Preparatory Study on

Eco-design of Boilers

Task 7 report (FINAL)

Policies, scenarios, impact & sensitivity analysis

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Delft, 30 September 2007

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1 INTRODUCTION

This Task Report regards subtasks 7.1 to 7.4 as defined in the contract:

- Policies (subtask 7.1, Chapter 2 of this report)
- Scenarios (subtask 7.2, Chapter 3 of this report)
- Impact Analysis (subtask 7.3, Chapter 4 of this report)
- Sensitivity Analysis (subtask 7.4, Chapter 5 of this report)

Subtask 7.1 looks at suitable policy means to achieve the potential e.g. implementing LLCC as a minimum and BAT as a promotional target, using legislative or voluntary agreements, labelling and promotion.

Subtask 7.2 draws up scenarios for 2025 quantifying the improvements that can be achieved vs. a Business-as-Usual scenario and compares the outcomes with EU environmental targets, the societal costs if the environmental impact reduction would have to be achieved in another way, etc...

Subtask 7.3 makes an estimate of the impact on consumers (purchasing power, societal costs) and industry (employment, profitability, competitiveness, investment level, etc.), explicitly describing and taking into account the typical design cycle (platform change) in a product sector.

Finally, subtask 7.4 studies the robustness of the outcome in a sensitivity analysis of the main parameters (as described in Annex II of the Directive) .

2 POLICY RECOMMENDATIONS

2.1 Introduction

Subtask 7.1 looks at suitable policy means to achieve the potential e.g. implementing LLCC as a minimum and BAT as a promotional target, using legislative or voluntary agreements, labelling and promotion.

The subtask will make proposals for product classification, appropriate energy labelling classes and a feasible levels of (mandatory or voluntary) MEPS for energy and emissions in the use phase. For the Ecodesign measures relating to production, distribution and end-of-life, the policy analysis will recommend appropriate measures. With this work VHK will indicate how an implementing directive under 2005/32/EC is coherent and consistent with other policy measures (labelling, training) and especially the Energy Performance of Buildings Directive.

The underlying report will follow the three elements for market transformation: minimum requirements, incentives and information a.k.a "sticks, tambourines and carrots"[1]. The third and final chapter will show alternative scenarios and why they will not deliver the best result for boilers.

2.2 Product definition

In this and the following paragraph we have listed the recommendations for product definition and classification. Where these recommendations could be used in future legislative texts, a first attempt at a legal format is used, but it is crude and far from complete. For instance, wherever it is referred to information "in the Annex", this annex still has to be constructed, mostly on the basis of the inputs from the preparatory sudy, but also additional information may be required.

Recommendations regarding the **product definition**:

- **Eco-design measures** proposed hereafter will relate to gas-fired, oil-fired and electric central heating boiler systems (hereafter "CH-boiler systems")
- A **CH-boiler system** is a device or set of devices that is equipped to transfer heat to a heat transfer fluid (hereafter "CH-water") circulating in a distribution system (hereafter "CH-distribution system") to which at least one heat exchanging means is connected (hereafter "CH-emitter", e.g. radiator, hydronic convector or floor heating system) that is equipped to transfer the heating energy stored in the CH-water into space heating of (a part of) buildings. The definition of a CH-boiler system applies to, but is not limited to, all "CH-boilers" as defined in EN standard as listed in Annex.

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[1] Cit. A. Warren.

- A CH-boiler system shall comply with all the **safety and functional requirements** in current legislation, e.g. in the Gas Appliances Directive, etc. [to elaborate in legislation]

- At least a CH-boiler system shall be capable of producing a **minimum heat output** that is required for its size class (see classification), which implies at least a heating output power of 3,6 kW, which is equivalent to the minimum requirement of the smallest size class (see product classification hereafter).

- The **CH-distribution system and CH-emitters**[2] shall not be part of the CH-boiler system For compliance assessment a reference distribution system and reference emitters shall be used, as defined in Annex.

- Means for circulating the CH-water (hereafter "**CH-circulator**") may or may not be part of the CH-boiler system. In case the CH-circulator is not part of the CH-boiler system offered for CE-marking, the testing or assessment for CE-marking Eco-design criteria will occur with a reference CH-circulator as defined in annex (90 W circulator).

- Possible means for abducting flue gases (hereafter "**flue ducts**") and for introducing oxygen to the combustion process (hereafter "**combustion air inlet ducts**") may or may not be part of the CH-boiler system, subject to specifications under e.g. the GAD. If no systems for flue gas abduction and/or combustion air introduction are part of the CH-boiler system, reference systems will be used as prescribed in the standard XXXX.

- Possible means for controlling the various stages of the heat transfer process (hereafter "**CH-controls**"), beyond those required to comply with the minimum safety requirements of current legislation[3], may or may not be part of the CH-boiler system offered for CE-marking. A definition of CH-controls is given in the Annex[4]. In case CH-controls are not part of the CH-boiler system offered for CE-marking, the testing or assessment for CE-marking Eco-design criteria will occur with reference CH-controls to be defined in the legislation (on/off room thermostat and TRVs 2K for smaller load profiles; fixed boiler thermostat and TRVs 2K for larger load profiles).

- If the CH-boiler system incorporates multiple heat generators and/or renewable energy sources (**heat pump, solar**) this will be included in the scope of Eco-design but only if the systems are fully functional. In other words, if a system only contains part of the components this will not be taken into account. E.g. for systems equipped solar controls and/or a double coil tank that could in principle also be used for solar installations, but without the solar collector, the possible solar contribution will not be taken into account.

- If the CH-boiler system contains the means for **sanitary hot water** supply (hereafter "HW") the compliance with Ecodesign criteria shall be subject to a separate procedure of compliance testing on Eco-design measures for water heaters, where part of the assessments of the space heating functions will be used as an input (see Annex)[5]. A CH-boiler system with HW-function (hereafter "CH-combi") shall comply with both sets of requirements in principle. In case a CH-boiler system only complies with either the space heating related requirements or the water heating related requirements, there is a possibility for compensation

[2] excl. means for flow –controls, which can be part of the CH-boiler system (e.g. TRVs)

[3] e.g. maximum boiler thermostat

[4] At the very least there will be a description of the Valve-controllers (manual/none, TRV 2K, TRV 1K, motor + PID loop, motor + CPU) and the Temperature controllers in the Integrated Model (fixed Boiler Thermostat, weather compensated Boiler Thermostat, On/off Room Thermostat, Modulating Room Thermostat, Time-proportional Room Thermostat)

[5] In other words, the space heating compliance assessment has to be performed first.

indicated by the ratio between the net space heating load of the CH-size class and the net water heating load of the HW-size class for which the manufacturer requests the CE-marking. [6]

- If the CH-boiler system contains the whole or part of the means required for **space cooling**[7], **ventilation**[8]**, air purification, humidification, de-humidification or any other functionality related to indoor air quality**, this extra functionality will not be part of the underlying compliance assessment. In due time, this functionality may –and probably shall—be part of a separate procedure of compliance testing on Eco-design measures, where part of the assessments of the space heating functions will be used as an input (see Annex)[9].
- If the CH-boiler system contains the whole or part of the means required for **other domestic heating functions, like cooking**[10], this extra functionality will not be part of the underlying compliance assessment. In due time, this functionality may –and probably shall—be part of a separate procedure of compliance testing on Eco-design measures, where part of the assessments of the space heating functions will be used as an input (see Annex)[11].
- The following CH-boiler systems are not included in the scope:
  - CH-boiler systems that produce a surplus of electricity, i.e. beyond what is needed for driving the electrical components within the system. They are regulated in the CHP-Directive [Note: If so desired CHP-systems could be included in the scope, but this would require an effort to synchronize the electricity credit values with the provisions of the CHP-Directive]
  - CH-boiler systems using solid fuels, including biomass, as an energy source. For this group the Commission is engaged in a separate preparatory study for Eco-design measures.
  - CH-systems driven by District Heating ("DH"). These are systems fuelled by waste heat from power plants, waste incineration plants, larger industrial installations, etc. [definition in Annex]
  - Centralized and local space heating devices based on air heating (e.g. reversible room- or centralized air conditioners). For this group the Commission is engaged in a separate preparatory study for Eco-design measures.
  - Local space heating devices that do not use separate CH-emitters and a CH-distribution system, i.e. where in fact the device itself acts as a heat emitter (e.g. fossil fuel fired stoves and convection heaters, electric radiators, etc.). For this group the Commission is engaged in a separate preparatory study for Eco-design measures.
  - [Note: The legislator may consider to include devices intended to function both as a local heater (e.g. a mother hearth, back-boiler, combi-range, combi-stove supplying direct heat to living room and/or kitchen) and as a CH-boiler system (e.g. for radiators in the bedrooms). This issue must be elaborated in the legislative process, but technically it does not seem impossible to accommodate this in the Integrated Model and there may be an interesting saving potential

[6] Typically the ratio of net heat loads of the same size class is 4/1 (CH/HW), but it depends on the size class.
[7] E.g. top cooling with cooling ceilings, fanned (hydronic) convectors or radiators, etc.
[8] E.g. ventilation based on mechanical extraction, combined with an air-based heat pump
[9] In other words, the space heating compliance assessment has to be performed first.
[10] E.g. ranges, but also water beds deriving their heat from CH-system.
[11] In other words, the space heating compliance assessment has to be performed first.

there, because local heating does not have the disadvantage of distribution losses]

For all space heating not (yet) defined within the current scope, it is recommended to be coherent with the methodology in the underlying study (see Assessment Procedure).

2.3 Product classification

Recommendations regarding **product classification**:

- 9 load profiles shall be used to distinguish Central Heating boiler-systems
- The familiar denomination S-M-L (small-medium-large) shall be used for the load profiles, downwards extended to XS and XXS and upwards extended to XL, XXL, 3XL and 4XL.
- the size class qualification shall depend on
  - A minimum required heating power output per class (Pmin in kW, see Table 2.1)
  - A load profile per class for energy efficiency and emission assessment (total "Net load" per profile in kWh/a, see Table 2.1)
- Whereby the minimum required heating power output is mandatory
- Whereby a maximum heating power output can also be applied if there is a jump in target levels (see par. 2.5).
- Whereby –within the above limits-- the load profile for which the energy efficiency and emission assessment during CE-marking should be performed is decided by the manufacturer.
- A manufacturer can decide to have one appliance tested for more than one load profile, but this appliance should be brought on the market with different model denominations depending on the load profile for which it is tested. Also registration numbers for CE-marking shall differ, depending on the load profile.
- The load profile shall be clearly marked as a prominent part of label, fiche and any commercial communication describing the product during the purchase process.

As mentioned in the Eco-design directive all previous and current technology-dependent classifications will not be used for measures, i.e. there is no distinction between e.g. "*gas/oil/electric*" or "*condensing/low temperature/standard*" or "*atmospheric/ fan-assisted/ pre-mix*" or classes based on "*fuel input in Net Calorific Value*" *(<70 kW, 70-300 kW, etc.).*

The definition of load profiles 3XL and 4XL occurred relatively late in the study and might be subject to change. Also the time path and the nature of measures for these largest classes may be different then the rest, e.g. in the field of controls. An absolute upper limit of the load profiles in EU-legislation is formed by the Large Combustion Plants Directive (LCPD, 2001/80/EC) , which starts at 50 MW and higher. In that sense, it might be necessary to define an extra 5XL class (e.g. at 800 kW and with maximum 10 MW) to bridge the gap between the 4XL and the LCPD-minimum. This may be subject for discussion during the technical consultation.

Table 2.1. Overview of load profiles

estimated market share, net heat load (kWh/a), minimum heat output required Pnom (in kW), examples of applications

Size			Examples of applications
XXS	market share	**2,3%**	**apartment new**
	Net load	**2.354 kWh/a**	passive house new
	Pmin	**3,6 kW**	professional practice (part of house) small shop-/ office-space new
XS	market share	**7,6%**	**average dwelling new**
	Net load	**3.699 kWh/a**	terraced or low-E house new
	Pmin	**5,1 kW**	large appartment new medium shop-/ office-space new
S	market share	**15,2%**	**apartment existing**
	Net load	**4.850 kWh/a**	house new/ fully renovated
	Pmin	**6,9 kW**	penthouse new small shop/ office space existing
M	market share	**51,5%**	**average existing**
	Net load	**7.480 kWh/a**	house partially renovated
	Pmin	**7,7 kW**	large appartment existing medium shop/ office space existing
L	market share	**9,9%**	**house existing**
	Net load	**10.515 kWh/a**	small low-rise ap. building (4 apt.s) new
	Pmin	**10,5 kW**	two-family house new
	Pmax	**45**	small office/shop building new
XL	market share	**9,9%**	**new avg. apt. building (8 apt.)**
	Net load	**20.284 kWh/a**	small low-rise ap. building (4 apt.s) existing
	Pmin	**30,6 kW**	villa, large house, 2-family house existing
	Pmax	**90**	medium shop/office building new
XXL	market share	**2,6%**	**existing avg. apt. building (8 apt.)**
	Net load	**42.195 kWh/a**	high-rise apt. building (12-20 apt.s) new
	Pmin	**46,4 kW**	medium shop/ office building existing
	Pmax	**180**	large low-rise shop/office building new
3XL	market share	**0,6%**	**high-rise apt. building (12-20 apt.) existing**
	Net load	**150.000 kWh/a**	large low-rise shop/office building existing
	Pmin	**150 kW**	medium/ high-rise office building new in cascade: larger high-rise building
4XL	market share	**0,6%**	**block heating 3 high-rise buildings (60 apts)**
	Net load	**400.00 kWh/a**	large high-rise office building
	Pmin	**300 kW**	hospital, shopping mall, small airport (cascades) district-heating substations

2.4 Assessment procedure

For compliance assessment it is proposed to follow the usual procedure for testing for CE-marking (Art. 95 of The Treaty).

As mentioned in the Task 1 report, the current EN test methods are deficient in describing energy efficiency and emissions of a CH-boiler system as a whole. Apart from NOx testing, where the current test at steady state efficiency do give a reasonable impression of real-life emissions, none of the other impact parameters can be tested adequately.

In the long run these deficiencies should be tackled –especially for the residential sizes-- through **new test methods**, featuring dynamic boiler testing (cycling), using real-life load patterns and emulation/tests of the system-components. Examples are given in the Task 1 report (e.g. UK chapter). The development of appropriate tests will take considerable time and effort and –also given the procedural lead times with CEN— can realistically not be concluded within the time-frame that is envisaged –e.g. by the European Parliament—for the implementation of Eco-design measures.

For that reason it is recommended to start a **transitory regime** for the compliance assessment for a CH-boiler system consisting of

- A series of tests according to harmonized European test standards
- Assessments to be made by the test institute / notified body
- A mathematical validation method that uses the above test results and other assessment as an input to calculate energy efficiency, carbon and NOx emissions of the CH-boiler system. For CO-emissions the steady state emissions do not represent realistic values in practice but could be used to set very preliminary targets.

The transitory regime is expected to be in place for at least a period of 4-6 years, after which time it can wholly or partly be replaced by the required dynamic test/emulation methods. Those latter would allow not only to assess more accurately energy, carbon and NOx impacts, but would also allow a realistic evaluation of CO, CH4, CxHy and particulate matter emissions in practice and the establishment of appropriate emission limit values (ELVs).

In the rest of this paragraph we will deal only with the requirements of the assessment procedure for the transitory regime.

2.4.1 Required Tests

The following is a list of parameters that come out of EN-standard test procedures and that are recommended to be used for the compliance assessment

- Boiler: heat input and heat output power in kW at 80/60 and 50/30 regime at nominal and minimum load (steady state) .
- Boiler: turndown ratio (minimum load) in % .
- Boiler: standby heat loss (at 50 °C)
- Boiler: Electricity consumption at nominal and minimum load as well as “burner off” (draft standard)
- Solar systems: Collector loop loss UL, tank heat loss coefficient UA, tank volume, etc.

- Heat Pump: Efficiency tests at the Tsink and Tsource indicated for the various types.
- Boiler: NOx and CO emissions (steady state testing at nominal capacity)
- Noise (NF and EN, but choice to be made)

Please note that fuel input and thereby energy efficiency values for fossil fuel should be assessed in terms of GCV (Gross Calorific Value). For electric power inputs as a part of the overall energy efficiency values a primary energy conversion factor 2,5 (1 kWhe = 2,5 kWhprim) will be used.

For a large part of the CH-boiler systems (all gas- and oil-fired boilers) Third Party Testing is current practice, involving specialized test institutes and Notified Bodies. If not for any other reason, the safety issues involved with the fossil fuels make Third Party testing indispensable.

Furthermore, the outcome of many tests is highly susceptible to fuel quality, ambient parameters and the overall quality of the test institutes. Given the fact that the Eco-design measures are an important competitive item in the sector and in the interest of a "level-playing-field" we therefore propose to extend current practice of Third Party Testing to all Boilers. The most recent round-robin tests by Labnet (see Task 1 report, par. 3.22.4) revealed –after the introduction of Good Practice—tolerances of ± 4% on part load efficiency and around ± 2% on full load efficiency. This of course does not take into account production tolerances.

Apart from Third Party testing, we recommend to create **Market Surveillance** at EU-level by an independent body performing 100-150 random spot checks annually. Costs could be limited (ca. € 1 mln. /yr.) and it would avoid discussions on the neutrality of the surveillance. As one CE-marking conformity test usually covers between 10 and 20 models, the 100-150 spot checks could cover around 1000-2000 models. [more information in the chapter on impact assessment]

2.4.2 Other assessments

Apart from the tests according to harmonized standards, a number of relatively simple assessments and measurements will be required. These basis of these assessments is on one hand a series of simple tests to identify certain boiler features (weight, envelope volume) and descriptions of these features. These will be incorporated in the legislation.

- Boiler envelope (in m3)
- Boiler weight (in kg)
- Room air intake (e.g. from type declaration)
- Boiler water content (in ltr.)
- Type of air-fuel mixer and/or air factor
- System of room temperature control, included in the package (if any): None (fixed BT), Weather controlled BT, On/off RT, Modulating RT, Time-proportional RT (requires definition in technical annex)
- System of valve controllers, included in the package offered for CE-marking: none, TRV 2 K, TRV 1 K, Motor + PID-loop, Motor + CPU (requires definition of minimum requirements in technical annex)
- In case of the use of a refrigerant, e.g. for a heat-pump based CH-boiler system, the type should be assessed (self declaration)

2.4.3 Validation of test results

For performance

The test house/ notified body checks whether the CH-boiler system meets the definition and the minimum heat output requirements for the load profile for which CE-marking is requested.

For energy/carbon

The results from the generic tests and the other assessments above feed into a mathematical model that will result in a single Index ("Eco-index) that are indicative of the main environmental impacts: the use of energy resources and the carbon (CO2) emissions.

This calculation is specific for the size class for which CE-marking is requested and uses the specific Load Profile. A description of the model and calculation procedure can be found in the Annex.

For NOx (acidification)

The test institute reports the NOx emissions during steady state, according to the indicated test method and certifies whether the NOx-emissions meets the target values (see next paragraph). The unit is ppm (parts per million) at 3% O2.

For CO (carbon/ toxicity)

The test institute reports the CO emissions during steady state, according to the indicated test method and certifies whether the CO emissions meets the target values (see next paragraph).. The unit is ppm (parts per million) at 3% O2.

For refrigerant

The test institute reports the nature and quantity of the refrigerant contained in the CH-boiler system and certifies whether the GWP (Global Warming Potential) meets the target values (see next paragraph).

2.5 Targets

2.5.1 LLCC and BAT Target levels

The energy efficiency levels at Least Life Cycle Costs (LLCC) and Best Available Technology (BAT) from Task 6 are summarized in the following table.

The LLCC-target levels can be summarized as 76% energy efficiency for load profiles XXS to XL. For load profiles XXL-3XL and 4XL an energy efficiency level of 96% applies. These two values are in the middle of efficiency classes proposed for labeling in par. 2.9, i.e. 76% is in the middle of class B and 96% is in the middle of class A+.

Table 2.2. Target levels

Load profile	Net heat load kWh/a	Net Heating Efficiency BASECASE	Net Heating Efficiency LLCC-LEVEL	Net Heating Efficiency BAT-LEVEL
XXS	2.350	53%	77%	160 - 170 %
XS	3.700	54%	77%	160 - 170 %
S	4.850	52%	79%	160 - 170 %
M	7.480	54%	78 – 80%	130 - 140 %
L	10.515	55%	78%	130 - 140 %
XL	20.000	44%	77%	125 - 135 %
XXL	42.195	45%	101%	125 - 135 % *
3XL	106.738	43%	98%	110 - 120 % *
4XL	320.215	43%	99%	110 - 120 % *

In combination with the LLCC targets also the following emission limit values are deemed feasible:[12]

- NOx emission limit value (long term): 20 ppm (for gas- and oil-fired boilers; whereby this requirement will be annulled in case of multi-valent systems involving renewable energy sources)
- CO emission limit value (preliminary): 400 ppm (for gas- and oil-fired boilers)

The NOx emission limit value (ELV), to be introduced at the end of 2012, brings the EU up to speed with the best current global legislative practice (California). Furthermore, at the LLCC-efficiency levels mentioned –which already require quality boiler systems-- the extra production costs for realizing this ELV are limited (around € 10). In this context it is important to note that if the European Commission and Consultation Forum should decide not to require at least the LLCC-target levels, then also the extra costs for realizing a NOx-ELV of 20 ppm will be much higher.

For emissions of CO, CH4, CxHy and PM (Particulate Matter) the LLCC emission limit values can as yet not be established as no appropriate test procedures –and thereby no data from boilers—are available. It is recommended that the Commission issues a mandate to CEN to develop the appropriate standards (see also Assessment Procedure). The CO ELV of 400 ppm is just a temporary, precautionary measure to limit excessive CO-levels, should designers try to realize the low NOx by over-exploiting the trade-off between CO and NOx.

2.5.2 Environmental impacts at target levels.

The following tables from Task 6 give the expected energy savings at target levels. Table 2.3 applies to the LLCC-level, yielding an average saving of 35-40% with respect of the Base Case. Table 2.4 relates to the BAT level, yielding savings of 60-70%.

[12] Please note that the ELVs are linked to the LLCC target level , at which they will incur little extra costs (e.g. € 10, - higher production costs). However, if the political discussion would lead to lower Index values for energy/ carbon, then also the value for NOx has to be revised (lower).

Table 2.3. Energy Savings LLCC level versus Basecase level

Load profile	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 2.4. Energy Savings BAT level versus Basecase level

Load profile	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

For an overview of other impacts, see the Chapter on Impact Analysis.

The BAT (Best Available Technology) or BNAT (Best Not yets Available Technology) levels in Task 6 are mostly based on heat pump technology sometimes with an add-on benefit from solar installations, which would have several drawbacks for application in mandatory measures.

- Heat pumps cannot be universally applied. Especially 'geothermal' or 'vertical' ground-source heat pumps require special permissions from the waterworks and/or the commune, etc..
- Specialist installers and special equipment are necessary and (as yet) not abundant
- The efficiency of the heat pump is highly dependent on the lay-out and installation.

- Often a heat pump is a base-load device, which means that a hybrid device (e.g. with a conventional boiler) may often be an economical solution to capture both base and peak loads
- The energetic benefits are highly dependent on the climate, especially with air-based heat pumps and of course with solar energy.
- As a result of the above, the pay-back time will vary widely per country and circumstance.
- The current heat pumps are mostly electric, which means that a hypothetical full EU heat pump strategy would lead to increased emissions of everything else besides CO2: more acidification, more VOCs, more heavy metals, etc.
- Most heat pumps are reversible, which means that they can supply both cooling an heating. If they are attached to a CH-system the cooling options will be limited (only top-cooling), but still this could lead to a summer operation that would be detrimental to the saving and mitigation effort.

All in all, the heat pump technologies represent an interesting option with a large saving potential and should be promoted whenever and wherever possible (with emphasis on possible). As such they should therefore have their place in the highest ranks of a labelling scheme. However, the uncertainties (and the costs) of the option should be taken into account. Regarding the solar-assisted space heating our technical and economical analysis indicates that yields are often higher than expected (usually solar heating is seen as typically for water heating only). However, the economical benefits are too small to make them qualify as LLCC-target, although in larger installations and at mass volume collector prices they can be competitive.

2.5.3 Life Cycle Costs at LLCC and BAT levels

The table below from Task 6 gives the Life Cycle Costs at LLCC and BAT levels. It shows savings at LLCC level of up to 16% for the smaller load profiles (up to L) and 30-46% for the largest sizes. The savings at BAT level indicate that, apart from the smallest XXS level, the BAT-solutions do not save as much as LLCC-solutions but are still more economical than the Base Case.

Table 2.5. Lifecycle costs and savings LLCC- and BAT- levels versus Basecase level

Load profile	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

2.6 Incentives

2.6.1 Introduction

The LLCC-targets above constitute the "sticks" part of a balanced strategy of "sticks, carrots and tambourines". And, as will be indicated in the Chapter on Alternative Scenario's, "sticks only" will not be enough to realize the full saving/ mitigation potential.

In general the aims of financial incentives like subsidies, tax deductions, low-interest loans are :

- To address the problem of "affordability" of Eco-design measures for low-income groups
- To smoothen the transition process towards mandatory LLCC targets, showing that the government is not just asking sacrifices from the market actors (manufacturers, consumers, etc.) but is also serious in contributing its share in the effort.
- To reach environmental and energy saving goals that go beyond the LLCC targets (27% saving) but that promote a move towards BAT-solutions (50-60% saving).

Of these three, the last two aims are a part of the policies of the Member States (subsidiarity principle) and here we will just give some information as regards the level of the incentives. However, the first purpose is by far the most important. The criterion of **"affordability" i**s also the only one explicitly addressed in the 2005/32/EC directive.

For problems related to affordability we refer to the paragraph on "negative stakeholder impacts", where it was mentioned that low- to medium income groups that own an apartment and an individual boiler but have to use a collective chimney, will be facing the serious problem of not only the costs of chimney renewal, but would have to synchronize their effort with other inhabitants that are connected to the same collective chimney and thereby could be forced to early replacement.

For them it is recommended to set-up an **"Early Replacement/ Chimney Renovation Program" t**hat would subsidize the effort.

Furthermore we recommend that –because of the criterion of "affordability" in the 2005/32/EC Directive—this Program is an indispensable part in reaching the full potential of LLCC-target level.

In other words, if this problem cannot be solved through financial incentives, with some technical measures for the interim, the LLCC-target levels for the XXS-XS-S load profiles can be deemed "not affordable" and for a significant group (ca. 8% of the population, see below) of EU-citizens and therefore the target level for those load profiles should be lowered to a level that would allow non-condensing technology.

2.6.2 Costs of Early Replacement & Chimney Renewal Program

As is shown in figure 1, the total group of dwellings with non-condensing individual boilers in apartment buildings in the EU is estimated at ca. 24 mln. dwellings/boilers in 3 to 3,5 mln. buildings. Of this, a part will be rental and a part will be privately owned dwellings. For the rented apartments the collective replacement is usually not a problem, because the boilers will have the same age and the landlord/ building owner will replace them all simultaneously anyway. We don't know the exact share of not privately owned apartments and will therefore assume the EU average of 60% privately owned and 40% rental or community owned. This leaves about 14,4 mln. apartments in ca. 2 mln. buildings. This represents around 8% of the EU-25 housing stock. If we assume a transition period of 4 years between the announcement of the measures and their implementation roughly some 3,6 mln. apartments per year (0,5 mln. buildings) should be subject to the Early Replacement & Chimney Renewal Program.

Assuming an 80% collection rate (not all subsidies are actually claimed) and 20% administration costs, we estimate the average cost and the average subsidy at around € 300,- per boiler unit. The total cost of such a program would be just over 1 bln./year for a period of 4 years. Most of these costs/subsidies (80%) are expected in Southern European Member States.

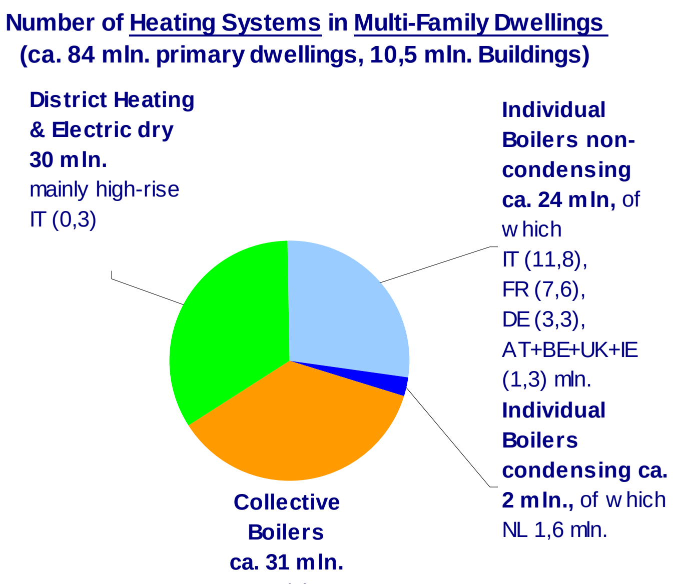

Fig. 2.1. Heating Systems in multi-family dwellings

Given the target group the most suitable form of such a subsidy would probably not be a loan or a tax deduction, but a cash-return. Because the subsidy would always be for groups of (on average) 8 apartments, the administration costs and the costs for spot checks will be limited.

The funding of such a program can take many forms and will be subject of the political debate. We can only suggest that in principle it would seem not unreasonable to have a fund where

- the governments that benefit, the most contribute the most (Italy, France, etc.). The funding helps them not only in terms of environmental goals, but also in terms of social policy (helping low-income groups to lower their housing costs) and employment (e.g. support for local SMEs engaged in installation work).
- the utilities (EdF/GdF, ENEL, etc.) could be involved through the "white certificates" and "green certificates" schemes.
- a contribution at EU-level is reasonable –i.e. also with tax money from Member States that do not benefit much directly but mostly indirectly from the realisation of the Eco-design measures. As mentioned, the alternative for not finding the funding is to lower the target level of the XXS-XS-S classes to non-condensing levels (ca. 10% lower), which would be detrimental to the environmental targets of those other countries as well.

2.6.3 *Other Financial Incentives*

As mentioned, generic incentive program can smoothen the implementation process towards and help to reach national goals beyond the LLCC targets. Although this is typically a matter that does not needs to be treated at an EU-level, this preparatory study can provide information on the subject.

In that sense, the Task 1 and Task 2 report are the most important, providing an overview of measures in each Member State and supplying information on the sales and the price levels per Member State.

In general one can say that the financial incentives for e.g. the promotion of condensing boilers (usually distinguished by a label, e.g. "HR" in NL), have been relatively modest. In several Member States (NL, BE, UK, etc.) a typical subsidy has been € 150,-. This is low in comparison to subsidies for other products (whitegoods, cars) and in comparison to the carbon and energy saving involved.

In the context of emission trading there appeared to be a consensus that a price of € 20,-/ tCO_2 is reasonable for carbon saving. An average boiler (M-size) uses around 47 tCO_2 over its product life (Base Case, see task 5) and a 27% saving (LLCC-target) would imply a saving of almost 13 tCO_2. In that case a subsidy of € 250,- would be reasonable. Similarly for larger boiler systems would be higher: € 350,- for L-class, € 800,- for XL-class, etc.. For smaller boiler systems these amounts are lower: € 200,- for S-class, € 160,- for XS-class and € 120,- for XXS.

Compared to whitegoods the subsidy level of € 150,- is also modest. The same Member States have given subsidies up to € 100,- or more for the most efficient refrigerators and freezers, despite the fact that the carbon saving involved is only a fraction (<5-10%) than that of heating boilers. Perhaps the bare product price in those countries, where condensing boilers are a competitive market, has something to do with it, but it was forgotten that the replacement also results in installation and other costs (e.g. new thermostat). How otherwise could one explain only a € 50,- subsidy difference between an average fridge-freezer of € 500,- and a completely installed boiler, which even in the Netherlands costs more than 4 times as much.

Compared to cars, the subsidies on boilers are extremely low. With past and current schemes for cars there have been take-back subsidies of around € 1000,- when purchasing efficient cars (label A or B) . The carbon saving from such an exercise is limited to on average around 8-9 tCO_2 over the life time of the car, e.g. going from an average stock-average of 160-170 gCO_2/km to around 100-110 gCO_2/km. At an optimistic 150.000 km over the car product life this 60 gCO_2/km saving results in the 9 tCO_2 mentioned. At € 20/ tCO_2 this should have resulted in € 180,- subsidy, but of course there are some lateral effects (lower NOx, SOx, PM, etc.), which –by the way— are not very different from those of CH-boilers.

We believe the labelling of cars, and the fact that it is a high-interest product considerably better known to the public, may have something to do with it. This allows for instance to introduce a sort of "bonus/ malus" arrangement, whereby the subsidies for the more efficient cars can be financed by extra road tax or extra levies on the least efficient cars.

The introduction of a **labelling program** as part of the Eco-design measures could therefore be of crucial importance, because it would identify not only the best products, but –for the first time-- also the worst products on the market. Especially in the transition period this would allow the application of a similar "bonus/ malus" subsidy/tax system as with cars.

2.7 Information: EPB & Labelling

Apart from minimum targets and financial incentives, promotional and educational activities at Member State level would usually accompany the intriduction and implementation of the new legislation. At EU-level we recommend measures that would create the right conditions and tools for such information activities, notably

- Labelling, which can also be an important tool for the financial incentives
- Coherence with other legislation for energy saving and emission mitigation, especially the efforts in the field of EPBD (Energy Performance of Buildings).

2.8 Labelling

Labelling, in the form of a star-rating, was part of the BED, which is now superseded by the Eco-design directive.

It is recommended to include mandatory labelling as an Eco-design measure and VHK has discussed several options with the expert group in order to be able to give the Commission a detailed advice in the matter.

2.8.1 Labelling: Good Practice

In general a label, and more specifically a label for the CH boiler system, has to meet a series of demands both on the lay-out and the content, notably its should be

- Recognisable and coherent across products (redundant style characteristics, like A-G and recognisable colour-scheme)
- Attractive *("rainbow")* and conspicuous *(bright colours)*, instil confidence *(EU flag and some legal small print)*,
- Avoid (technical) texts, but use symbols, icons, well-known classifications, etc.. Technical information should be on the "fiche" as much as possible.
- Performance indications should be based on the function that the consumer wants (e.g. "heating power" or "hot water"), not on the technology involved (e.g. "electric storage water heater").
- Any other label-information on the product besides energy/environment should be very limited, e.g. to the main performance characteristic. "More information" isn't "Better information". Furthermore, a label isn't the only source of information on the product. For more extended information there is the "fiche", the nameplate and any other information that a manufacturer wants to put in its brochure, internet-site, etc..
- Give consumers the correct impression of energy efficiency and environmental benefits available, within that function.
- Give a complete impression of where a specific product is placed in the total field. For instance, if an extra class exists better than A (A+ or A++) this should be instantly clear to the consumer by adding the extra bars above the "A"
- Easy to understand for lay-men,
- Acceptable to experts (scientifically sound)
- Give a fair and "level" playing field for the manufacturers.
- Be exact, without overstating exactness when it isn't there. E.g. for "solar" and "heat pumps" the class-widths can/should be much bigger because of uncertainty in yield → 16 index points instead of 8 class-widths for A+ to A+++.

- Based on a correct understanding of the test tolerances involved. For instance, the inter-laboratory tolerances for part load testing of boilers is in the range of ±4%. Therefore, it may give rise to conflict (jumping two classes) and confusion with the authorities to use class-widths smaller than ca. 7-8% efficiency.
- Be robust in a court of law, founded on clear rules and test procedures. In the past there have been court-cases for fraud against white-good manufacturers, who allegedly claimed much too high efficiency classes. In the following court case it was clear that judges were baffled by the phenomenon of tolerances, which has been seriously detrimental to the credibility of those labelling schemes, especially when used for public subsidies ("tax payer's money"). In the future this should be avoided at all costs.
- Be ambitious, whereas at the same time leave enough room to differentiate between existing products and thereby also trigger improvement in the lower-end products.
- Should stimulate innovation, i.e. rewarding the most advanced technology.
- Reward (the use of) renewables, but with factual information and subject to the same validation as conventional products (Let the figures speak for themselves).
- In the case of multi-function appliances, where the space heating function is combined with other functions (hot water, cooking, etc.) the label should be able to accommodate classifications per function. This is especially so, if the consumer has a choice between a multi-function appliance and dedicated products.
- Also in the case of multi-function appliances the user should at least optically be given an idea of the relative environmental impact of each function. For instance, for existing dwellings the hot water function of a combi constitutes only a quarter or one-fiftht of the impact of the space heating.
- Being and eco-index it should take into account all relevant eco-aspects (NOx, CO, noise, GWP refrigerant) and not just energy and carbon.
- Should help to enforce LLCC-targets, e.g. the target level should be identical to a class limit (e.g. between B and A).
- Should be coherent with, and possibly applicable in other existing and future legislation, notably the EPBD and notably Eco-design measures for related products (e.g. solid fuel boilers, local heaters, space cooling, ventilation, etc.) .
- Should be useable in incentive-schemes: Subsidies, loans, tax-deductions, but also schemes like the "white certificates" and –as far as renewables are a part— "green certificates".

2.8.2 Label design

Based on the above the proposal for a design of the label was made. Figure 2 shows the label for an Eco-index of a solo-boiler and for a combi-boiler system.

The label is based on the outcomes of the Assessment Procedure, i.e.

- Energy efficiency[13], as a measure for energy resources use and carbon emissions is the main parameter. The CH net efficiency limits are:
- G <40%, F<48%, E<56%, D<64%, C<72%, B<80%, A<88%, A+<104%, A++<120%, A+++>120%.
- Following the recommendations by prof. Oschatz we propose to use the Net Efficiency values (ratio between energy input and net heat load of the dwelling/ building) . This results in class limits that are ca. 12% lower than e.g. a comparison with an ideal boiler. For instance, the maximum achievable efficiency with a conventional boiler (no renewables) is not 100% but only 88% . The reason for the difference between the efficiency values lies in the fact that the CH-boiler system –however perfect—can only be responsible for a part of certain losses, like distribution and stratification losses. The other part of the losses are inherent in the effect that a CH-system, i.e. a system with piping and emitters is used, is used that –even with the lowest possible CH-water temperature—will always show a loss that is due to e.g. limits in the insulation of the pipes.

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[13] We propose to use the Net Efficiency values (ratio between energy input and net heat load of the dwelling/ building) . But it has to be taken into account that in that case the maximum achievable efficiency for a conventional boiler is not 100% but 88%, because certain losses will be unavoidable (e.g. distribution, stratification)

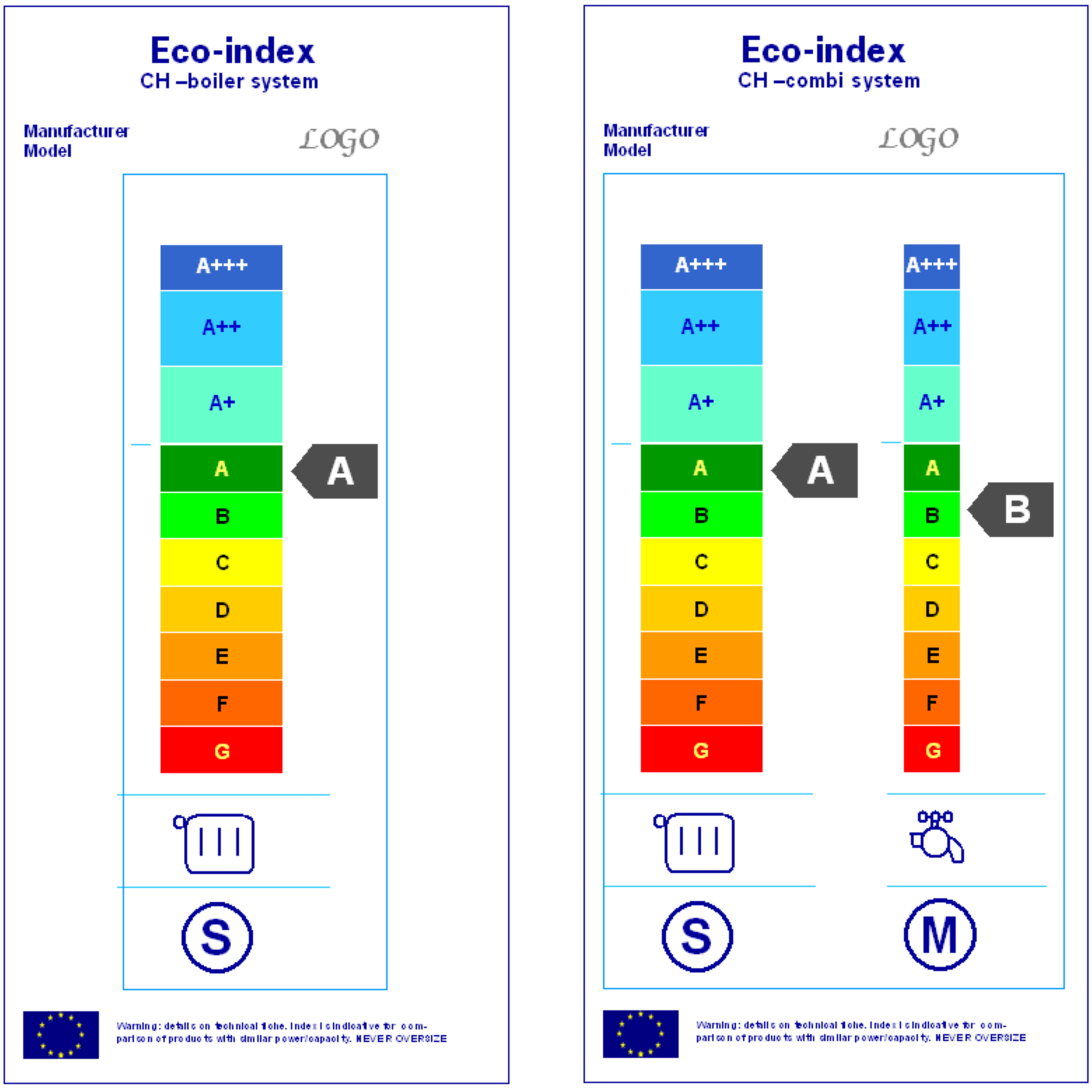

Fig. 2.2. Proposal for label-design: Left: boiler. Right: Combi-boiler.

Table 2.6. Overview of index classes for CH-boiler systems (space-heating function)
estimated market share, class limits in system efficiency, net efficiency and emission

Class			Examples
A+++	market share	**<1%**	**vertical ground-source heat pumps (GSHP)**
	sys-eff	>132%	best horizontal GSHP
	net eff.	**>120%**	
A++	market share	**<1%**	**gas-fired heat pump**
	sys-eff	>116%	best air-based electric heat pump
	net eff.	**>104%**	average horizonal GSHP low-end vertical GSHP
A+	market share	**2,0%**	**best condensing+ solar**
	sys-eff	>100%	good air-based heat pump
	net eff.	**>88%**	low-end horizontal ground source el. heat pump low-end gas-fired heat pump
A	market share	**8,0%**	**best condensing**
	sys-eff	>92%	average air-based heat pump
	net eff.	**>80%**	average condensing + solar
B	market share	**10,0%**	**average condensing**
	sys-eff	>84%	low-end air-based heat pump
	net eff.	**>72%**	best LT + solar
C	market share	**12,0%**	**best LT**
	sys-eff	>76%	low-end condensing
	net eff.	**>64%**	average LT + solar
D	market share	**15,0%**	**average LT**
	sys-eff	>68%	best atmospheric + solar
	net eff.	**>56%**	low-end LT + solar
E	market share	**30,0%**	**low-end LT** **BASE CASE**
	sys-eff	>60%	best atmospheric
	net eff.	**>48%**	average atmospheric + solar
F	market share	**15,0%**	**average atmospheric**
	sys-eff	>52%	electric resistance CH-boiler-systems + solar
	net eff.	**>40%**	low-end atmospheric + solar
G	market share	**6,0%**	**low-end atmospheric**
	sys-eff	<52%	electric resistance CH-boiler-systems
	net eff.	**<40%**	

2.8.3 Fiche

Apart from the label there will also be a "fiche", which contains all the technical information and test results. The correct format for the fiche has to be elaborated in the process leading up to the legislation.

Fig. 2.3 gives a first (incomplete) example.

Technical Fiche

Boiler			
Nominal (max.) input	24	kW	
Minimum input (40%)	9,24	kW	
On-off / high-low / modulating	modulating		
Efficiency at max. capacity and 80/60 regime	87	%	
Efficiency at max. capacity and 50/30 regime	89	%	
Efficiency at min. capacity and 80/60 regime	88	%	
Efficiency at min. capacity and 50/30 regime	95	%	
Heat loss at burner off	0,22	kW	
etc.			
Solar collector			
Collector surface	-	m2	
Storage vessel	-	ltr.	
Glazed / unglazed / vacuum tub	-		
Efficiency	-		
Efficiency	-		
Heat loss storage tank	-	W	
Solar pump power	-	W	
Anti-frost energy use	-	kWh/a	
etc.			

Fig. 2.3. Example of fiche (incomplete)

2.8.4 Coherence with EPBD and other legislation

As mentioned before, the mathematical validation in the Assessment Procedure is fully in line with the harmonised standards that are being prepared for a harmonised approach. VHK has derived the common denominators from these standards (EN 832, prEN 51316 series, etc.) and used them in the mathematical model. Only in some instances, e.g. where the standards left gaps, we have gone beyond what was in the standards. For instance regarding the CH-controls we have filled in the gaps and also we have anticipated that certain items like “summer comfort” that are in some new standards but not the older ones would be implemented throughout all standards.

The result is a mathematical model of both space heating and water heating that is reasonably robust and where at least the boiler- and water heater industry seems to agree with.

At this point, the question arises whether it would not be timely to “hand back” this mathematical model to CEN and now ask them to continue their work on this harmonised basis. The reason why we are proposing this, is because it appears that also the harmonisation work inside the EPB seems to be in a transitory phase: In three years time a large number of pre-standards have been produced that more or less contain all the know-how on installations that is in the national standards. However, this has as yet not resulted in a single harmonised system where all Member States agree on. In fact, several Member States in the so-called Paragraph 13 committee have proclaimed that they will (continue to) use their own national standards. Although they are of course perfectly in their right, it is no exactly what is in the spirit of the EPBD. In such a situation an outside influence, like the Eco-design legislation may help.

In that context we recommend not just to incorporate the bare minimum text required in the legislation concerning Eco-design measures, but also to include an Informative Annex that explains the modelling that is behind the measures. As it is then incorporated in legislation, it can easily be used as a reference for the EPB harmonisation.

In the same spirit it is advised to expand on the general model in an Explanatory Memorandum that could incorporate not just the EU-average climate and building data, but also the national data that have been used and that will show policy makers in the Member States how such a single harmonised model would work out for their particular national circumstances.

2.8.5 Related Eco-design projects/ products

Apart from the EPBD we recommend that the mathematical model, expanded where necessary, shall be used a basis for preparatory studies and possibly measures for related products: Solid fuel boilers, Local Heaters, Space cooling, ventilation systems, etc..

Furthermore, we recommend that also Eco-design measures on a component level should benefit from the model, notably

- Indirect cylinders, other storage tanks (also for solar/ HP/etc.)
- Thermostats
- Valve controllers
- Pumps (boiler integrated)
- Air/fuel mixers
- Solar collectors
- Heat pump components (compressor, controls, evaporator, condenser, etc.)

In particular the above components could each be subject to a separate A-G energy labelling system that of course has to be consistent with the overall boiler labelling scheme. Minimum targets can also be considered in preparatory studies.

Less important (and perhaps more difficult to do) but worth considering:

- CPU (SMPS-level mandatory)
- Fans (permanent magnet DC fans mandatory)
- Fuel “transport” and preparation: Gas valves, oil pumps

The preparatory study for the components could be treated in one single study, because commercial and technical parameters are linked to the boiler.

- Task 1 (standards) would be unique, but still should always be seen as coherent with boilers
- Task 2 numbers commercial identical to boilers.
- Task 3 (dwellings and infrastructure) → boilers

- Task 4 (technical analysis)→ unique, but always linked to boiler
- Task 5 (BaseCase) → already given: pump 90 W + 1000 l/h, on/off thermostat, TRV 2K
- Task 6 (design options) → unique
- Task 7→ impact is already given in Integrated Model.

2.9 Timing

The following gives an overview:

- Labelling in place Jan. 2009 at the latest (part test, part model).
- MS promotion from Jan. 2009 (concurrs with EPBD certificates and standards)
- Staged introduction of minimum standards (3 tiers):
- Jan. 2009/ 2011/ 2013
- Minimum standards energy/carbon (system efficiency) and NOx. Preliminary standard for CO.
- Introduction of new test/emulation standard Jan. 2013
- Revision of label, based on new test standard, completed Jan. 2013.
- Also minimum standards for CO, CxHy, PM, CH4 based on new standard, starting 2013.

2.10 Alternative policies

During the study in the past 18 months we have been confronted with several alternatives to the scenario we have recommended in the previous chapters. Here we would like to briefly present these alternatives and the reasons why we do not recommend them.

2.10.1 Minimum Targets Only

This scenario is based on an opinion that lateral policy measures are superfluous, because the minimum standard will in itself push away the bad solutions. No labelling, no promotion, no MS subsidies or other incentives, but just "tough" legislation. The expected effect of such a strategy is that it provokes defensive behaviour, delaying tactics, lack of understanding. It may create protests from consumer associations and those defending a real or perceived disadvantage for the lower income groups. And ultimately it will result in the realisation of only a part of the saving potential.

Keywords for a successful market transformation and transition are "trust", "responsibility" and "commitment" from all stakeholders. And a strategy of "mandatory targets only" may well be perceived as the opposite.

2.10.2 Labelling and Promotion Only

Alternatively, it could be decided that there is no need to set a mandatory minimum limit for energy efficiency and emissions: just labelling, subsidies and promotion (e.g. directly and through the EPBD) would be sufficient in this strategy.

What will be the effect of such a strategy can be seen e.g. from Switzerland, which has been highly successful in approaching home owners with its Minergie-approach. A high percentage of these home-owners and especially private builders have invested in insulation, heat pumps, etc.. At the same time however, this strategy has almost completely failed with regards to buildings where the home-owner (landlord, property manager, developer) is not the one paying the energy bill. For this considerable group the absolute height of the investment (the price of the installation) has been and still is the one and only selection criterion. And there has been no government willing to subsidize all the extra costs of an efficient installation over the very cheapest installation. As a consequence, the cheapest is always chosen. This is of course done at the expense of the –very often economically weaker—families renting the apartments that have to pay the energy bill. There is of course the hope that energy certification and other measures (lower "all-in" rent) will convince the property owners that an efficient installation will also be to their benefit, but that is just hope....

Another segment of the building market where just "carrots and tambourines" can count on limited success is the segment of (semi-)public buildings, especially those at the local and regional level. Some of the oldest and most inefficient heating installations around can be found in schools, hospitals, homes for the elderly, sports facilities, prison buildings, etc.. The reason behind this is is often that the budgets are limited and often issues like a new heating installation are not explicitly budgeted, but have to come from a total annual budget. This means that a new boiler has to be weighed against e.g. postponing the building of a new wing for the school, a new operating room in a hospital, etc.. And the current political reality is that the new, better boiler almost never wins, so the investment is postponed until the boiler is really beyond repair and the new boiler will be the cheapest option available.

2.10.3 EPB Only

It has been claimed in the very beginning of the study that we don't need EU-wide measures because we have the EPBD and other promotional instruments on a national scale that will promote the introduction of the best boiler solutions in situations (and countries) where this is most appropriate. As far as we know this not the current position of the industry anymore, but it is a tempting thought. And there is certainly some truth in it, because for new housing and renovations this will certainly be a big influence. However, it is not certain what this will mean for the biggest boiler market: i.e. the existing buildings. They represent 70% of the market in unit sales and even if the EU succeeds in finding a common grounds also for regulating the existing buildings, it will never be as ambitious as for new houses. But even for new houses there is always a competition between building technologies, where for most contractors there is a higher profit margin in building more insulated walls than just buying a better boiler (which is just a profit for the installer). Another consequence of national EPB standards regulating the boiler market is the fact that currently most EPBs are different. This means that for each EU Member State the manufacturer has to develop a specific commercial strategy and most likely country-specific products. The production-series of the latter will be lower than for products that can be sold EU-wide and therefore the prices will be higher. This isn't to the advantage of the consumer, of the manufacturer, of his/her global competitiveness, etc.. In short, such a strategy is in contrast with the EU strategy for the development of an EU-market. Instead, the EU should strive for harmonised EPB standards that in each MS are in line with Eco-design measures for boilers and vice versa.

The authors believe that any of the above strategies will lead to a saving of no more than 5-10%, which is a factor 3 to 5 lower than the economical potential. Furthermore, it has to be considered that –at least in part—some of these strategies are irreversible. Once a policy maker has gone down the path of “simplification”, “just sticks”, “just carrots” or “just tambourines” it will provoke a series of events and behaviours of stakeholders which will have a lasting effect in the future. Also in that sense we recommend a “system approach” which has the advantage that it is much more flexible: should the need arise it is much easier trim a more simplified approach (the opposite is more difficult). It is also open for a much more differentiated strategy in terms of “carrots, sticks and tambourines”.

3 SCENARIOS: INTRODUCTION

3.1 Introduction

Subtask 7.2 (Scenario Analysis) draws up the scenarios for 1990-2020 on the basis of policy measures indicated in Subtask 7.1. To this end, VHK extends the Analyses and Models in the previous Task Reports to make projections for 2010 and 2020 and acomparison with a Business-as-Usual (BaU) reference scenario.

Furthermore, VHK uses the ECOBOILER model for the environmental impacts and the Life Cycle Cost evaluation.

Subtask 7.2 comprises the following scenario's:

- **BaU** (Business-as-Usual) : Based on BRG sales projections in Task 2 report, trends in Task 3 report regarding the load, BaseCase (2005 sales) figures from the Task 5 report
- **Slow:** Implementation of targets 31.12.2014 and after that no improvement beyond LLCC level
- **Realistic** scenario: Staged introduction minimum targets. Final tier 31.12.2012. Labelling per 1.1.2009. Support by labelling, EPBD, ESD, financial incentives, green/white certificates, promotion etc. boosts efficiency by 3% annually over the 2009-2018 period. After that, the market is expected to stabilize.
- **Ambitious** scenario Measures as above. Efficiency-increase 5% annually 2009-2018. Continued efforts will lead to further increase of 2% annually also after 2018.
- **Amb + ER**: "Ambitious" plus Early Replacement of 3 mln. water heaters annually starting 2013.
- **NOx 20 ppm**: As "Amb+ER" plus emission limit value of 20 ppm for fossil-fuel fired water heaters not utilizing at least 10% renewables.
- **Freeze_2005**: Theoretical reference scenario. No technology change and technology market share changes since 2005. Only replacement effect.

Please note, that this subtask is based on modelling with the ECOBOILER model and the CH STOCK model, which are both added as separate "deliverables" for this subtask. (MS Excel files)

The underlying Word-report shows the highlights regarding the inputs and the conclusions. Numerical tables of the scenario outcomes are given in the Annex.

3.2 Base Case (avg. sales 2005)

The table on the next page summarizes the findings from the Task 5 report. It gives the 2005 sales figure **[part A]**, of close to 7 mln. units/a, subdivided by load profile.

The net load applicable to each size class, multiplied by the sales, is given in **[part B]**. This amounts to an EU total of 29.721 GWh/a for the BaseCase. For the scenario analysis especially the weighted average load is important, because it will be used throughout the analysis.

[Part C] gives the estimated efficiencies of the BaseCases.

Table 3.1. Calculation of annual primary energy consumption Base Case (avg. EU-25, sold in 2005)

A. Total sales EU-25 in '000 units in the year 2005

in '000 units	**XXS**	**XS**	**S**	**M**	**L**	**XL**	**XXL**	**3XL**	**4XL**	**Total**
Boiler	150	500	1000	3400	650	650	170	40	40	6600
Total	150	500	1000	3400	650	650	170	40	40	**6600**

B. Net load in GWh/a

Net load kWh/a.unit	*2350*	*3700*	*4850*	*7480*	*10515*	*20000*	*42195*	*106738*	*320215*		
total net load in GWh/a	**XXS**	**XS**	**S**	**M**	**L**	**XL**	**XXL**	**3XL**	**4XL**	**Total GWh/a**	**Average kWh/a**
Boiler space heating	353	1.850	4.850	25.432	6.835	13.000	7.173	4.270	12.809	76.571	11602
Total GWh/a	353	1.850	4.850	25.432	6.835	13.000	7.173	4.270	12.809	**76.571**	**11602**

C. Efficiency in % (primary energy, Gross Calorific Value)

in %	**XXS**	**XS**	**S**	**M**	**L**	**XL**	**XXL**	**3XL**	**4XL**	**weight avg.***
Boiler space heating	53%	54%	52%	54%	55%	44%	45%	43%	43%	48%

D. Energy consumption in GWh/a (net load efficiency)

Sales	**XXS**	**XS**	**S**	**M**	**L**	**XL**	**XXL**	**3XL**	**4XL**	**Total**
Boiler space heating	665	3.426	9.327	47.096	12.427	30.233	15.940	9.929	31.240	160.284
Total	**665**	**3.426**	**9.327**	**47.096**	**12.427**	**30.233**	**15.940**	**9.929**	**31.240**	**160.284**
Efficiency aggreg.	53%	54%	52%	54%	55%	44%	45%	43%	43%	48%

**=weighted for total net load in GWh/a, so taking into account both sales and load*

E. Energy consumption at LLCC targets (in MWh/a)

target	76%	76%	76%	76%	76%	76%	96%	96%	96%	**81%**
energy in GWh/a	464	2.434	6.382	33.463	8.993	17.105	7.472	4.447	13.342	**94.103**

[Part D] calculates the annual energy consumption of Water Heaters sold in 2005 from the above. In total this amounts to 92 TWh/a of primary energy. The overall weighted efficiency is 48%.

The LLCC target level is given in **[Part E]** and amounts to 81% efficiency (weighted average).

3.3 BaU-scenario

Table 3.2 gives the relevant data for the Business-as-Usual (BaU) scenario. It is based on the Task 2 and Task 5 reports and it is the starting point of the scenario analysis.

The CH_STOCK model takes into account the following effects in the BaU scenario:

- Negative effects 2005-2020: Increase in number of households (10-12%), increase in floora area (3-5%), increase heating comfort (8-10%),
- Positive effects 2005-2020: insulation and ventilation measures (30% over 2005-2020), increase boiler efficiency through park replacement (5%), extra efficiency through measures (3-5% efficiency points from low-end condensing being 50% of EU-sales in 2010), increase outdoor temperature (1%)
- Overall effect 2005-2020: Ca. 18% decrease.

In the CH_STOCK model these effects are calculated throughout the whole period (1990-2020) in the following ways:

- The **load effect** (more comfort, more floor area, more insulation) is controlled by a load factor ("LoadCor"), which is set at 1,8% annually. The pivot-point for this load factor is the "net load" value for the base year 2005 [see worksheet STOCK 1YR in model].
- The **efficiency effect** is given in Table 3.2, which is equivalent to worksheet STOCK 5YR. These values are used as anchor points for the respective years in the STOCK 1YR worksheet. The values are based on the base year 2005 , where it is derived from the Base Case values as shown in Table 3.1 [from worksheet BASE CASE in spreadsheet] and estimates for pre-2005 and post-2005 as shown in Table 3.2. Especially for post-2005 the BRG prediction of 48% (low-cost) condensing boilers in 2010 was taken into account.
- The **growth effect** of increasing number of households and ownership comes from the unit sales projections by BRG Consult in Task 2. But we did calibrate the "ProductLife" parameter and individual sales slightly to match sales and park data. Graph 3.1 gives the unit sales projections (from Task 2).

Please note that the efficiency figures in Table 3.2 [and worksheet STOCK 5YR] are weighted for the loads and sales in the various load profiles as indicated in Table 3.1 . This aggregated efficiency figures is used in the worksheet STOCK 1YR , which is the actual stock model.

Table 3.2. BaU Scenario

year-->	1990	1995	2000	2005	2010	2015	2020
Boiler sales (000 units)	4778	5520	5993	6600	6952	7432	7911
Weighted efficiency (for load and sales)							
Boiler space heating	42%	44%	46%	48%	51,5%	52,5%	53,5%
Average net load in kWh/a							
Boiler space heating	15162	13868	12684	11602	10595	9675	8835
TWh primary/a							
Boiler space heating	172,5	174,0	165,2	**158,0**	143,0	137,0	130,6
Total in PJ/a	**621**	**626**	**595**	**569**	**515**	**493**	**470**
avg. kWh/a.unit	36099	31518	27575	**23942**	20572	18428	16514
avg. efficiency	42%	44%	46%	**48%**	52%	53%	54%

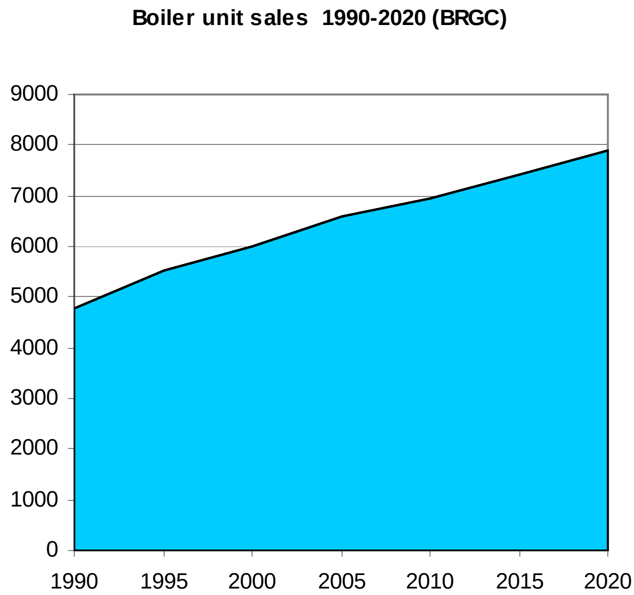

Fig. 3.1. Unit sales projections, derived from BRG Consult (1990-2025) In Task 2 Report.

3.4 CH_STOCK Model

3.4.1 Energy

All alternative scenarios in the CH_STOCK model are treated in the worksheet "STOCK 1YR". This sheet covers BRG **sales data** 1990-2020 for the BaU, as discussed in the previous paragraph, but also forward projections to 2025 and backward projections for 1970-1990 based on the extrapolation of 1990-2020 trends[14].

From the accumulation of historical sales data over the Product Life the **park data ("stock")** are built, indicating the number of boilers installed in a particular year.

For most scenarios this is pretty straightforward. Only in an Early Replacement scenario "Amb+ER", there are extra sales due to an extra replacement of the oldest products on the market (15 years old in the model). The gain of this scenario comes from the difference in efficiency between the old and the new appliances. The relevant parameter is **"ER"** with a default setting of 0,2 years[15], which amounts to ca. 1 mln. extra boilers sold annually.

Similarly to the park data, the **efficiency data** are given for each individual year . How this works for the BaU data 1990-2020 has been explained in the previous paragraph. Also here we made backward projections up to 2025 and backwards projections 1970-1990 for the BaU scenario.

Until 2009, the year in which the labeling and other lateral measures are introduced, the BaU-scenario applies to all alternative scenarios, except the "Freeze_2005" scenario, which freezes its efficiency numbers from 2005 onwards (but maintains BaU sales data). From 2008 the efficiency data start to differ between the scenarios. And for the "Amb+ER"scenario even the sales data start to differ, as ecplained before. We will discuss this later, after we have treated the general principles.

Once we have the efficiency data as well as the average **"net load"** (in kWh/a, see previous paragraphs), we can calculate the average **annual unit energy consumption** of a water heater sold in a particular year (in kWh/a).

Multiplying the unit energy consumption with the EU-sales in that year gives the total **sales energy consumption** of those sales (in TWh/a)

Accumulating the year energy consumptions over a number of years equal to the product life, we find the **stock energy consumption** of all water heaters in operation in a particular year. This is the base figure from which most impacts are derived. Contrary to the situation with the water heater study (Lot 2) we do not introduce a correction factor for secondary dwellings, assuming that boilers are typically placed in primary dwellings.

[14] Note that when opening the WH_Stock model the columns 1970-1989 are hidden. Unhide to check if required.

[15] This means the model takes 20% of the sales of 15 years ago

From the stock energy consumption in TWh/a we now derive:

- Energy consumption in PJ/a (conversion 1 TWh= 3,6 PJ)
- Carbon emission in Mt CO2 equivalent/a, using a multiplier based on electricity and gas shares (see below) and the values from the EcoReport.
- Acidification emissions (e.g. NOx, SO2) in kt SOx equivalent/a, using a multiplier based on electricity and gas shares (see below) and the values from the EcoReport. For the "NOx 20 ppm" scenario we use half the values (EcoReport uses around 40 ppm) for the gas share starting from 2013 , with a linear extrapolation from the "old"2009 values.
- Energy expenditure in € bln./a in the "ECONOMICS" section, using an average energy price in €/kWh (see below).

3.4.2 Economics

In the **"Economics"** section of the spreadsheet, we calculate the total expenditure of EU-25 water heater users, i.e. the energy expenditure, maintenance costs and the purchase costs (=price + installation) for the EU in a particular year. The input values and methodology is the same as is used for the LCC-calculations in Tasks 5 and 6, but the difference is that we are using aggregated data.

In that sense, the **average energy price** in €/ kWh primary energy is built from

- Electricity, gas- and oil rates per kWh primary energy (!) in the base-year
- Annual (long-term) price rate increase of the individual energy sources
- Relative share of electricity, gas and oil employed for water heaters

The data for the two first sets of inputs can be found in the Task 5 report. The outcome for 2005 --for instance-- is an aggregated energy rate for water heaters of € 0,053/ kWh. The average water heater energy price increase is around 4,4 %/a (over 6% for fuel, 2% for electric).

The last set of data, i.e. the relative share of electricity vs. gas [16] , was estimated from the relative market share of technologies as given by BRG consult, but also taken into account that electric water heaters will the primary choice for secondary homes. In that sense an electricity share of 45% was estimated for 2005, coming down from ca. 60% in 1990 and going towards around 40% in 2010. After 2010 we assumed a constant share of 40%.

From the Task 5 Report we found for the aggregated **purchase price** € 3645,- in the base year 2005 (product + installation, consumer price incl. VAT) at an aggregated efficiency level of 48%. The relevant parameter in the spreadsheet is "BasePrice". Using the Task 6 report we could also make an estimate that every 1% efficiency improvement resulted in a price increase (parameter "PriceInc") of € 111,-/%. With these two parameters we calculated the purchase costs in a particular year.

Finally, the **maintenance costs** were derived from the BaseCase with an (extra correction) of 2% in other years, because the average inflation rate in 1990-2005 was much higher than today.

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[16] Oil share negligible (set at 2% throughout)

From the above three data –and of course the sales, stock and energy consumption data—it was possible to make an estimate of the **total EU monetary expenditure on water heaters.**

Finally, as the customary unit is 2005 Euro, we had to correct the findings for inflation (2%) to find the **corrected EU expenditure.**

3.4.3 Accuracy

The model constitutes the best effort of the authors, based on the data available. Model outcomes, especially regarding carbon emissions, have been checked against the results of the preparatory study on the eco-design central-heating boilers (Lot 1) and the totals given by the latest outcomes of the EU GreenHouse Gas (GHG) Inventory 2005, issued by the European Environmental Agency (EEA, May 2007). Data are also in line with ECCP figures, especially when taking into account that the New Member States constitute only about 8% of the EU-25 boiler park at present.

Having said all that, it is unrealistic to expect a higher accuracy than ±5-10% from the model outcomes, especially for the projections of the monetary expenditure.

3.5 Alternative Scenarios

The graphs in this section give the outcomes of the calculations for alternative scenarios (alternative to BaU). Numerical tables of the scenarios can be found in the Annex. Discussion of the main results is given below, whereby we use the annual carbon emissions in Mt CO2 equivalent (hereafter "Mt") as a main yardstick.

3.5.1 Freeze_2005

The **"Freeze_2005"** scenario is a theoretical reference, which freezes the efficiency numbers from the year 2005 for all future sales. There is still an efficiency improvement through park replacement (= historical improvements) for which it uses the BaU sales data, but no continuation of existing trends in technologies and market shifts. The comparison between the "BaU" and "Freeze_2005" shows projections of carbon and energy if e.g. all current measures and efforts for efficiency improvement would have stopped in 2005. The difference with BaU is around 45 Mt CO2 in 2025.

3.5.2 Slow

In the "Slow" scenario, the minimum target level is introduced 2 years later than in the "Realistic" scenario, i.e. by 31.12.2004 following a linear extrapolation from 2009 BaU data. Furthermore, after 2015 there is no efficiency improvement because there are no lateral measures. The effect in 2025 is a saving of 137 Mt with respect of BaU, which is a difference of 43 Mt with the Realistic scenario. Energy scenarios predict similar results. Consumer expenditure is projected to be € 14 bln. more in 2025 than with the "Realistic" scenario, but still € 55 bln. less than with Bau in that same year.

3.5.3 Realistic

In the Realistic scenario not only it is assumed that between 2009 and 2013 the efficiency will move from the BaU level to the LLCC-target level, but also that starting 2012 there will be an additional efficiency improvement of 3% (parameter "RealGrow") until 2018, after which the market will stabilize (parameter "RealGrow2"=0%). This extra grow is due to lateral measures and account for the difference with the "Slow" scenario mentioned above. The 2025 carbon saving in 2025 is 180 Mt, which constitutes a saving of 35% with respect of BaU. (see chapter on impact analysis for more evaluation).

3.5.4 *Ambitious*

The Ambitious scenario is similar to the Realistic scenario, but the additional efficiency improvement in 2012-2018 is 5% annually (parameter “AmbGrow”). After 2018 the improvement continues albeit at a lower level of 2% (parameter “AmbGrow2”). In 2025 the saving is almost 200 Mt with respect of BaU and almost 20 Mt with respect of the Realistic scenario.

3.5.5 *Amb + ER*

The most ambitious carbon saving scenario enhances the Ambitious scenario by adding also an Early Replacement strategy whereby starting 2013 around 1 mln. boiler extra are sold (16-17% sales increase) as replacement sales (e.g. sales schemes where old boilers are recollected).

3.5.6 *NOx 20 ppm*

This scenario builds on the “Amb+ER” scenario but it also introduces an emission limit value of 20 ppm for gas-fired appliances. As the graph shows, this may be an important extra measure, because we expect that especially in the larger sizes more electric heat pump technology may be employed. This creates a slight increase of the electric share in space heating, which in turn causes a considerable surge in NOx and SO2 (and other electricity-related emissions). The projection is that it might take around 10 years (2020) before the NOx level is back at the 2009 level. Of course, this projection does not take into account lateral effects, so must be interpreted with caution.

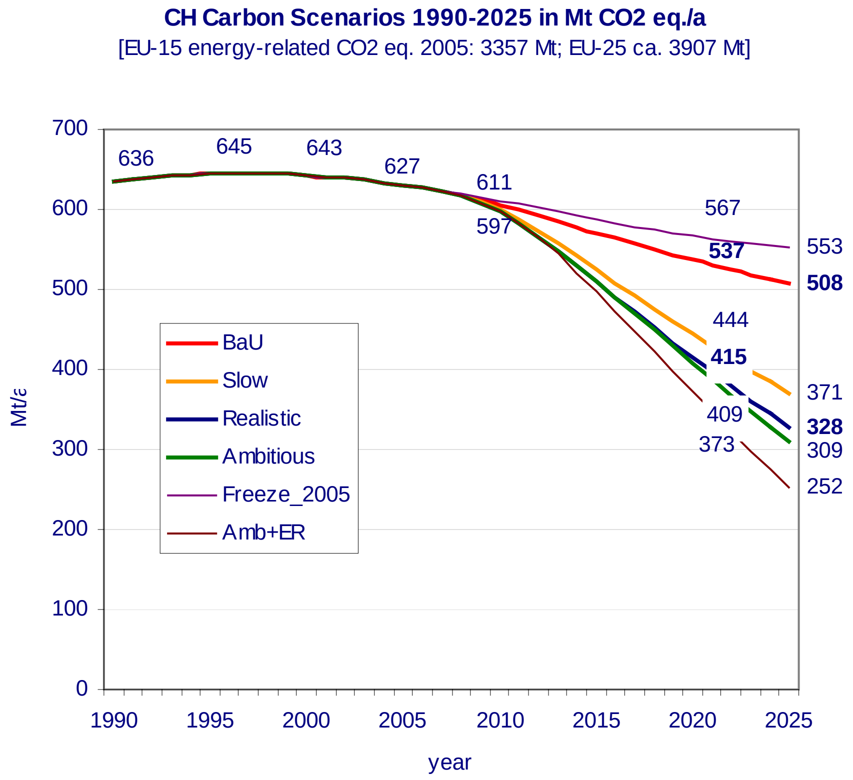
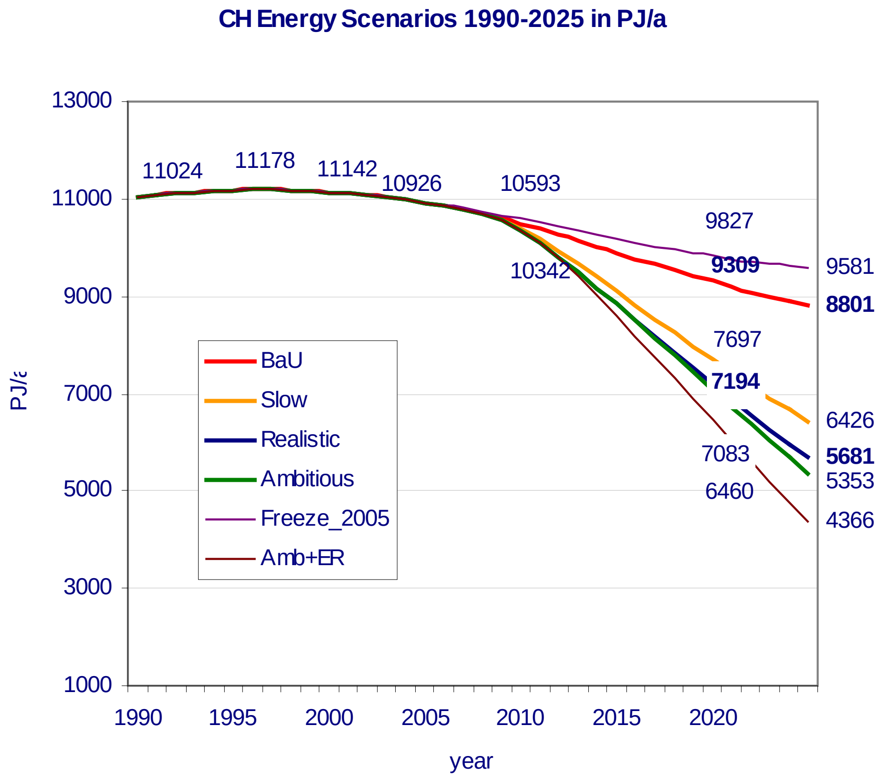


Fig. 3.2. Carbon scenarios for CH-boilers (space heating function only). In a realistic scenario the saving vs. Business-as-Usual is 537-415= 122 Mt CO2 equivalent in 2020. In 2025 this saving is projected to be 180 Mt. The most ambitious scenario, involving Early Replacement (Amb+ER), can be up over 250 Mt.



scenario
the saving vs. Business-as-Usual is 2115 PJ/a in 2020. In 2025 this saving is projected to be 3120 PJ/a. Conversion to mtoe: 1 mtoe = 41,87 - 44 PJ (depending on Net Calorific Value - Gross Calorific Value as a base; the study uses GCV).

CH Boiler Expenditure Scenarios 1990-2025 in bln. Euro/a
[Euro 2005, inflation corrected at 2%; Compare: EU-25 residential housing expenditure in 2003 is 1112 bln. and total household expenditure 6791 bln. Euro]

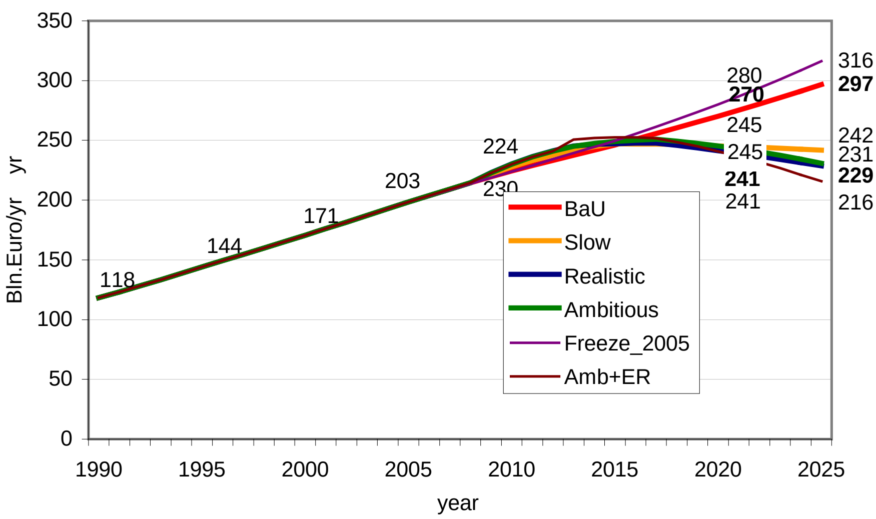


Fig. 3.4. Expenditure scenarios for CH-boilers (space heating function only). In a realistic scenario the saving vs. Business-as-Usual is € 30 bln. in 2020. In 2025 this saving is projected to be € 68 bln. (consumer rates). Based
€ 0,051 per kWh primary in the 2005-mix, as well as 6% fuel price and 2% electricity price increase per year.

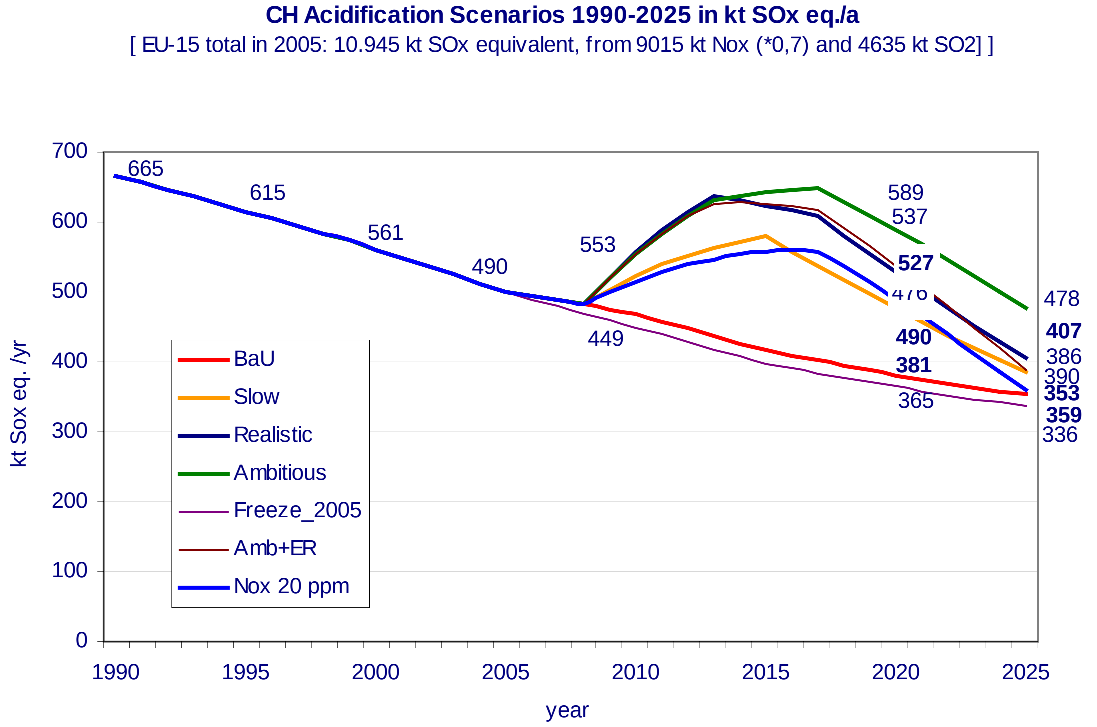


Fig. 3.5. Acidification-related emissions scenarios for CH-boilers (space heating function only). The design analysis shows that LLCC-targets for the larger boilers will require more heat pump solutions and hence higher share of electricity in the mix . This causes a surge in NOx and SO2 emissions in the transition phase 2009-2018 but can be remedied in 2018-2025.

4 IMPACT ANALYSIS

4.1 Introduction

Subtask 7.3 makes an estimate of the impact on consumers (purchasing power, societal costs) and industry (employment, profitability, competitiveness, investment level, etc.), explicitly describing and taking into account the typical design cycle (platform change) in a product sector.

The impact analysis has played a role throughout Tasks 1 to 4 and it has been extensively studied with the ECOBOILER model and it has been discussed with expert group.

This chapter merely highlights the outcomes.

4.2 Economic impacts at LLCC-target levels:

An overview of economic impact at the level of individual units is given in paragraph 2.5.3.

An overview of the total EU impact in terms of consumer expenditure is given in Chapter 3 and the Annex.

The sensitivity analysis depicting variations in Life Cycle Costs in various EU Member States is given in Chapter 5.

4.3 Technology impacts at LLCC-target levels:

- No fuel technology bans apply. Several options are possible to achieve targets: gas-fired condensing, solar-assisted systems, heat-pumps and/or hybrid heat generator systems, combined at least with a modulating or weather compensated control and TRV-valves. For NOx compliance of fossil-fuel fired systems: pre-mix technology with ionisation-control or better. Overall, not just for the heat generator (fossil, solar, heat pump) also for several system components like room temperature controls, valve controllers, CPU's, circulators, combustion fans, air-fuel controls, etc. the most advanced solutions will be promoted.
- Under threat: Single-source (non-hybrid) oil-fired and electric resistance CH-boiler systems, non-condensing gas-fired systems (i.e. without solar assistance and/or heat pump technology). For NOx and CO-compliance open combustion systems (not room-sealed). Appliances with noise emissions >44 dB-A and dimensions that do not allow installation in the heated will be penalized through the calculation method.
- Fuel shifts: VHK does not expect major fuel shifts from the Ecodesign-measures between gas/oil/electric. Electric "Joule-effect" CH-boilers are a very small niche market and their disappearing will be more than compensated by the rise of electric heat pumps. Gas-fired CH-boilers already have a significant share, which has been rising for many years and will continue to do so. Oil-fired CH-boiler sales have been dropping rapidly over the last decade (from 22% market share in the stock to only 11 % in unit sales) and facing a bleak future as a single fuel option. However, as a hybrid in combination with renewables (notably solar) the systems approach of the Eco-design measures may actually help oil-fired boilers to survive in a niche market where there is no gas-supply grid.

4.4 Stakeholder impacts at LLCC targets

Positive impacts on stakeholders:

- for innovative manufacturers, who can capitalize on current and past R&D efforts, profit from a more unified internal market and harmonized rule-making. They can increase their global competitiveness, because the quality of their leading-edge technology can now be "proven" with objective yardsticks and compliance with tough rule-making ,
- for installers where especially the small installer will benefit from the shift of the system design towards manufacturers, enabling them to play their role, for intermediaries (whole-sellers, etc.) because of higher income but also because again the shift of system-design responsibility will save on costs for technical know-how and stock,
- for low-income groups in rented apartments and houses who can expect a considerable drop in housing costs,
- for medium- and high-income groups –who would have chosen the most economical and –in part—the most ecological system anyway—the options become more transparent and the chances increase on proper installation (and thereby realizing the projected saving also in practice),
- for builders and specifiers roughly the same goed: options become more transparent and the chances of proper installation increase.
- for building inspectors and other local housing organizations compliance checks will become simpler (especially also with labeling and integration with the EPBD requirements),
- for central governments in Member States –especially NMS—who will have a robust handle in realizing environmental targets to meet their obligations.
- For the EU as a whole, who has an instrument for targets relating to trade (internal market and global competitiveness), environment (Kyoto, Gothenburg, etc.), energy and security of supply as well as the on innovation (Lisbon).

Negative stakeholder impacts or at least for those that will perceive the targets as a "mixed blessing" in the short term:

- Utilities and tax offices will see their revenues from energy sales to the residential sector drop by 15% and their income from the tertiary sector drop by around 10%. This will take place over a long period (2009-2025) and is usually compensated by energy rate increases and/or an increase in energy demand from other products/ sectors in that same period. Furthermore, both utilities and governments have long recognized energy saving ("negawatts") to be A Good Thing and pushing for high energy volume sales is not the most advantageous strategy. In fact, utilities may become one of the strongest advocates of the most efficient heating boilers, especially if it is linked to lateral measures like the "white certificates" or the "green certificates".
- Manufacturers and OEMs, who derive their competitive edge from local regulations and circumstances and are (no longer) equipped to innovate. For these groups R&D support on a national scale may be adequate.
- Negative impacts, which are not due to the measures but that are due anyway with the increase of wealth in e.g. the New Member States, will be that several households with a low heating comfort (e.g. just a stove for the whole house) will switch to a CH-boiler system. Another negative impact, which again has nothing

- to do with measures but will restrain the final result of the measure, is the increase of the average floor area per dwelling and the decreased occupancy (smaller family size) per dwelling.

- Positive impacts are the increase of insulation measures, low-E windows, etc., which again will not be due to the measures but will increase their effect.

- For test houses and notified bodies that derive their competitive edge from knowledge of the local circumstances and rule-making, any harmonized measures are a threat and there will be an increasing pressure to either invest, merge, diversify or to perish. On the other hand, for those that do invest the Eco-design measures for boilers offer interesting opportunities: New EU test methods have to be developed, EU standards have to be revised and –because Europe will be a global leader with the methodology—the know-how can be "exported".

- With the need of Third Party testing, the testing costs will go up. However, the effect will be very limited and the experts have indicated that this is an acceptable price to pay for a "level playing field", especially for SMEs that might find themselves in a disadvantage if the system would rely solely on self-declaration. Testing costs for a boiler are around € 2.500,- to € 3000,- . For solar-assisted and heat pump installations it would be some 50% more. For gas-fired boiler manufacturers, where external testing is already mandatory, these costs constitute less than 3-4% of R&D costs. The R&D costs in turn are around 3-4% of the product price, so the overall effect on the price will be negligible (around 0,1-0,2% higher product price).

- Heating installations are usually the last item in the building process and it is tempting to cut some budgetary corners with a cheap installation to stay within budget. For those builders and contractors that are engaged in this practice, it will become impossible at least below a certain minimum level. On the long run, helped by information campaign and an adequate transition period, this 'problem' will solve itself because this budget-item will be easily explainable to clients and there is a level playing field for all builders.

- The extra construction costs (=price increase) of new dwellings and buildings will be between 0,2 and 0,5% of the total. However, if the building has to meet the EPB standards anyway, this is not really an extra cost but rather a part of the minimum EPB requirements for the building as a whole. For private house purchaser the price increase is not believed to be disruptive for obtaining financing, especially as more and more financial institutions look at sustainability issues, energy certificates, etc. as a factor in the value of real estate and an extra argument to facilitate loans.

- For landlords having to replace the heating system(s) in a collective apartment building or a commercial office building the investment costs will go up, while the economical benefits (lower running costs) will go to the tenants especially if --as is the case in most countries—the maximum annual increase of the rent is state-regulated. On the other hand, there are several trends whereby the governments (and building corporations) are looking no more at just the rent of the apartment and social housing, but at the total housing costs (rent+energy+other) and allowing special provisions.

- For low- to medium-income groups that own an apartment with an individual boiler attached to a collective chimney, the switch to e.g. condensing boilers may be difficult. As a transitory measure, in a period where only a few apartment owners in the building will have switched to condensing technology, there are some technical solutions that could be applied, e.g. lateral flue ducts through the façade (for size class S, XS and XXS) or the addition of some positive pressure inner-liners in an otherwise negative pressure chimney. (see Chapter 2, early replacement programme)

- Some insulation manufacturers and suppliers of other installation components may initially not be entirely happy. Minimum targets and labeling for CH-boiler systems will clearly put in evidence the energy saving effect of efficient boilers vis-à-vis other saving measures . And because the builder can "spend his/her money only once", they may fear that the builder may save on insulation measures and low-E windows. We expect that this fear will be short-lived, because experience from countries where e.g. condensing boilers are the standard product (NL, UK) shows that all building measures, including insulation, benefit from a heightened awareness of the saving potential in the building sector.
- Manufacturers from competing space heating products (local heaters, air conditioners, etc.) may fear that the targets and labeling of boiler-systems will affect their market share. We expect this to be correct; therefore it is of the utmost importance that not only CH-boiler systems are labeled, but also the other space heating options.

5 SENSITIVITY ANALYSIS

Subtask 7.4 studies the robustness of the outcome in a sensitivity analysis of the main parameters, changing energy prices, interest rates, etc.. (as described in Annex II of the Directive) . For this we have used the ECOBOILER model, which differentiates climate, building and environmental parameters for 25 EU Member States. The results from this analysis are discussed in paragraph 5.1 and 5.3.

But basically, the sensitivity analysis has played a role from the very beginning of the study and has been a guiding principle throughout much of the Tasks 1 to 4. This is discussed in paragraph 5.2.

5.1 Sensitivity LLCC-targets

- Per country, taking into account local climate, rates and tariffs, the payback time varies between 4,5 years for Warschau (colder climate, lower costs, average energy rates) Poland and 16 years for Malta (warmest climate, high costs, lower energy rates), all within the projected lifetime of 17 years and therefore resulting in a net saving.
- Purchase prices are based on worst-case scenario, i.e. countries where condensing boilers are currently a niche market. For more competitive condensing boiler markets the price increase will be considerably less and payback times considerably more favourable.
- Energy rates are based on average long-term annual price increases over the period 2000-2006 (5-6% for gas, 8-9% for oil, 1,5-2% for electric). If we take the most recent annual price increases as an input --between 1.1.2005 and 1.1.2006-- the annual price increase is more than double (16% for gas, 32% for heating oil, 4,6% for electricity), which would more than half the pay-back times.
- Doubling inflation (now set at 2%) to 4% will also reduce the pay-back time, but will in practice be counterbalanced by an increase in interest rates (now set at 4%) which will offset this effect.
- Combining the effects above, the discounted payback time for LLCC-targets would drop from an average 6-7 years to around 1,5-2 years.
- The next step in design improvement -after the LLCC-point- will most likely require at least heat pump technology (electric or gas-fired) possibly with add-on solar assistance and will show a wider spread because the technology is more climate-dependent.

5.2 Sensitivity analysis in Tasks 1 to 4

At the outset of the study stakeholders were sceptical regarding a possible outcome whereby condensing boilers would be mandatory throughout the EU. This scepsis was based on a number of –sometimes contradictory—arguments as to why it would not be possible to create a pan-European standard, especially one that would aim at condensing boilers as a minimum standard:

- Climates in the EU differ, therefore what is economical in Northern Europe would be very uneconomical in Southern Europe. In short, measures should be national and not EU-wide (= no Eco-design measures).
- Condensing boilers require the consumers not just to change their boiler but also change the radiators, otherwise the boiler does not condense and therefore the saving is very limited while the cost to the consumer is very high.
- Condensing boilers will achieve a sufficient market penetration anyway, so there is no need for EU-measures to achieve their goal.
- If fossil-fuel fired boilers are made more expensive because of Eco-design measures, then the consumers will switch to electric solutions like electric radiators or reversible air conditioners; both would be detrimental to the EU goals in the field of energy and carbon emissions.
- Condensing boilers are impossible to implement in apartment buildings with individual boilers with a collective chimney, because of local regulation and technical safety limitations. This is said to be particularly true for Southern European countries.
- Eco-design measures will increase boiler-prices and inflict the global competitiveness of the industry.

During the course of the project the “content” was developed, i.e. Tasks 1 to 7 in chronological order. During this process new insights were gained and communicated, leading to a situation where the industry experts now seem willing to accept that

- Not only climates differ per country, but also building practice (insulation, thermal mass of construction), energy rates and product prices and installation costs. Therefore what is economical in Northern Europe can very well –and mostly is-- economical in Southern Europe.
- Condensing boilers generally do not require the consumers to change their radiators. The practice in several EU-Member States has shown that radiator-capacity is considerably over-dimensioned for the normal load. Partially, this over-dimensioning is functional if the installation has to meet the heat demand also in extreme winters. In part, there is a common practice for installers to apply a “safety factor” of 2 to 3 (e.g. OPTIMUS study in Germany). This over-dimensioning makes the radiator network aptly suited for the low-temperature (LT) regime that is needed for condensing operation (and heat pumps, for that matter). A key factor in this is not just the boiler, but a correct installation and setting of the room-temperature and valve controllers. If indeed the system design and components are incorrect, the industry is right: the boiler does condense very little and therefore the energy/carbon saving of a condensing boiler is very limited (5-7%).
- Efficient boilers will not achieve a sufficient market penetration in a Business-as-Usual scenario. As mentioned in Task 2 by BRG Consult, the most part of France, Italy, Spain, etc. will not switch to condensing boilers without legislative action.

- But also in the Northern European market, niches that have proven to be difficult to penetrate are existing apartment buildings, rented dwellings in general and public/community buildings. Together these represent around half of the boiler market. Furthermore, it must be said that the recent jump in the "condensing" market share (from 10 to 25%) was not due to a spontaneous process, but due to legislative pressure in the UK. Finally (see also "Only Sticks" scenario in the next chapter), even those builders and home-owners that will switch to condensing boilers will only realize a third or less of the potential because of inadequate system design.
- Certain parts of the market will indeed be tempted to switch to electrical solutions, but in general this will be the high-end of the market and not the low-income end. It is indeed true that for luxury apartments in London there has been a tendency to use electric radiators. Furthermore, there is undoubtedly a fast rising market for (reversible) air conditioners, which is again not a low-income product. And finally, the market for (heating only) electric heat pumps is rising. None of this is linked to lower affordability of efficient boiler systems. E.g. most low-income groups are well aware that they wouldn't be able to pay the electricity bill that goes with electric radiators in the UK. But it does stress the need for policy measures to cover all angles of the heating market so that consumers can make an informed choice.
- Condensing boilers are not impossible to implement in apartment buildings. In several EU countries it has been proven that acceptable and affordable solutions. Having said that, there is a group of privately owned apartments, i.e. where every inhabitant can decide on his/her own boiler purchase, where it will be difficult. The problem lies with the collective chimney which can accommodate either positive pressure appliances (e.g. condensing boilers) or negative pressure appliances (atmospheric boilers), but not easily both. Technical solutions exist (e.g. individual façade outlets just for the apartment owners that switch to condensing), but very often are hindered by local regulations. Any Eco-design measures will have to take into account –and solve—this particular problem, which will apply primarily to the smaller boilers.
- As regards global competitiveness especially the Task 1 report on e.g. international mandatory minimum standards and emission limits is believed to have made a considerable impact with the industry. It has shown that the EU legislator is far behind the rest of the world in this field. Although the EU boiler technology may well be more advanced than in other parts of the world, we have no objective governmental yardstick to prove it. At the same time, the need for such an authoritative measure has risen, because the demand for energy-efficient appliances has clearly grown in many parts of the world (e.g. China, Japan and the US). As yet, the EU boiler-industry plays only a limited role in this, not because it has strict rules, but because it doesn't have strict rules.
- As regards the expected impact of pricing we believe that it has been made plausible by the contractors that there are considerable differences between EU markets where condensing boilers are currently a niche market with small production volumes and EU markets where condensing boilers are the mainstream products. As a consequence the prices of efficient heating technology are expected to drop with measures. Having said that, even at worst-case pricing –which is the one we used in our Life Cycle Cost analysis—condensing boilers and other system components are economical to the consumer. In other words, any measures that would strengthen the internal EU market for efficient heating solutions may constitute an opportunity and not a threat.

The consensus on the above subjects is not confirmed by official industry statements, but based on discussions with the industry experts and the comments on especially the first 4 Task reports (see also minutes of experts meetings).

5.3 Country-specific LCC analysis

This paragraph elaborates on the general conclusions in par. 5.1. It shows the country-specific analysis for selected countries representing extremes in terms of climate, labour and energy costs.

To check weather the LLCC-target levels are also valid for Member States with more extreme climate conditions or extreme high or low energy prices, the lifecycle costs of the two load profiles that represent the biggest energy consumption in the EU (size class M (30%of total energy consumption) and size class 4XM (18% of total)) are calculated for :

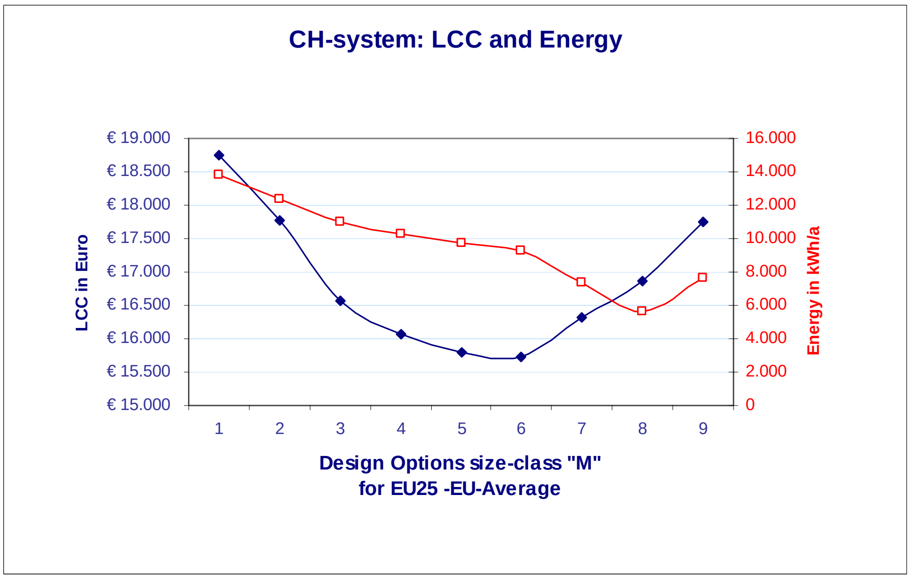
- Italy or Malta (warm climate
- Poland (land climate)
- Finland (cold climate)
- Denmark (high E-price)
- Estonia (low E-price)

5.3.1 Sensitivity load profile "M"

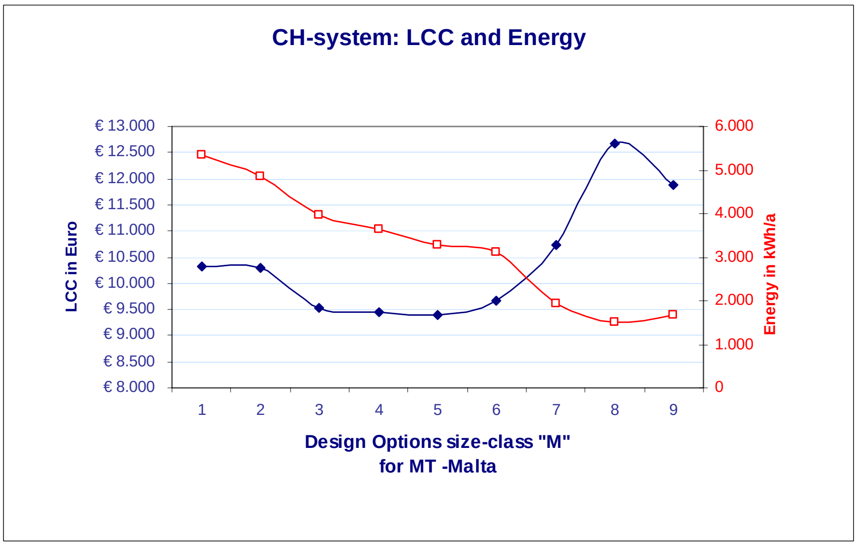
Table 5.1. Lifecycle costs and payback periods size class "M" for 'extreme' MS at LLCC_level = Design Option nr. 5

Member States		Climate/ E-price	Efficiency [%]	Energy consumption [kWh/a]	LCC [€]	Purchase price [€}	Pay Back Period [yr]
EU 25		EU average	78	9.735	15.797,-	3.737,-	5,1
Malta	MT	Warm climate	64	3.279	9.404,-	3.737,-	10,4
Poland	PL	Land climate	81	11.434	12.816,-	1.869,-	3,2
Finland	FI	Cold climate	80	10589	18.523,-	5.793,-	8,4
Denmark	DK	High E-price	78	11.992	36.440,-	8.222,-	4,3
Estonia	EE	Low E-price	82	13.473	10.405,-	2.429,-	6,9

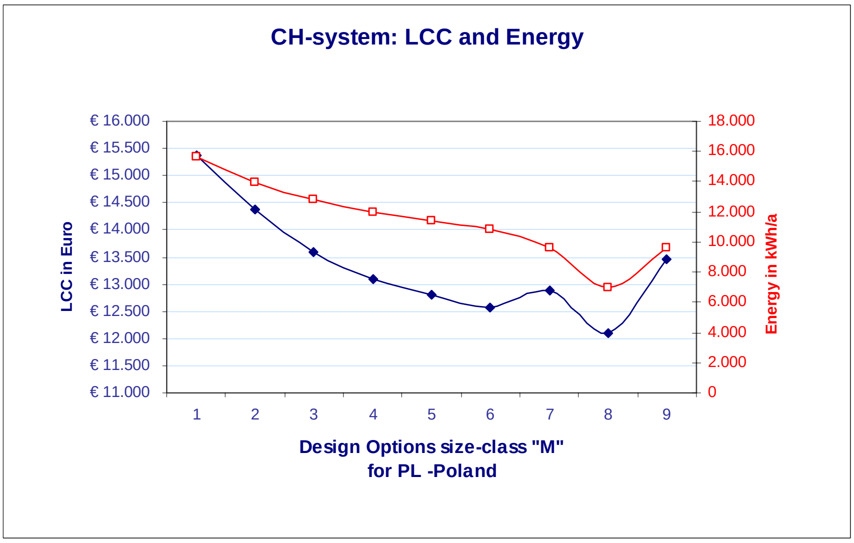
Design Options "M"in EU25



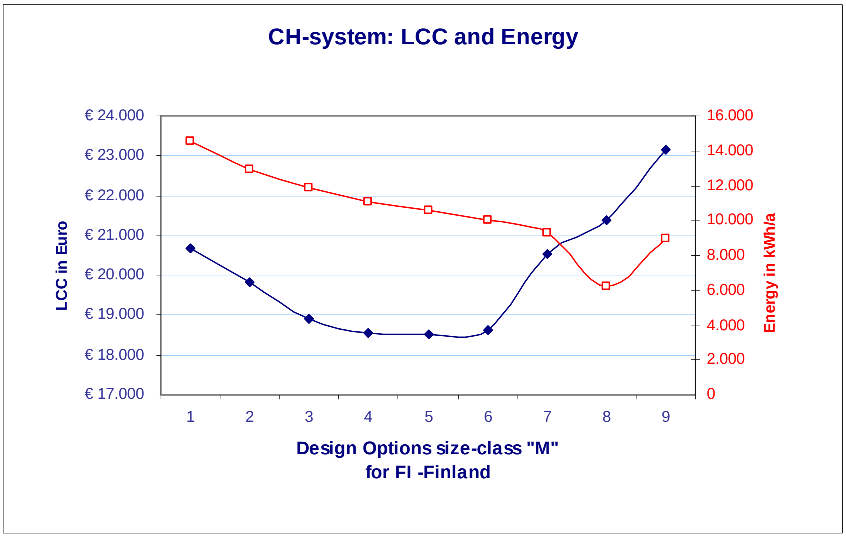
Design Options “M” in Malta



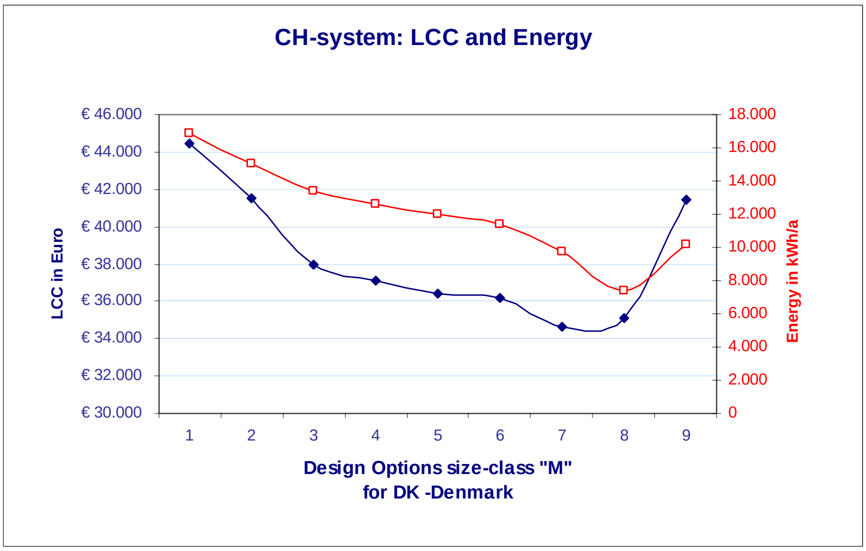
Design Options “M” in Poland



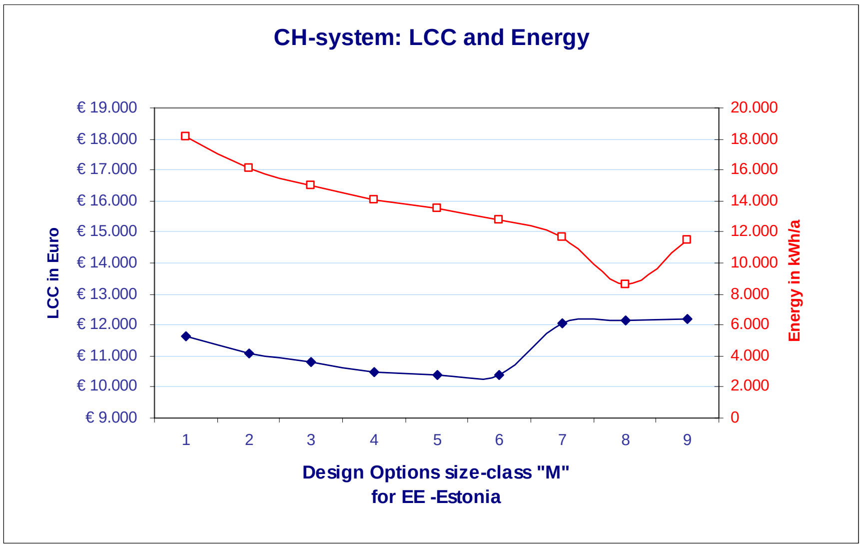
Design Options “M” in Finland



Design Options "M" in Denmark



Design Options "M" in Estonia

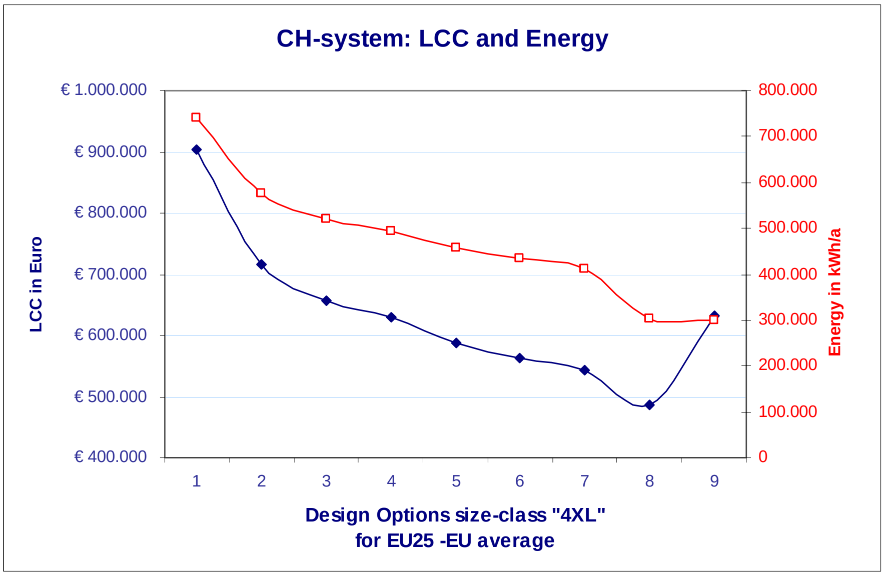


Conclusion: The LLCC-target level of design option nr. 5 is also valid for member states with more extreme climate conditions and/or energy prices.

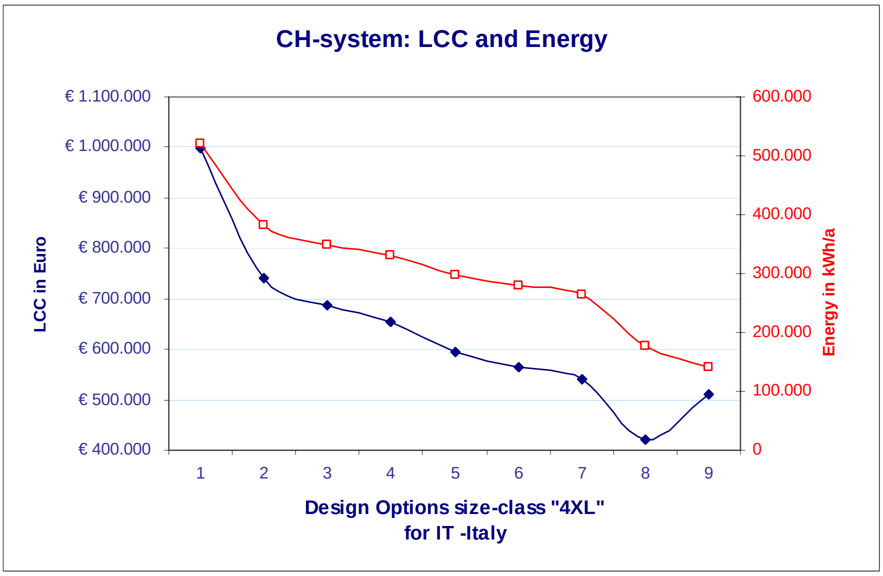
5.3.2 Sensitivity load profile "4XL"

Table 5.2. Lifecycle costs and payback period size class "4XL" for 'extreme' MS at LLCC-level = Design Option nr. 8							
Member States		Climate/ E-price	Efficiency [%]	Energy consumption [kWh/a]	LCC [€]	Purchase price [€}	Pay Back Period [yr]
EU 25		EU average	99	303.343	487.237,-	174.373,-	5,6
Italy	IT	Warm climate	94	176.218	421.602,-	156.936,-	3,9
Poland	PL	Land climate	98	483.229	523.871,-	87.187,-	2,8
Finland	FI	Cold climate	96	341.232	563.523,-	270.278,-	8,9
Denmark	DK	High E-price	95	395.519	1.082.204,-	383.621,-	6,2
Estonia	EE	Low E-price	97	572.356	499.711,-	113.343,-	3,9

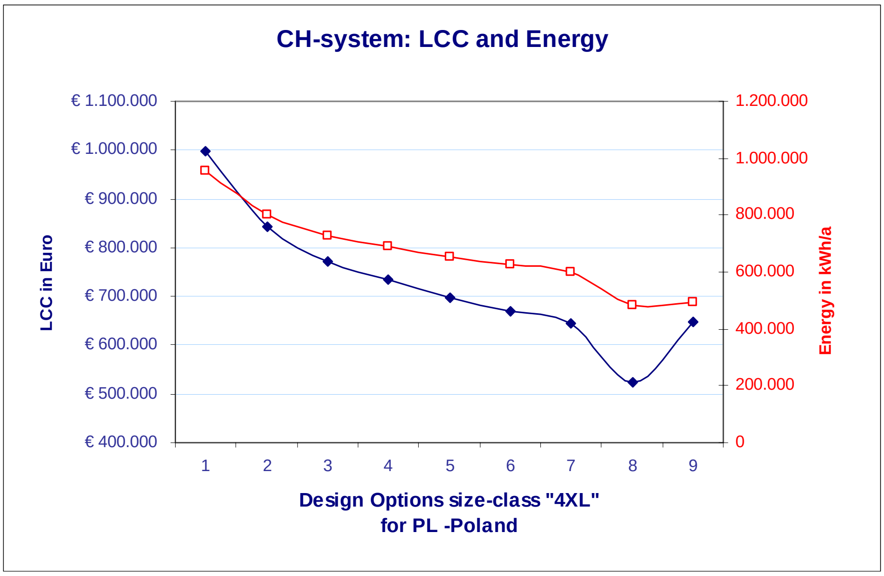
Design Option "4XL" in EU25



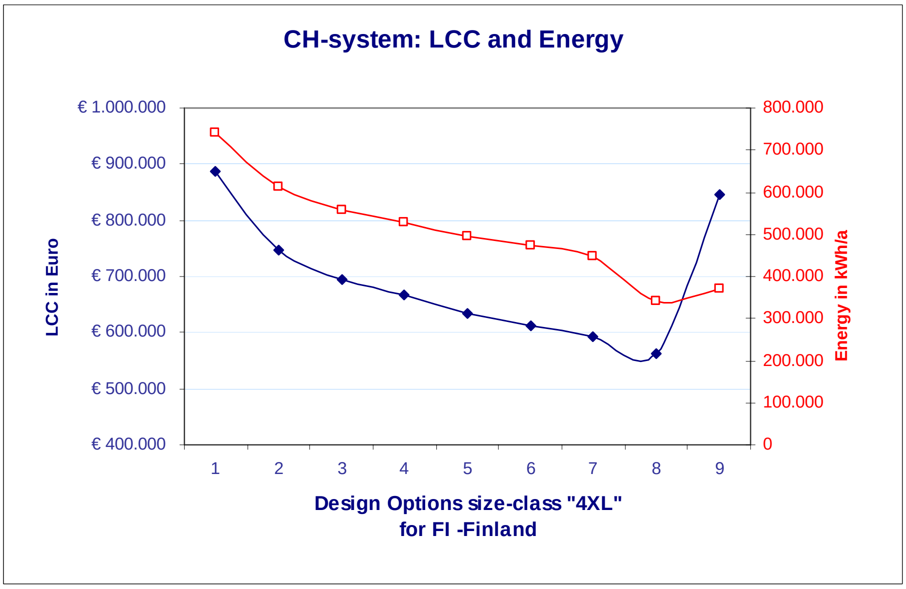
Design Options '4XL" in Italy



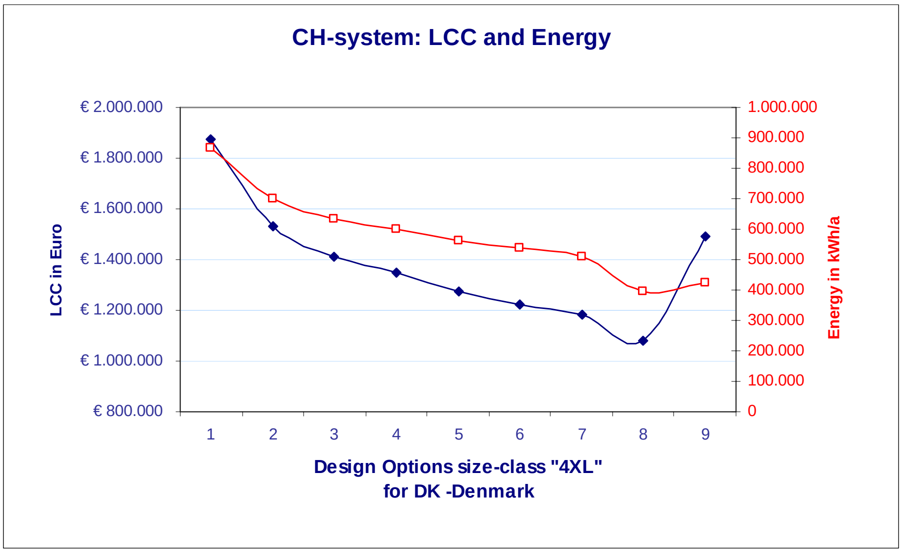
Design Options "4XL" in Poland



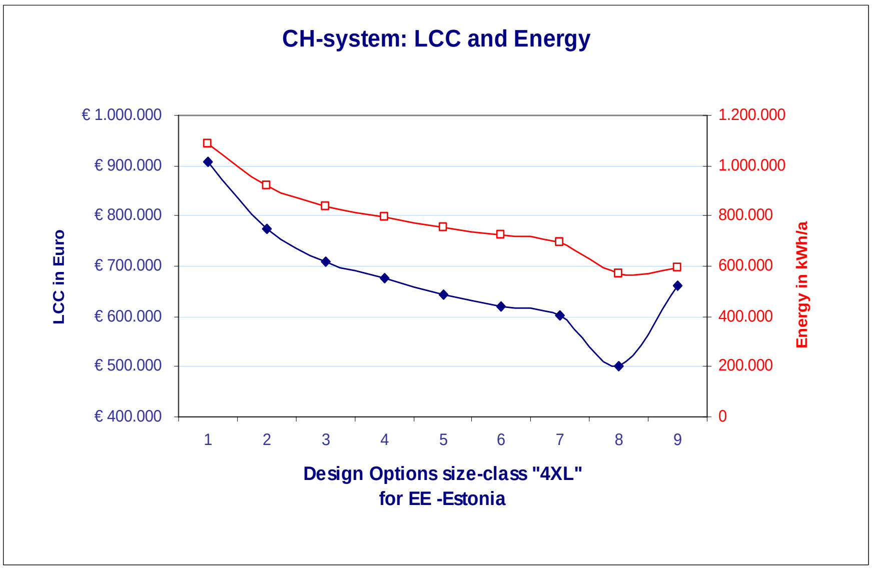
Design Options "4XL" in Finland



Design Options "M" in Denmark



Design Options “M” in Estonia



Conclusions: The LLCC-target level of design option nr. 8 is also valid for member states with more extreme climate conditions and/or energy prices.

Please note, that the ECOBOILER model, which is a separate deliverable of the contract, contains climate and building data for all EU-25 capitals and would therefore allow an infinite amount of country-specific analyses for those aspects.

ANNEX

Scenario Tables

CH_STOCK

Table A1. CH Stock environmental

	1990	1995	2000	2005	2010	2013	2015	2020	2025
net load (kWh/a)	15162	13868	12684	11602	10595	10033	9675	8835	8068
sales (000)	4778	5520	5993	6600	6952	7240	7432	7911	8686
park (000)	74660	86236	97964	109709	120975	127183	131058	140638	150734
Extra ER sales 2013 onwards						1104	1142	1247	1348
Efficiency									
Freeze_2005	42%	44%	46%	48%	48%	48%	48%	48%	48%
BaU	42%	44%	46%	48%	52%	52%	53%	54%	55%
Slow	42%	44%	46%	48%	59%	72%	81%	81%	81%
Realistic	42%	44%	46%	48%	64%	84%	90%	96%	96%
Ambitious	42%	44%	46%	48%	63%	83%	93%	109%	119%
kWh/a.unit									
Freeze_2005	36099	31518	27575	23942	21863	20704	19965	18232	16649
BaU	36099	31518	27575	23942	20572	19257	18428	16514	14669
Slow	36099	31518	27575	23942	17939	13891	11944	10907	9960
Realistic	36099	31518	27575	23942	16614	11944	10750	9203	8404
Ambitious	36099	31518	27575	23942	16719	12088	10403	8105	6780
TWh primary/a									
Freeze_2005	172	174	165	158	152	150	148	144	145
BaU	172	174	165	158	143	139	137	131	127
Slow	172	174	165	158	125	101	89	86	87
Realistic	172	174	165	158	116	86	80	73	73
Ambitious	172	174	165	158	116	88	77	64	59
	172	174	165	158	116	67	56	42	42
Sales year energy									
Without correction									
Freeze_2005	3062	3105	3095	3035	2942	2873	2827	2730	2661
BaU	3062	3105	3095	3035	2915	2815	2747	2586	2445
Slow	3062	3105	3095	3035	2886	2688	2529	2138	1785
Realistic	3062	3105	3095	3035	2872	2635	2455	1998	1578
Ambitious	3062	3105	3095	3035	2873	2639	2456	1967	1487
Amb+ER	3062	3105	3095	3035	2873	2618	2392	1794	1213
Stock energy in TWh/a									
WITH CORRECTION									
Freeze_2005	11024	11178	11142	10926	10593	10341	10178	9827	9581
BaU	11024	11178	11142	10926	10493	10134	9890	9309	8801
Slow	11024	11178	11142	10926	10391	9678	9104	7697	6426
Realistic	11024	11178	11142	10926	10338	9485	8838	7194	5681
Ambitious	11024	11178	11142	10926	10342	9500	8840	7083	5353
Amb+ER	11024	11178	11142	10926	10342	9425	8612	6460	4366
CO2 in Mt (1 PJ= 0,0577 Mt)									
Freeze_2005	636	645	643	630	611	597	587	567	553
BaU	636	645	643	630	605	585	571	537	508
Slow	636	645	643	630	600	558	525	444	371
Realistic	636	645	643	630	596	547	510	415	328
Ambitious	636	645	643	630	597	548	510	409	309
Amb+ER	636	645	643	630	597	544	497	373	252
Acidification (in kt Sox equivalent; gas 60 mg/kWh; oil 310 mg/kWh)									
Freeze_2005	665	615	561	500	449	418	398	365	336
BaU	665	615	561	500	469	437	417	381	353
Slow	665	615	561	500	523	564	580	476	386
Realistic	665	615	561	500	556	637	623	527	407
Ambitious	665	615	561	500	553	631	643	589	478
Amb+ER	665	615	561	500	553	626	626	537	390
Nox 20 ppm	665	615	561	500	516	546	558	490	359

Table A2. CH Stock economics

		1990	1995	2000	2005	2010	2013	2015	2020	2025
Oil share		47%	39%	32%	25%	20%	17%	15%	12%	9%
Oil price		0,019	0,028	0,041	0,061	0,090	0,115	0,134	0,199	0,295
Gas price		0,021	0,027	0,036	0,047	0,062	0,073	0,081	0,106	0,140
El price		0,045	0,049	0,054	0,060	0,066	0,070	0,073	0,081	0,089
Maintenance		133	147	163	180	199	211	219	242	267
Share electricity										
Freeze_2005		4,4%	4,4%	4,4%	4,4%	4,4%	4,4%	4,4%	4,4%	4,4%
BaU		4,4%	4,4%	4,4%	4,4%	5,2%	5,4%	5,5%	5,8%	6,2%
Slow		4,4%	4,4%	4,4%	4,4%	7,3%	11,0%	13,4%	13,4%	13,4%
Realistic		4,4%	4,4%	4,4%	4,4%	8,6%	14,2%	15,9%	17,6%	17,6%
Ambitious		4,4%	4,4%	4,4%	4,4%	8,5%	14,0%	16,7%	21,2%	23,9%
Amb+ER		4,4%	4,4%	4,4%	4,4%	8,5%	14,0%	16,7%	21,2%	23,9%
Avg. Fuel price										
Freeze_2005		0,02	0,03	0,04	0,051	0,07	0,08	0,09	0,12	0,15
BaU		0,02	0,03	0,04	0,05	0,07	0,08	0,09	0,12	0,15
Slow		0,02	0,03	0,04	0,05	0,07	0,08	0,09	0,11	0,15
Realistic		0,02	0,03	0,04	0,05	0,07	0,08	0,09	0,11	0,14
Ambitious		0,02	0,03	0,04	0,05	0,07	0,08	0,09	0,11	0,14
Amb+ER		0,02	0,03	0,04	0,05	0,07	0,08	0,09	0,11	0,14
Avg. Price (incl. install)										
Freeze_2005		2928	3150	3372	3645	3645	3645	3645	3645	3645
BaU		2928	3150	3372	3645	3982	4049	4093	4204	4371
Slow		2928	3150	3372	3645	4822	6283	7257	7257	7257
Realistic		2928	3150	3372	3645	5344	7590	8256	8922	8922
Ambitious		2928	3150	3372	3645	5300	7479	8589	10365	11475
Amb+ER		2928	3150	3372	3645	5300	7479	8589	10365	11475
Avg. Energy costs Eur/a.unit (not corrected)										
Freeze_2005		754	895	1055	1219	1474	1644	1763	2113	2512
BaU		754	895	1055	1219	1387	1527	1624	1906	2196
Slow		754	895	1055	1219	1209	1094	1038	1228	1445
Realistic		754	895	1055	1219	1119	937	930	1022	1197
Ambitious		754	895	1055	1219	1126	949	898	890	938
Total purchase costs EU per annum										
Freeze_2005	mln. Eur	13.990	17.388	20.207	24.057	25.340	26.389	27.088	28.836	31.661
BaU		13.990	17.388	20.207	24.057	27.686	29.314	30.421	33.263	37.967
Slow		13.990	17.388	20.207	24.057	33.520	45.486	53.931	57.412	63.036
Realistic		13.990	17.388	20.207	24.057	37.155	54.950	61.355	70.584	77.499
Ambitious		13.990	17.388	20.207	24.057	36.846	54.146	63.830	82.000	99.675
							62.403	73.637	94.927	115.145
Total running costs (energy+maint)										
Freeze_2005	mln. Eur	73.872	100.870	134.298	174.290	222.402	254.865	278.449	350.464	441.906
BaU		73.872	100.870	134.298	174.290	220.509	250.026	270.904	332.491	406.345
Slow		73.872	100.870	134.298	174.290	218.521	238.568	248.470	274.803	299.301
Realistic		73.872	100.870	134.298	174.290	217.476	233.528	241.089	256.034	265.016
Ambitious		73.872	100.870	134.298	174.290	217.560	233.920	240.816	249.997	245.940
Amb+ER		73.872	100.870	134.298	174.290	217.560	232.291	235.335	230.999	208.035
Total consumer expenditure										
Freeze_2005	**mln. Eur**	87.862	118.258	154.505	198.347	247.742	281.254	305.537	379.300	473.567
BaU		87.862	118.258	154.505	198.347	248.194	279.340	301.325	365.754	444.312
Slow		87.862	118.258	154.505	198.347	252.040	284.054	302.401	332.215	362.337
Realistic		87.862	118.258	154.505	198.347	254.631	288.478	302.445	326.619	342.515
Ambitious		87.862	118.258	154.505	198.347	254.406	288.066	304.646	331.997	345.616
Amb+ER		87.862	118.258	154.505	198.347	254.406	294.694	308.972	325.926	323.180

Consumer expenditure corrected for inflation (EU 2005)

Freeze_2005	bln. Eur	118	144	171	198	224	239	250	280	316
BaU		118	144	171	198	224	238	246	270	297
Slow		118	144	171	198	228	242	247	245	242
Realistic		118	144	171	198	230	245	247	241	229
Ambitious		118	144	171	198	230	245	249	245	231
Amb+ER		118	144	171	198	230	251	252	241	216