,1**	36,7
Water (cooling)	m3	**1910,7**	1910,3	**1439,7**	1439,4	**1645,7**	1645,3	**1655,6**	1655,2	**1655,7**	1655,2	**1554,8**	1554,0	**1391,0**	1389,8	**11037,4**	11034,1	**1476,5**	1466,2
Waste, non-haz./ landfill	kg	**21,3**	16,5	**17,3**	12,4	**19,0**	14,2	**19,1**	14,3	**19,1**	14,3	**17,7**	13,4	**18,5**	12,0	**113,5**	95,3	**68,3**	12,7
Waste, hazardous/ incinera	kg	**901,9**	830,6	**697,1**	625,8	**786,7**	715,4	**818,5**	719,7	**832,3**	719,7	**809,1**	675,7	**801,3**	604,3	**5374,5**	4797,5	**2412,4**	637,5
EMISSIONS TO AIR																			
GHG in GWP100	tCO2	**858,1**	857,9	**667,8**	667,6	**603,6**	603,4	**571,3**	571,0	**529,4**	529,2	**504,0**	503,5	**477,4**	476,7	**333,5**	331,7	**362,2**	356,7
AP Acidification	kgSOx	**588,2**	587,2	**453,8**	452,7	**440,7**	439,7	**426,1**	424,8	**405,8**	404,4	**384,5**	383,0	**357,7**	355,4	**1145,3**	1139,1	**322,6**	303,7
VOC Volatile Organic Com	kg	**11,4**	11,4	**8,8**	8,8	**8,0**	8,0	**7,5**	7,5	**7,0**	7,0	**6,7**	6,6	**6,3**	6,3	**3,7**	3,6	**5,1**	4,7
POP Persist.Organic Poll.	mg i-Te	**5,4**	4,7	**4,3**	3,5	**4,8**	4,0	**5,1**	4,1	**5,2**	4,1	**5,8**	3,8	**6,4**	3,4	**35,8**	27,1	**30,4**	3,6
HMa Heavy Metals	mg Ni	**13,2**	12,3	**10,1**	9,3	**11,5**	10,6	**11,8**	10,7	**11,9**	10,7	**11,3**	10,0	**10,7**	9,0	**75,9**	71,0	**24,5**	9,5
PAHs	mg	**2,0**	1,8	**1,5**	1,4	**1,7**	1,5	**1,7**	1,5	**1,7**	1,5	**1,5**	1,4	**1,4**	1,3	**8,5**	8,3	**2,0**	1,3
PM Particulate Matter	kg	**12,7**	11,7	**10,2**	9,2	**10,2**	9,1	**10,1**	8,8	**9,8**	8,5	**11,9**	8,1	**14,7**	7,5	**42,8**	24,9	**61,2**	6,7
EMISSIONS TO WATER																			
HMw Heavy Metals	g Hg/2(	**5,2**	4,6	**4,1**	3,5	**4,6**	4,0	**4,7**	4,0	**4,8**	4,0	**4,4**	3,8	**4,3**	3,4	**29,1**	26,7	**10,9**	3,5
EP Eutrophication	g PO4	**33,7**	22,0	**28,3**	16,6	**30,7**	19,0	**33,5**	19,1	**34,9**	19,1	**34,8**	17,9	**39,0**	16,0	**190,7**	127,2	**211,6**	16,9
ANNUAL SPACE HEAT ENERGY breakdown																			
TOTAL	kWh/a	**246159**	100%	**191530**	100%	**173312**	100%	**164060**	100%	**152105**	100%	**144722**	100%	**136977**	100%	**101118**	100%	**102729**	100%
Tset	kWh/a	**105759**	43%	**74731**	39%	**74731**	43%	**74731**	46%	**74731**	49%	**74731**	52%	**74731**	55%	**74731**	74%	**74731**	73%
Tmass	kWh/a	**979**	0%	**16178**	8%	**17782**	10%	**17782**	11%	**17782**	12%	**17782**	12%	**17782**	13%	**17782**	18%	**17782**	17%
Tintrans	kWh/a	**0**	0%	**6778**	4%	**6814**	4%	**6814**	4%	**6814**	4%	**6814**	5%	**6814**	5%	**6814**	7%	**6814**	7%
Tfluct (cntrl)	kWh/a	**13968**	6%	**13221**	7%	**13483**	8%	**13649**	8%	**6596**	4%	**2426**	2%	**770**	1%	**770**	1%	**770**	1%
Tstrat(emit)	kWh/a	**10188**	4%	**10061**	5%	**10081**	6%	**10083**	6%	**9975**	7%	**9927**	7%	**9883**	7%	**9883**	10%	**9883**	10%
Distr. loss	kWh/a	**43148**	18%	**21618**	11%	**19943**	12%	**19977**	12%	**19754**	13%	**19000**	13%	**17647**	13%	**17647**	17%	**17647**	17%
Steady st.	kWh/a	**46393**	19%	**33266**	17%	**13684**	8%	**4022**	2%	**2738**	2%	**1827**	1%	**26**	0%	**878**	1%	**1896**	2%
Start/stop	kWh/a	**1512**	1%	**865**	0%	**891**	1%	**906**	1%	**801**	1%	**631**	0%	**264**	0%	**85**	0%	**186**	0%
Stby heat	kWh/a	**14179**	6%	**7253**	4%	**7262**	4%	**7403**	5%	**4222**	3%	**3423**	2%	**1762**	1%	**575**	1%	**1248**	1%
Electric	kWh/a	**10033**	4%	**7560**	4%	**8641**	5%	**8693**	5%	**8693**	6%	**8162**	6%	**7299**	5%	**7299**	7%	**7299**	7%
Credit solar	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**35526**	0%
Credit HP	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**35344**	0%	**0**	0%
Net heating efficiency	%	**43%**		**51%**		**57%**		**61%**		**65%**		**69%**		**73%**		**98%**		**97%**	
gross heat load	kWh/a	**124.389**		**115.107**		**117.072**		**117.272**		**117.272**		**117.272**		**117.672**		**117.672**		**117.672**	
net heat load	kWh/a	**106.738**		**97.687**		**99.327**		**99.327**		**99.327**		**99.327**		**99.327**		**99.327**		**99.327**	
net load per unit floor area	kWh/m	**145**		**113**		**102**		**97**		**90**		**85**		**81**		**60**		**61**	
CH system efficiency	%	**50%**		**59%**		**66%**		**70%**		**75%**		**79%**		**83%**		**113%**		**111%**	

2.7.2 Results size-class 4XL

Figure 2-36.
Design options, lifecycle costs and annual energy consumption category "4XL"



The average annual primary energy consumption for the BaseCase "4XL" sized boilers amounts to 739.894 kWh (net heating efficiency is 43%), with a total lifecycle costs of €904.288,-

Also in this category size, the LLCC-option clearly is **Design Option 8**, that combines a state-of-the-art condensing boiler with a collective electric water-to-water heat pump and achieves a net heating efficiency of **99%**. With this **LLCC-level** the annual primary energy consumption is reduced from 739.894 (basecase) to 303.343 kWh, a reduction of 59%! The lifecycle costs are reduced from € 904.288,- to € 487.237,- (reduction of 46% !).

The net heating efficiency of this Design Option 8 can be further improved by increasing the nominal load of the heat pump. The net heating efficiency can in this way be increased to values up to **115%**. This can be seen as **BAT level for the collective boiler**.

Design Options nr. 9 combines a state-of-the-art condensing boiler with 400 m² vacutube solar collectors (6,6 m² for each apartment), resulting in net heating efficiencies of around 100% with lifecycle costs of around € 631.043-. Considerably lower than the current basecase lifecycle costs but still around €143.000,- more than the LLCC level.

The ultimate BAT level is best represented with a system that combined individual local state-of-the-art condensing boilers with a collective water-to-water heat pump. Net heating efficiencies can then be increased to levels above 140 % (see also BAT-options for XXS to S)

The impact of the Design Options are summarized in the tables on the next four pages:

Table 2-37: Input Design Options in EcoBoiler Integrated Model for size category "4XL"

Table 2-38: Prices & Installation costs PER UNIT for Design Options size category "4XL"

Table 2-39: Life Cycle Costs and Annual Expenditure PER UNIT for size category "4XL"

Table 2-40: Environmental Impact PER UNIT over lifetime for size category "4XL"

Table 2-37. Input Design Options in EcoBoiler Integrated Model for size category "4XL"

DESIGN OPTIONS	1 BaseCase	2	3	4	5	6	7	8	9
INPUTS CH									
CH-power class	9 -4XL	9 -4XL	9 -4XL	9 -4XL	9 -4XL	9 -4XL	9 -4XL	9 -4XL	9 -4XL
	10 -block avg. (60 ap)	*10 -block avg. (60 ap)*	*10 -block avg. (60 ap)*	*10 -block avg. (60 ap)*	*10 -block avg. (60 ap)*	*10 -block avg. (60 ap)*	*10 -block avg. (60 ap)*	*10 -block avg. (60 ap)*	*10 -block avg. (60 ap)*
boiler characteristics									
power input in kW*	750 kW	750 kW	750 kW	750 kW	750 kW	750 kW	750 kW	750 kW	750 kW
turndown ratio	33%	33%	33%	33%	33%	20%	10%	10%	10%
standby heat loss (% of Pnom)	1,0%	1,0%	1,0%	1,0%	0,5%	0,5%	0,5%	0,5%	0,5%
steady st. efficiency %	5 -80/80/80/80	5 -80/80/80/80	3 -85/85/91/91	1 -89/89/97/97	1 -89/89/97/97	1 -89/89/97/97	9 -ideal 96/96/97/97	9 -ideal 96/96/97/97	9 -ideal 96/96/97/97
fuel (dewpoint)	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas	1-gas
air-fuel mix control	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	2 -pneumatic	3 -ionisation	3 -ionisation	3 -ionisation
circ. pump power	9 -1800W	9 -1800W	9 -1800W	9 -1800W	9 -1800W	9 -1800W	9 -1800W	9 -1800W	9 -1800W
fan power	8 -P=400W	8 -P=400W	8 -P=400W	8 -P=400W	8 -P=400W	8 -P=400W	8 -P=400W	8 -P=400W	8 -P=400W
CPU power sb/on	10 -P=220/250W	10 -P=220/250W	10 -P=220/250W	10 -P=220/250W	10 -P=220/250W	10 -P=220/250W	10 -P=220/250W	10 -P=220/250W	10 -P=220/250W
controls power sb/on	5 -P=0/72W	5 -P=0/72W	5 -P=0/72W	5 -P=0/72W	5 -P=0/72W	5 -P=0/72W	5 -P=0/72W	5 -P=0/72W	5 -P=0/72W
comb. air intake	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed	1 -room sealed
boiler mass (empty), kg	2000 kg	2000 kg	2000 kg	2000 kg	2000 kg	2000 kg	2000 kg	2000 kg	2000 kg
water content in kg	200,0 kg	200,0 kg	200,0 kg	200,0 kg	200,0 kg	200,0 kg	200,0 kg	200,0 kg	200,0 kg
envelope volume in m3	6,00 m3	6,00 m3	6,00 m3	6,00 m3	6,00 m3	6,00 m3	6,00 m3	6,00 m3	6,00 m3
noise level in dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A	50 dB-A
controllers									
auto-timer control	no	yes	yes	yes	yes	yes	yes	yes	yes
valve control	2 -RTV 2K	2 -RTV 2K	2 -RTV 2K	2 -RTV 2K	3 -RTV 1K	4 -Motor + PID-loop	5 -Motor + CPU	5 -Motor + CPU	5 -Motor + CPU
boiler temp control	4 -fixed BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT	5 -weather ctrl. BT
	no	no	yes	yes	yes	yes	yes	yes	yes
autoset weather control	N/A	N/A	no	N/A	N/A	N/A	no	no	no
solar (for combi only)									
collector type	N/A	1 -glazed	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube	3 -vacutube
collector surface m2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	400,0
tank position	N/A	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors	1 -indoors
CH-fraction served	0%	100%	0%	0%	0%	0%	0%	0%	100%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
heat pump (HP)									
Reference type	1 -El. brine/ water 0/50	3 -El. air/ water 7/50	3 -El. air/ water 7/50	3 -El. air/ water 7/50	3 -El. air/ water 7/5	3 -El. air/ water 7/50	2 -El. water/ water 10/5	2 -El. water/ water 10/50	2 -El. water/ water 10/5
Power nominal in kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	0,0 kW	70,0 kW	0,0 kW
COP nominal 0/50	0,00	0,00	0,00	2,50	0,00	3,50	3,70	4,30	3,80
Ratio CH : DHW	100%	80%	80%	80%	80%	80%	80%	80%	80%
CH-fraction served	100%	0%	100%	100%	100%	50%	100%	100%	0%
El. back-up heater CH?	no	no	no	no	no	no	no	no	no
MAIN ENERGY OUTPUTS									
Net heating efficiency	43%	51%	57%	61%	65%	69%	73%	99%	100%
Primary energy consumption	739894 kWh/a	576868 kWh/a	521267 kWh/a	493450 kWh/a	457388 kWh/a	435154 kWh/a	412351 kWh/a	303343 kWh/a	298747 kWh/a
-of which fuel (primary kWh GCV)	710017 kWh/a	554297 kWh/a	495496 kWh/a	467518 kWh/a	431456 kWh/a	410879 kWh/a	390157 kWh/a	144248 kWh/a	275270 kWh/a
-of which electricity (primary kWh)	29.877 kWh/a	22.571 kWh/a	25.771 kWh/a	25.932 kWh/a	25.932 kWh/a	24.276 kWh/a	22.194 kWh/a	159.096 kWh/a	23.477 kWh/a
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 40.477	€ 40.908	€ 48.506	€ 52.384	€ 54.115	€ 54.991	€ 60.373	€ 174.373	€ 281.223
Lifetime Running costs (NPV)	€ 863.811	€ 675.407	€ 609.375	€ 576.788	€ 534.609	€ 509.120	€ 483.097	€ 312.864	€ 349.819
Life Cycle Costs LCC	€ 904.288	€ 716.315	€ 657.880	€ 629.172	€ 588.724	€ 564.111	€ 543.471	€ 487.237	€ 631.043
Simple Payback Period PBB	reference yrs	0,0 yrs	0,7 yrs	0,9 yrs	0,9 yrs	0,8 yrs	1,1 yrs	5,6 yrs	9,7 yrs

Table 2-38. Prices & Installation costs PER UNIT for Design Options size category "4XL"

DESIGN OPTIONS	1		2		3		4		5		6		7		8		9	
	9 -4XL		9 -4XL		9 -4XL		9 -4XL		9 -4XL		9 -4XL		9 -4XL		9 -4XL		9 -4XL	
PRODUCT PRICE break down																		
OEM Subass. Costs (Task 2, Ch. 5)	Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system		Euro/ system	
Heat exchanger group	**1.620**		**1.620**		**2.070**		**2.250**		**2.250**		**2.250**		**2.700**		**2.700**		**2.700**	
El. controls group	**469**		**563**		**750**		**938**		**938**		**938**		**938**		**938**		**938**	
Burner group	**216**		**216**		**216**		**270**		**270**		**270**		**270**		**270**		**270**	
Fuel controls group	**328**		**328**		**328**		**328**		**328**		**422**		**750**		**750**		**750**	
CH-return group	**600**		**600**		**750**		**900**		**900**		**900**		**900**		**900**		**900**	
CH-supply group	**94**		**94**		**94**		**94**		**94**		**94**		**94**		**94**		**94**	
Fan group	**450**		**450**		**525**		**525**		**600**		**600**		**600**		**600**		**600**	
Casing	**540**		**540**		**540**		**540**		**720**		**720**		**720**		**720**		**720**	
Condensate collect	**120**		**75**		**328**		**328**		**328**		**328**		**328**		**328**		**328**	
Hot water group	**21**		**21**		**21**		**21**		**21**		**21**		**21**		**21**		**21**	
Packaging etc.	**180**		**180**		**180**		**180**		**180**		**180**		**180**		**180**		**180**	
Extra oil-fired (*0,11)	**3.895**		**3.936**		**4.873**		**5.353**		**5.568**		**5.646**		**6.300**		**6.300**		**6.300**	
Subtotal OEM		**8.533**		**8.622**		**10.675**		**11.726**		**12.196**		**12.368**		**13.800**		**13.800**		**13.800**
Labour		2.560		2.587		3.202		3.518		3.659		3.710		4.140		4.140		4.140
Overhead		5.973		6.036		7.472		8.208		8.537		8.658		9.660		9.660		9.660
total MSP		**17.065**		**17.244**		**21.350**		**23.453**		**24.391**		**24.736**		**27.600**		**27.600**		**27.600**
Ex wholesale		22.185		22.418		27.755		30.489		31.709		32.157		35.880		35.880		35.880
Ex installer excl. VAT		26.451		26.729		33.092		36.352		37.806		38.341		42.779		42.779		42.779
BOILER consumer street price incl. VAT		**31.477**		**31.807**		**39.380**		**43.259**		**44.989**		**45.626**		**50.908**		**50.908**		**50.908**
CONTROLLERS incl. VAT		0		100		125		125		125		365		465		465		465
INSTALLATION (Labour, materials, VAT)		9.001		9.001		9.001		9.001		9.001		9.001		9.001		9.001		9.001
subtotal Boiler (all in)		**40.477**		**40.908**		**48.506**		**52.384**		**54.115**		**54.991**		**60.373**		**60.373**		**60.373**
SOLAR materials incl. VAT		0		0		0		0		0		0		0		0		160.500
SOLAR installation incl. VAT		0		0		0		0		0		0		0		0		60.350
HEAT PUMP materials incl. VAT		0		0		0		0		0		0		0		71.000		0
HEAT PUMP installation incl. VAT		0		0		0		0		0		0		0		43.000		0
TOTAL PURCHASE		**40.477**		**40.908**		**48.506**		**52.384**		**54.115**		**54.991**		**60.373**		**174.373**		**281.223**

Table 2-39. Life Cycle Costs and Annual Expenditure PER UNIT for size category "4XL"

DESIGN OPTIONS	1	2	3	4	5	6	7	8	9
	9 -4XL	9 -4XL	9 -4XL	9 -4XL	9 -4XL	9 -4XL	9 -4XL	9 -4XL	9 -4XL
LCC break down									
Product Price	€ 31.477	€ 31.907	€ 39.505	€ 43.384	€ 45.114	€ 45.991	€ 51.373	€ 122.373	€ 211.873
Installation	€ 9.001	€ 9.001	€ 9.001	€ 9.001	€ 9.001	€ 9.001	€ 9.001	€ 52.001	€ 69.351
Fuel energy (gas, oil)	€ 830.473	€ 648.335	€ 579.558	€ 546.834	€ 504.654	€ 480.586	€ 456.348	€ 168.720	€ 321.970
Electricity	€ 25.620	€ 19.355	€ 22.099	€ 22.237	€ 22.237	€ 20.817	€ 19.032	€ 136.426	€ 20.132
Repair & Maintenance	€ 7.718	€ 7.718	€ 7.718	€ 7.718	€ 7.718	€ 7.718	€ 7.718	€ 7.718	€ 7.718
TOTAL LCC	€ 904.288	€ 716.315	€ 657.880	€ 629.172	€ 588.724	€ 564.111	€ 543.471	€ 487.237	€ 631.043
Annual expenditure									
Product Price	€ 1.852	€ 1.877	€ 2.324	€ 2.552	€ 2.654	€ 2.705	€ 3.022	€ 7.198	€ 12.463
Installation	€ 529	€ 529	€ 529	€ 529	€ 529	€ 529	€ 529	€ 3.059	€ 4.079
Fuel energy (gas, oil)	€ 41.537	€ 32.385	€ 29.264	€ 27.702	€ 25.677	€ 24.429	€ 23.149	€ 17.029	€ 16.771
Electricity	€ 1.793	€ 1.354	€ 1.546	€ 1.556	€ 1.556	€ 1.457	€ 1.332	€ 9.546	€ 1.409
Repair & Maintenance	€ 540	€ 540	€ 540	€ 540	€ 540	€ 540	€ 540	€ 540	€ 540
TOTAL expenditure/a	€ 46.251	€ 36.686	€ 34.203	€ 32.879	€ 30.957	€ 29.661	€ 28.572	€ 37.372	€ 35.263
MAIN LCC OUTPUTS									
Purchase (incl. installation)	€ 40.477	€ 40.908	€ 48.506	€ 52.384	€ 54.115	€ 54.991	€ 60.373	€ 174.373	€ 281.223
Lifetime Running costs (NPV)	€ 863.811	€ 675.407	€ 609.375	€ 576.788	€ 534.609	€ 509.120	€ 483.097	€ 312.864	€ 349.819
Life Cycle Costs LCC	€ 904.288	€ 716.315	€ 657.880	€ 629.172	€ 588.724	€ 564.111	€ 543.471	€ 487.237	€ 631.043
Simple Payback Period PBB	reference yrs	0,0 yrs	0,7 yrs	0,9 yrs	0,9 yrs	0,8 yrs	1,1 yrs	5,6 yrs	9,7 yrs

Table 2-40. Environmental Impact PER UNIT over lifetime for size category "4XL"

DESIGN OPTIONS		1		2		3		4		5		6		7		8		9	
		9 -4XL		9 -4XL		9 -4XL		9 -4XL		9 -4XL		9 -4XL		9 -4XL		9 -4XL		9 -4XL	
ENVIRONMENTAL IMPACT PER UNIT OVER LIFE																			
MATERIALS		**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE	**TOTAL**	USE
TOTAL	kg	**1997,9**		**1997,9**		**1997,9**		**1997,9**		**1997,9**		**1997,9**		**1997,9**		**1997,9**		**1997,9**	
of which																			
Disposal	kg	**17,0**		**17,0**		**17,0**		**17,0**		**17,0**		**17,0**		**17,0**		**152,6**		**152,6**	
Recycled	kg	**204,1**		**204,1**		**204,1**		**204,1**		**204,1**		**204,1**		**204,1**		**1845,3**		**1845,3**	
OTHER RESOURCES																			
Total Energy (GER)	GJ	**46108,2**	46105,5	**35942,6**	35939,9	**32529,5**	32526,8	**30809,0**	30805,6	**28576,0**	28572,3	**27185,3**	27179,6	**25756,3**	25747,7	**20316,5**	20293,1	**18795,9**	18724,2
of which, electric(in primary)	GJ	**2133,8**	2133,2	**1612,2**	1611,6	**1840,7**	1840,1	**1852,3**	1851,5	**1852,3**	1851,5	**1734,4**	1733,3	**1586,2**	1584,7	**11363,5**	11359,4	**1688,9**	1676,2
Water (process)	m3	**142,7**	142,2	**107,9**	107,4	**123,1**	122,7	**124,0**	123,4	**124,0**	123,4	**116,1**	115,6	**106,4**	105,6	**759,1**	757,3	**117,1**	111,7
Water (cooling)	m3	**5689,0**	5688,6	**4297,9**	4297,5	**4907,2**	4906,8	**4937,8**	4937,4	**4937,9**	4937,4	**4622,8**	4622,1	**4227,0**	4225,8	**30295,1**	30291,8	**4480,3**	4470,0
Waste, non-haz./ landfill	kg	**54,0**	49,2	**42,0**	37,1	**47,2**	42,4	**47,5**	42,7	**47,5**	42,7	**44,2**	39,9	**43,0**	36,5	**279,9**	261,8	**94,3**	38,6
Waste, hazardous/ incinerate	kg	**2544,7**	2473,3	**1939,8**	1868,5	**2204,8**	2133,5	**2245,6**	2146,7	**2259,4**	2146,7	**2143,0**	2009,6	**2034,4**	1837,3	**13747,6**	13170,6	**3718,5**	1943,5
EMISSIONS TO AIR																			
GHG in GWP100	tCO2	**3090,4**	3090,2	**2410,3**	2410,1	**2172,1**	2171,9	**2054,5**	2054,3	**1902,3**	1902,1	**1810,5**	1810,0	**1716,7**	1716,1	**1106,4**	1104,6	**1240,6**	1235,1
AP Acidification	kgSOx	**3509,9**	3508,9	**2726,5**	2725,4	**2540,2**	2539,2	**2426,8**	2425,5	**2276,6**	2275,2	**2160,6**	2159,0	**2036,6**	2034,3	**3532,5**	3526,3	**1598,0**	1579,0
VOC Volatile Organic Comp.	kg	**48,7**	48,6	**38,0**	38,0	**34,1**	34,1	**32,2**	32,2	**29,8**	29,8	**28,4**	28,3	**26,9**	26,9	**14,2**	14,0	**19,6**	19,2
POP Persist.Organic Poll.	mg i-Te	**14,7**	14,0	**11,3**	10,6	**12,8**	12,1	**13,1**	12,1	**13,3**	12,1	**13,3**	11,4	**13,4**	10,4	**83,2**	74,5	**37,8**	11,0
HMa Heavy Metals	mg Ni	**37,5**	36,6	**28,5**	27,7	**32,4**	31,6	**32,9**	31,8	**33,0**	31,8	**31,0**	29,8	**28,9**	27,2	**199,8**	194,9	**43,8**	28,8
PAHs	mg	**5,5**	5,4	**4,3**	4,1	**4,6**	4,5	**4,6**	4,5	**4,6**	4,4	**4,2**	4,1	**3,9**	3,8	**22,9**	22,7	**4,6**	3,8
PM Particulate Matter	kg	**63,7**	62,7	**49,9**	48,9	**47,1**	46,0	**45,3**	44,1	**42,8**	41,5	**43,3**	39,4	**44,3**	37,1	**91,4**	73,5	**84,1**	29,5
EMISSIONS TO WATER																			
HMw Heavy Metals	g Hg/2(	**14,3**	13,8	**11,0**	10,4	**12,5**	11,9	**12,7**	11,9	**12,8**	11,9	**11,9**	11,2	**11,1**	10,2	**75,6**	73,2	**18,2**	10,8
EP Eutrophication	g PO4	**77,3**	65,6	**61,3**	49,5	**68,3**	56,6	**71,4**	56,9	**72,7**	56,9	**70,2**	53,3	**71,7**	48,7	**412,7**	349,3	**246,3**	51,5
ANNUAL SPACE HEAT ENERGY breakdown																			
TOTAL	kWh/a	**739894**	100%	**576868**	100%	**521267**	100%	**493450**	100%	**457388**	100%	**435154**	100%	**412351**	100%	**303343**	100%	**298747**	100%
Tset	kWh/a	**317277**	43%	**224192**	39%	**224192**	43%	**224192**	45%	**224192**	49%	**224192**	52%	**224192**	54%	**224192**	74%	**224192**	75%
Tmass	kWh/a	**2938**	0%	**49766**	9%	**54135**	10%	**54135**	11%	**54135**	12%	**54135**	12%	**54135**	13%	**54135**	18%	**54135**	18%
Tintrans	kWh/a	**0**	0%	**20762**	4%	**20716**	4%	**20716**	4%	**20716**	5%	**20716**	5%	**20716**	5%	**20716**	7%	**20716**	7%
Tfluct (cntrl)	kWh/a	**41905**	6%	**39586**	7%	**40392**	8%	**40908**	8%	**19765**	4%	**7271**	2%	**2308**	1%	**2308**	1%	**2308**	1%
Tstrat(emit)	kWh/a	**30565**	4%	**30198**	5%	**30253**	6%	**30258**	6%	**29935**	7%	**29793**	7%	**29661**	7%	**29661**	10%	**29661**	10%
Distr. loss	kWh/a	**129442**	17%	**64853**	11%	**59826**	11%	**59929**	12%	**59259**	13%	**56992**	13%	**52928**	13%	**52928**	17%	**52928**	18%
Steady st.	kWh/a	**139556**	19%	**100290**	17%	**41208**	8%	**12130**	2%	**8265**	2%	**5524**	1%	**101**	0%	**2932**	1%	**5519**	2%
Start/stop	kWh/a	**4543**	1%	**2556**	0%	**2633**	1%	**2679**	1%	**2408**	1%	**1897**	0%	**792**	0%	**285**	0%	**540**	0%
Stby heat	kWh/a	**43791**	6%	**22093**	4%	**22141**	4%	**22571**	5%	**12782**	3%	**10359**	2%	**5325**	1%	**1929**	1%	**3649**	1%
Electric	kWh/a	**29877**	4%	**22571**	4%	**25771**	5%	**25932**	5%	**25932**	6%	**24276**	6%	**22194**	5%	**22193**	7%	**22194**	7%
Credit solar	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**117095**	0%
Credit HP	kWh/a	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**0**	0%	**107935**	0%	**0**	0%
Net heating efficiency	%	**43%**		**51%**		**57%**		**61%**		**65%**		**69%**		**73%**		**99%**		**100%**	
gross heat load	kWh/a	**371.657**		**345.457**		**350.726**		**351.326**		**351.326**		**351.326**		**352.526**		**352.526**		**352.526**	
net heat load	kWh/a	**320.215**		**294.720**		**299.043**		**299.043**		**299.043**		**299.043**		**299.043**		**299.043**		**299.043**	
net load per unit floor area	kWh/m	**146**		**114**		**103**		**97**		**90**		**86**		**81**		**60**		**59**	
CH system efficiency	%	**50%**		**59%**		**66%**		**70%**		**75%**		**79%**		**83%**		**113%**		**115%**	

2.7.3 Summary

The results of the design option calculations for the 3XL and 4Xl size categories clearly show, than an LLCC - level of around 96-98% is economically and technically a viable proposition. However, the initial investments related to this LLCC-level are substantial higher than the basecase option and since the investments and related profits (lower energy bill) are not always in the same hands, some kind of political and financial support is appropriate to facilitate the achievement of this **LLCC-level of 96-98%**.

Another technical options with which this net efficiency level of 96-98% can be achieved is the combination of state-of-the-art condensing boilers with vacutube solar collectors, although lifecycle costs are 10 to 20% higher and simple pay-back period somewhat longer (8 to 9 years instead of 6 to 7 years).

Another option still – although not covered by this Ecodesign Survey – is the CHP option. CHP has the potential of considerable CO2 savings provided the right type and size is used in combination with state-of-the-art condensing boilers. An indicative calculation is made to get a first impression on the savings that can be achieved by applying CHP.

Please note that additional research is needed to fully understand the potential of this option in the light of technical model that is used as basis for the Ecoboiler Integrated Model.

With current CHP technology it is vital that long and steady operating times are achieved, because dynamic losses (start/stop-, high/low- losses) can be considerable. Since no data on this type of dynamic losses are available, the indicative calculation below are related to CHP-systems that only cover a part of the heat demand, in order to facilitate a continuous and steady state operation for a long a period as possible. Furthermore, the heating part of the CHP unit is treated in a similar way as a boiler, meaning that the heat heating efficiency is calculated in the same way (with system losses).

Table 2-41. Indicative and preliminary calculation of energy savings for a specific configuration of a collective boiler combined with CHP.

Reference situation		**4XL**		
Net heat load	[kWh]	320.214		
Reference Pnom boiler	[kW]	750		
Heating season	[h]	6500	***Energy input separate generation***	
Reference net heating efficiency	[%]	73%	Energy input for heating	438.649
Reference electric efficiency	[%]	40%	Energy input for electricity production	278.688
			Total	717.337
Collective CHP				
Pnom	[kW]	70		
Steady-state heating efficiency	[%]	55%	***Energy input and output CHP***	
Steady state electric efficiency	[%]	35%	Neat Heat Production CHP	111.475
Net heating efficiency	[%]	35%	Electricity Production CHP	111.475
Operating time (% of heating season)	[%]	70%	Total Energy input CHP	318.500
Collective Boiler				
Pnom	[kW]	680	***Energy input and output collective boiler***	
Steady state efficienct boiler	[%]	96%	Neat Heat Production CHP	208.739
Net heating efficiency boiler	[%]	73%	Energy input collective boiler	285.944
			Total input collective boiler & CHP	604.444
			Savings on separate generation	16%
			Net system efficiency *	**99%**

* Net system efficiency = (net heat load + energy input reference electricity production) / total input collective boiler & CHP)

3 SUMMARY TABLES

3.1 Size characteristics

Based on the market-share of the various size classes in the sales of 2005 and assuming an similar market-share is applicable for the stock, the following estimate is given for the market share of the various size-classes in the EU25 Stock. Total number of boilers of the stock is set at 105 million (see Task 2 report).

Table 3-1. Overview of size classes, their market share in EU- stock and typical examples of application.

Size-Class	Indicative Range for Pnom	Market share	Nr of units in stock *mln.	Avg. Net heat load kWh/a	Examples of application
XXS	< 10 kW	2,3 %	2,4	2.350	- **Apartment new** - Passive new house - Professional practice (part of house) - Small shop- / office-space new
XS	10-15 kW	7,6 %	8,0	3.700	- **Average dwelling new** - Terraced or low-E house new - Large apartment new - Medium shop / office space new
S	16-20 kW	15,2 %	16,0	4.850	- **Apartment existing** - House new / fully renovated - Penthouse new - Small shop / office space existing
M	21-25 kW	51,5 %	54,1	7.480	- **Average existing** - House partially renovated - Large apartment existing - Medium shop / office space existing
L	26-32 kW	9,9 %	10,4	10.515	- **House existing** - Small low-rise apt. Building (4 apts) existing - Two family house new - Small office/ shop building new
XL	33-70 kW	9,9 %	10,4	20.000	- **New avg. apt. building (8 apts.)** - Small low-rise apt. building (4 apts) existing - Villa, large house, 2 family house existing - Medium shop/office building new
XXL	70-150 kW	2,6 %	2,7	42.195	- **Existing avg. apt. building (8 apts.)** - High-rise apt. building (12 – 20 apts) new - Medium shop/office building existing - Large low-rise shop/office building new
3XL	150-350 kW	0,6 %	0,6	106.738	- **High-rise apt. building (16-24 apt.) existing** - Large low-rise shop/office building existing - Medium high-rise office building new - In cascade: larger high rise building
4XL	>350 kW	0,6 %	0,6	320.215	- **Block heating 3 high-rise buildings** (60 apt.) - Large high-rise office building - In cascades: Hospital, shopping mall, small airport, district heating substations.
		100 %	105		

3.2 Energy & lifecycle costs at Basecase, LLCC and BAT-levels

Knowing the number of boilers per size-class in the EU stock, their base-case efficiencies and their net heat loads, we can calculate the share of the various size-classes in the overall energy consumption for space heating.

Table 3-2. Share of energy consumption per size class (in % of total)

Size-Class	Pnom [kW]	Net heat load kWh/a	BaseCase Net heating efficiency[1]	Energy consumption kWh/unit/a	Market share in number of boilers	Nr of units in stock *mln.	Total energy consumption per class [TWh/a]	Share of total energy consumption
XXS	10	2.350	53,1%	4.422	2,3%	2,4	10.679	0,4%
XS	14	3.700	54,0%	6.852	7,6%	8,0	54.678	2,2%
S	19	4.850	51,8%	9.368	15,2%	16,0	149.513	5,9%
M	22	7.480	54,1%	13.827	51,5%	54,1	747.695	29,7%
L	29	10.515	55,1%	19.095	9,9%	10,4	198.493	7,9%
						90,8	**1.161.058**	**46,1%**
XL	60	20.284	44,1%	45.965	9,9%	10,4	477.806	19,0%
XXL	115	42.195	45,2%	93.407	2,6%	2,7	255.001	10,1%
3XL	250	106.738	42,8%	249.392	0,6%	0,6	157.117	6,2%
4XL	750	320.215	43,3%	739.894	0,6%	0,6	466.133	18,5%
						14,4	**1.356.057**	**53,9%**
					100%	105	**2.517.115**	**100%**

*1 . Calculated with Ecoboiler Integrated model version 5a

Based on the design options that are selected for the various size classes and calculated with the Ecoboiler Integrated Model version 5a, the following LLCC- and BAT- levels in terms of net heating efficiency are produced (See table 3-3). Please note that NOT all 4600 quadrillion design options were evaluated and that – despite a lot of design options remain un-discussed – the energy savings of the logical and obvious design options that were evaluated, are substantial.

Table 3-3. Net Heating Efficiency for Basecase-, LLCC- and BAT-levels

Size-Class	Pnom [kW]	Net heat load kWh/a	Net Heating Efficiency[1] BASECASE-LEVEL	Net Heating Efficiency LLCC-LEVEL	Net Heating Efficiency BAT-LEVEL	Explanation BAT
XXS	10	2.350	53%	77%	160 - 170 %	Apartments connected to a collective water/water heat pump
XS	14	3.700	54%	77%	160 - 170 %	Apartments connected to a collective water/water heat pump
S	19	4.850	52%	79%	160 - 170 %	Apartments connected to a collective water/water heat pump
M	22	7.480	54%	78 – 80%	130 - 140 %	House with brine/water heat pump
L	29	10.515	55%	78%	130 - 140 %	House with brine/water heat pump
XL	60	20.000	44%	77%	125 - 135 %	Apartments connected to a collective water/water heat pump
XXL	115	42.195	45%	101%	125 - 135 % *	Apartments connected to a collective water/water heat pump with an increased output
3XL	250	106.738	43%	98%	110 - 120 % *	Apartments connected to a collective water/water heat pump with an increased output
4XL	750	320.215	43%	99%	110 - 120 % *	Apartments connected to a collective water/water heat pump with an increased output

* BAT-levels can be further increased by combining a collective hp with state-of-the-art individual boilers

With the data in the previous tables, the annual energy consumption (and savings) for the LLCC- and BAT- levels can be calculated for each size-category:

Table 3-4. Energy Savings LLCC level versus Basecase level

Size-Class	Net heat load kWh/a	BaseCase Net heating efficiency[1]	Energy consumption kWh/unit/a	LLCC Efficiency level	Energy consumption kWh/unit/a	Savings versus Basecase
XXS	2.350	53,1%	4.422	77%	3052	31%
XS	3.700	54,0%	6.852	77%	4805	30%
S	4.850	51,8%	9.368	79%	6139	34%
M	7.480	54,1%	13.827	78%	9590	31%
L	10.515	55,1%	19.095	78%	13481	29%
XL	20.284	44,1%	45.965	77%	26343	43%
XXL	42.195	45,2%	93.407	101%	41777	55%
3XL	106.738	42,8%	249.392	98%	108916	56%
4XL	320.215	43,3%	739.894	99%	323449	56%

*1 . Calculated with Ecoboiler Integrated model version 5a

Table 3-5. Energy Savings BAT level versus Basecase level

Size-Class	Net heat load kWh/a	BaseCase Net heating efficiency[1]	Energy consumption kWh/unit/a	BAT Efficiency level	Energy consumption kWh/unit/a	Savings versus Basecase
XXS	2.350	53,1%	4.422	165%	1424	68%
XS	3.700	54,0%	6.852	165%	2242	67%
S	4.850	51,8%	9.368	165%	2939	69%
M	7.480	54,1%	13.827	135%	5541	60%
L	10.515	55,1%	19.095	135%	7789	59%
XL	20.284	44,1%	45.965	130%	15603	66%
XXL	42.195	45,2%	93.407	130%	32458	65%
3XL	106.738	42,8%	249.392	115%	92816	63%
4XL	320.215	43,3%	739.894	115%	278448	62%

*1 . Calculated with Ecoboiler Integrated model version 5a

Table 3-6. Lifecycle costs and savings LLCC- and BAT- levels versus Basecase level

Size-Class	BaseCase lifecycle costs	LLCC lifecycle costs	BAT lifecycle costs	LLCC **savings**	LLCC saving in %	BAT saving	BAT Savings in %
XXS	€ 9.085	€ 8.716	€ 10.943	€ 369	4%	-€ 1.858	-20%
S	€ 14.172	€ 12.313	€ 13.352	€ 1.859	13%	€ 820	6%
M	€ 18.750	€ 15.797	€ 16.859	€ 2.953	16%	€ 1.891	10%
L	€ 24.119	€ 20.259	€ 21.262	€ 3.860	16%	€ 2.857	12%
XL	€ 57.697	€ 37.851	€ 38.668	€ 19.846	34%	€ 19.029	33%
XXL	€ 108.111	€ 65.623	€ 73.738	€ 42.488	39%	€ 34.373	32%
3XL	€ 272.770	€ 164.057	€ 190.187	€ 107.943	40%	€ 81.813	30%
4XL	€ 904.288	€ 487.237	€ 495.964	€ 417.051	46%	€ 408.324	45%

*1 . Calculated with Ecoboiler Integrated model version 5a