ECO-ECONOMIC ANALYSIS OF DIFFERENT HEATING SYSTEMS FOR A NEW HOUSING PROJECT

AMARYLLIS AUDENAERT
Faculty of Applied Engineering
University of Antwerp
Paardenmarkt 92, BE-2000 Antwerp
BELGIUM
Amaryllis.audenaert@ua.ac.be http://www.ua.ac.be/amaryllis.audenaert

SVEN DE CLEYN
Faculty of Applied Engineering
University of Antwerp
Paardenmarkt 92, BE-2000 Antwerp
BELGIUM
Sven.decleyn@kdg..be

LIESJE DE BOECK
Center for Informatics, Modeling and Simulation HUBrussel
Warmoesberg 26, BE-1000 Brussels,
BELGIUM
liesje.deboeck@hubrussel.be
&
Affiliated researcher Research Center for Operations Management
Faculty of Business and Economics; KU Leuven
Naamsestraat 69, 3000 Leuven
BELGIUM

Abstract: Given the large energy consumption of energy heating for residential and commercial use in the world, optimising heating systems makes sense, both from an ecologic and an economic point of view. Therefore, this study evaluates five different space heating systems through a case study on a new housing project. The assessment comprises both economic factors (payback period as compared to a reference heating system) and ecologic (E-levels,K-value and CO_2 emissions) under different energy price scenarios.

The results clearly indicate that large differences occur, mainly driven by the yearly energy consumption of the systems. The more traditionally used systems with condensing heating systems with radiators or classical electric heating systems tend to perform worse than more recent systems with underfloor heating and/or heat pumps. These results are true for all scenarios with regard to the evolution of energy prices and are valid for both the ecologic and economic aspects.

Key-Words: Space heating systems; economic evaluation; ecologic analysis; heat pump; condensing heating unit; underfloor heating; radiator; electric heating

1. Introduction

In Europe, energy consumption and greenhouse gas emissions for the residential and commercial (including institutional) sector account for 17% of all emissions (European Environmental Agency, 2007). As the energy demand used for space heating accounts for 78% of EU15 household delivered energy consumption (Eurostat, 1999) and similar figures have been reported for other regions in the world (Meier & Rehdanz, 2010; Rehdanz, 2007; Stepanov et al., 2000; Xi et al., 2011), significant reductions in energy demand and emissions can be achieved by promoting energy-efficient systems and technologies. Furthermore, these can potentially lead to significant cost reductions for the households and commercial users. In this regard, optimising technologies for space heating can contribute significantly to less worldwide energy consumption and to reducing the energy costs of households and commercial entities.

In the last decade, scholars have frequently investigated both the ecologic and economic impact of various (renewable) energy sources and technologies for space heating purposes in different European countries. Examples include the studies of Hughes (2010) on wind-generated electricity for space heating in Canada, Xi (2011) on coupled heat pump and solar thermal collectors in China, Badescu (2002) on an integrated system with a heat pump, photothermal collectors and solar cells in Roemenia, Marcos et al. (2011) on a solar system in Italy, Audenaert at al. (2008) on the effect of passing and low-energy housing on space heating requirements in Belgium, Anastaselos et al. (2011) on radiative (infrared) heating systems in Germany, Monahan & Powell (2011) on ground sourced heat pumps, active solar (thermal and photovoltaic), passive solar and mechanical ventilation with heat recovery, and conventional high efficiency gas boiler in the UK, Comakli (2008) on conventional and condensing natural gas fired combi boilers in the individual heating systems in Turkey, Audenaert et al. (2012) on condensing gas boiler, non-condensing gas boiler, oil boiler, and heat pump combined with ventilation systems (with or without heat exchanger) in Belgium.As far as our literature review revealed, current literature has spent less efforts in revising the ecologic and economic effects of more common space heating systems and comparing them in terms of energy consumption, CO_2 emissions and economic characteristics. Therefore, the aim of this study is to determine the most optimal system or combination of systems for household and commercial space heating using an eco-economic analysis on a case study. The most common alternatives will be considered, being for Flanders (Belgium):

-a condensing heating unit running on fuel oil combined with radiators,
-a condensing heating unit running on natural gas combined with radiators,
-a condensing heating unit running on natural gas combined with underfloor heating,
-a classical electric heating system with radiators,
-a heat pump combined with underfloor heating.

The remainder of the paper is structured as follows. In the second section, the basic configuration of the new housing project will be discussed, which includes a doctor's practice and three apartments. The third section then presents the characteristics of the five different space heating systems. Afterwards, some methodological aspects will be highlighted in the fourth section, including some characteristics of the Belgian green energy system and subsidies, the variables considered in the evaluation, and the different scenarios used in the calculations. The two last sections respectively deal with the results of the study and some conclusions and implications.

2. Configuration of the new housing project

The eco-economic analysis will be applied to a specific case study, in order to obtain relevant, real-life results. The new housing projects concerns a joint doctor's practice situated on the ground floor, with four consultation rooms and a shared anteroom, and three levels with one apartment on each level.

As the focus of this study clearly lies on the space heating requirements, the other construction characteristics will be assumed to be constant for all scenarios (the 'ceteris paribus' principle). With regard to insulation materials for the walls, the new housing project makes use of Mupan Façade insulating boards with a thickness of 12 cm ($\lambda = 0.032$ W/mK), while the roof is insulated with boards of mineral wool with a thickness of 20 cm ($\lambda = 0.034$ W/mK). For further details on the materials, their insulation values (λ or U) and the coefficient of the permeability of total solar radiation energy (g-value), we refer to Appendix 1.

The new housing unit is equipped with a ventilation system type C. This means that in dry spaces, ventilation grilles integrated in the windows are used to obtain natural air ventilation. Through openings, this natural air ventilation reaches the wet rooms, such as the kitchen and bathroom(s). The air is discharged mechanically. The system is composed of a thermally interrupted self-regulating ventilation grille with valve. The throughput Q1 in case of 2 Pa is 52.7 $m^3/h/m$ (U-value for heat loss = 3.9 W/m^2K; throw length L0 at 2 Pa = 0.066 m), while it is 59.8 $m^3/h/m$ in case of 10 Pa (same U value and throw length).

3. Different space heating systems

This sections deals with the main characteristics of the five different space heating systems under investigation. The costs, energy consumption, ecologic footprint and economic performance of the different systems will be discussed in the results' section.

Condensing heating unit running on fuel oil combined with radiators

Using oil fuel for space heating systems is a well-established practice in Belgium and a number of surrounding countries (Rehdanz, 2007). Given the widespread use in current private housing and commercial space heating, including this system is obvious. In these systems, heat is being created through burning fuel oil. The generated heat is then transmitted through a kettle to the liquid that circulates through the heating pipes that brings the heat towards the radiators in the various rooms and spaces.

In traditional heating units, a large portion of the energy is wasted through water vapour, which obviously deteriorates their efficiency . In order to increase the efficiency, condensing heating units are used currently, which recover the lost heat of the water vapour (partially). This recovered heat is then used to pre-heat the cold water returning to the heating unit.This technology obviously reduces total required energy consumption, which both increases efficiency, decreases total operating and energy costs and leads to a smaller ecologic footprint.

Condensing heating unit running on natural gas combined with radiators

The second alternative is a similar system as the previously described heating unit, but running on natural gas instead of fuel oil. This system is also commonly used in Western Europe. The way the system operates, is a copy of the system running on fuel oil.

Condensing heating unit running on natural gas combined with underfloor heating

The third alternative considered concerns a condensing heating unit running on natural gas (operations again equal to those of the previous two systems), but in combination with an underfloor heating system instead of 'classical' radiators. In these systems, heating pipes are integrated in or just above the floor finish. Basically two types exist: [1] hydraulic underfloor heating making use of warm fluid that passes through the pipes and delivering its heat to the surrounding floor and [2] an electric variant, which is most often used in renovation projects . Therefore, this study focuses on the hydraulic variant.

Underfloor heating systems offer multiple advantages. Obviously, no radiators need to be installed, allowing using the full wall space for other purposes. Furthermore, an underfloor heating system requires almost no maintenance, results in 100% radiation heat (which has the further advantage that the relative humidity in a room is maintained and is not lowered as with many other heating systems), does not lead to circulation of dust and requires less high kettle temperatures than other heating systems .

Classical electric heating system with radiators

A classical electrical heating system with radiators outshines in simplicity of use and usually has limited investment and maintenance costs. However, due to high energy costs and unfavourable ecologic characteristics (Kroetz & Friedland, 2008), electrical heating systems are often discouraged.

Electric heating systems basically comprise two types: direct electric heating and accumulation heating. The former type of electric heating generates heat as soon as the system is switched on, while the latter charges with electricity at night and emits its heat during daytime .

Heat pump combined with underfloor heating
Heat pumps are a group of systems with a few possibilities, mainly divided in two large groups. The first group, geothermal heat pump, retrieve heat from the surface (Xi et al., 2011). This can occur either through horizontal capturing, using the garden as heat source, or through vertical capturing, requiring a drilling hole. The second group of aero-thermal heat pump retrieves the necessary heat from the outside air. In terms of efficiency, geothermal heat pumps achieve better performance, which also translates in higher investment costs . For the current study, a geothermal heat pump system will be chosen over an aero-thermal system.

Heat pumps optimally perform when combined with low-temperature heating systems (Harvey, 2009). In this sense, underfloor heating is complementary and will be used as complement to the heat pump in this study.

4. Methodology

As already discussed in the introduction, we will perform an (1) economic as well as an (2) ecologic analysis of the five different heating systems under (3) different price scenarios. We will discuss these in the following two subsections. As the study was performed in 2011, all values in the next subsections and sections are applicable to 2011.

4.1. Economic analysis and scenarios

The investment required for each of the five heating systems is composed of different components. The basic investment concerns the price to be paid to acquire and install,the heating system. In combination with the second part, being eventual subsidies granted or monetary penalties to be paid depending on the ecologic characteristics of the system, this leads to a net investment cost for each of the five systems. The third part of the investment concerns the operational and maintenance costs (i.e., costs related to yearly energy use and maintenance). The yearly energy use is calculated by the EPB-software (see subsection 4.2) and the unit energy price for gas, oil and electricity is retrieved from

Given the sum of this net investment cost and the discounted yearly maintenance cost (referred to as the discounted total cost in what follows), a payback period for the various heating systems can be computed (the discount rate used throughout the computations is the current 25 years interest rate on Belgian state obligations (i.e., 4.51%); obviously, in the case of constant energy prices, the discount rate will not be applied). To this end, we consider the space heating system based on a condensing heating unit on fuel oil with radiators as reference point. That is because this system is the more commonly applied heating system as of today in Belgium. The revenue of the other heating systems then consists of the discounted yearly difference in operational cost as compared to the reference heating system. A lower (higher) operational cost as compared to the reference system results in a positive (negative) revenue. An important factor in determining this operational cost is the energy cost. In order to have a somewhat more critical view on the impact of this energy cost, the payback period will be calculated for different energy price scenarios (i.e., a yearly decrease of the energy price with 5%, a stable energy price and a yearly price increase with respectively 5%, 10% and 15%). The payback period is then calculated as the year in which the cumulative discounted total revenue exceeds the cumulative discounted total cost for the first time. This boils down to the first year where the sum of cumulative discounted total revenues and costs (represented as a negative value) is positive. Note that this sum is the net present value.

4.2. Ecologic analysis

The Belgian green energy policy for new housing projects has been reformed since a number of years. Every project now has to obtain an energy efficiency certificate, analysing and stating its ecologic and energy characteristics. Subsidies for green energy changes are tailored to those systems with better ecologic and energy performance. A software tool, the EPB software, has been developed to allow private persons and professionals to calculate the ecologic and energy characteristics of new (and renovation) buildings projects and new installations. The EPB software takes the primary energy consumption into account, which is independent of the type of energy used in a building or installation. We refer to Audenaert et al. (2010) for more detailed information about the EPB-software.

Two main variables calculated through the EPB software are the E-level and K-value. The E-level provides an indication of the energy efficiency of a building and the fixed installations in it (e.g. space heating and cooling systems) under standard circumstances (i.e. under normal climate conditions for a specific region and assuming average energy consumption in daily use). The lower the E-level, the more energy efficient the building is. This E-level depends on a number of variables, including the compactness, thermal insulation, air tightness, ventilation, space and water heating and cooling systems, orientation and sun characteristics and lighting infrastructure (only for commercial and institutional buildings) (Audenaert et al., 2010). The K-value provides a maximal value of the heat insulation characteristics of a building (Audenaert et al., 2010). As can be expected, the better the insulation of a building, the less energy is required for space heating and/or cooling (Jaber, 2002; Stepanov et al., 2000). Unlike the E-level, which can differ per living unit, the K-value applies to an entire building.

For the ecologic analysis, we will use both these E-levels and K-value. On top, we will also present the CO_2 emissions retrieved from the EPB software.

This study adopts a case study based approach. For a specific, real-life new housing project (which includes a doctor's practice and three apartments above it) the variables and values have been calculated based on real offerings and details provided by the architect and a company specialised in space heating and cooling installations. As such, this approach has pros and cons. Obviously, it offers the advantage that the results obtained are relevant and apply to a realistic new housing project. On the other hand, a single case study has the drawback of not necessarily being applicable to all kinds of situations and combinations. Therefore, the results of this study should be interpreted with this limitation in mind.

The main limitation of adopting a single case study methodology has partially been countered by using scenarios for the evolution of the energy prices. As annual energy consumption is the main cost and ecologic driver of space heating systems, these scenarios add substantially to the more widespread validity of this study's conclusions.

5. Findings

The findings' section will be subdivided into three parts. Firstly, we will address the economic results associated to each of the five heating systems. Secondly, an evaluation will be made based on the ecologic footprint of the systems, based on the outcomes of the EBP software (i.e., the E-levels and Kvalue). Finally, the economic and ecologic (in terms of CO_2 emissions) results will be brought together in the final eco-economic analysis, in which by means of scatter diagrams, the different systems will be compared, again under various energy price evolution scenarios.

5.1. Economic results

We first present the net investment cost, operational, and maintenance costs for all heating systems. The values of the first and the latter costs used are based on real sales prices obtained from a Belgian company specialised in installing and maintaining heating systems for the residential and commercial market. Table 1 provides an overview of the net investment costs for each of the five heating systems (including VAT), while Table 2 provides an overview of the yearly operating and maintenance costs (again, including VAT).

Table 1. Investment costs for the five space heating systems (incl. VAT)

1. Heating system	2. Initial price (EUR)	3. Subsidy (EUR)	4. Penalty (EUR)	5. Net investment (EUR)
6. Condensing heating unit on fuel oil with radiators	7. 20,555.00	8. 0.00	9. 2,980.55	10. 23,535.55
11. Condensing heating unit on natural gas with radiators	12. 19,149.00	13. 0.00	14. 2,648.15	15. 21,797.15
16. Condensing heating unit on natural gas with underfloor heating	17. 18,149.00	18. 0.00	19. 1,777.19	20. 19,926.19
21. Electric heating system with radiators	22. 8,000.00	23. 0.00	24. 43,077.11	25. 51,077.11
26. Heat pump with underfloor heating	27. 37,000.00	28. 2,830.00	29. 0.00	30. 34,170.00

The results in Table 1 indicate that the classic electric heating system requires by far the highest net investment cost, largely due to the high monetary penalty due to its unfavourable ecologic footprint. The condensing heating unit on natural gas with underfloor heating is the cheapest in terms of initial net investment required.

Table 2. Yearly operating and maintenance costs for the five space heating systems (incl. VAT)

31. Heating system	32. Total consumption (kWh)	33. Unit cost (EUR / kWh)	34. Yearly energy cost (EUR)	35. Yearly maintenance cost (EUR)	36. Total yearly cost (EUR)
37. Condensing heating unit on fuel oil with radiators	38. 48,637.22	39. 0.076	40. 3,705.99	41. 150.00	42. 3,855.99
43. Condensing heating unit on natural gas with radiators	44. 47,835.28	45. 0.0636	46. 3,029.09	47. 60.00	48. 3,089.09

49. Condensing heating unit on natural gas with underfloor heating	50. 45,734.17	51. 0.063	52. 2,896.04	53. 60.00	54. 2,956.04
55. Electric heating system with radiators	56. 40,038.89	57. 0.107	58. 4,039.92	59. 0.00	60. 4,039.92
61. Heat pump with underfloor heating	62. 12,023.33	63. 0.10	64. 1,213.15	65. 0.00	66. 1,213.15

In terms of total yearly costs (i.e. the costs required to use the heating system and maintain it), the results in Table 2 clearly illustrate the high costs associated with the classical electric heating systems (despite their low initial price). The heat pump combined with underfloor heating has by far the lowest total yearly cost.

Figures 1 to 5 provide a view on the different payback periods of the four alternative systems when compared to the reference system (condensing heating unit on fuel oil with radiators). The results clearly indicate that for all energy price evolution scenarios, the heating system based on classical electric heating performs worst in terms of economic benefit. Furthermore, the other three systems are consistently better than the reference system, whereas the heat pump with underfloor heating mostly exceeds any other system in terms of economic benefit. Only in the rather unlikely case of decreasing annual energy prices, the two other heating systems on natural gas come close to the long term economic benefits of the heat pump-based system. It usually takes about four years for the heat pump system to outperform the reference case, while the two systems with natural gas are better from an economic point of view right from the start (given the lower initial investments). However, given the low operational costs for the heat pump system, the largest economic benefits can clearly be obtained when investing in the heat pump with underfloor heating system.

Figure 1. Economic results of the heating systems – Annually decreasing energy prices with 5%

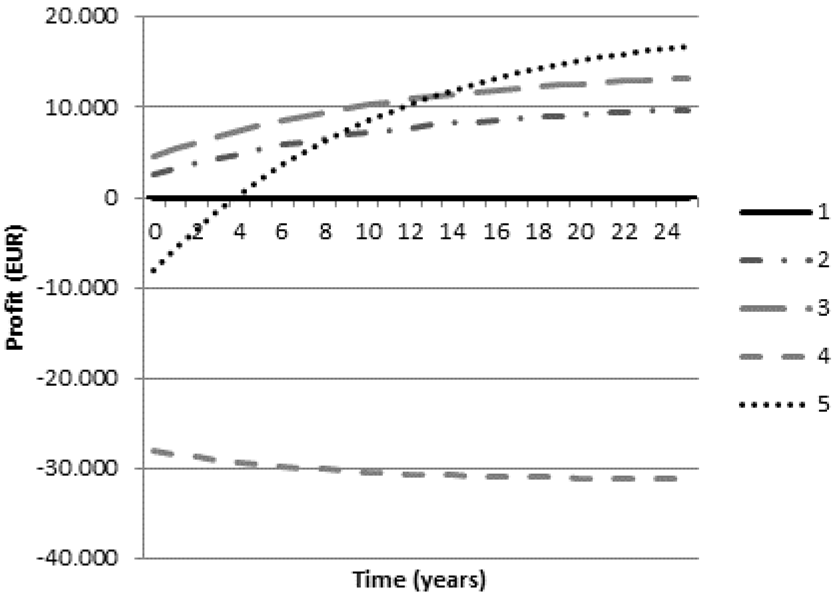


Figure 2. Economic results of the heating systems – Constant energy prices

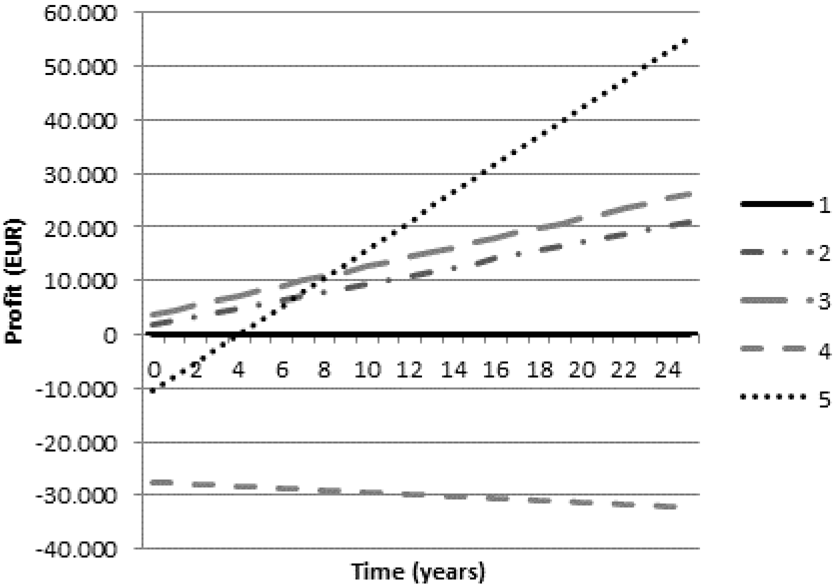


Figure 3. Economic results of the heating systems – Annually increasing energy prices with 5%

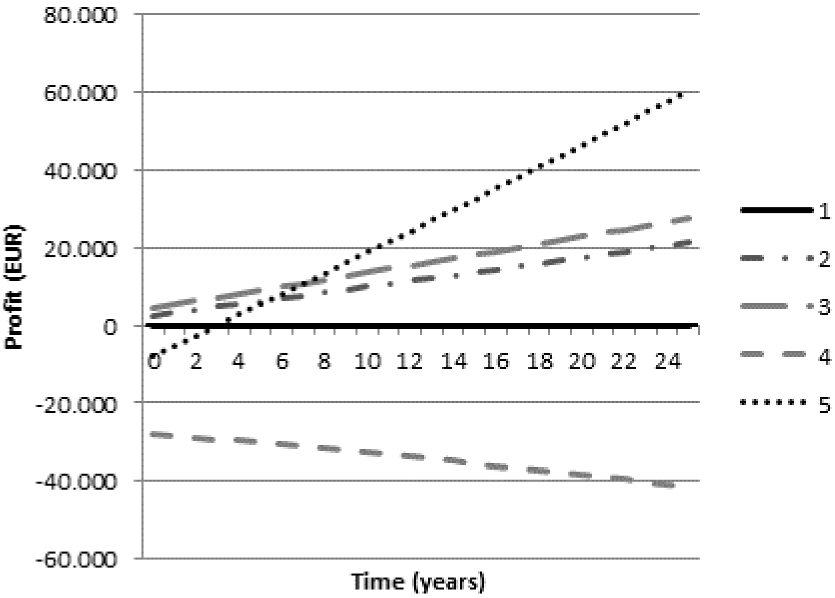


Figure 4. Economic results of the heating systems – Annually decreasing energy prices with 10%

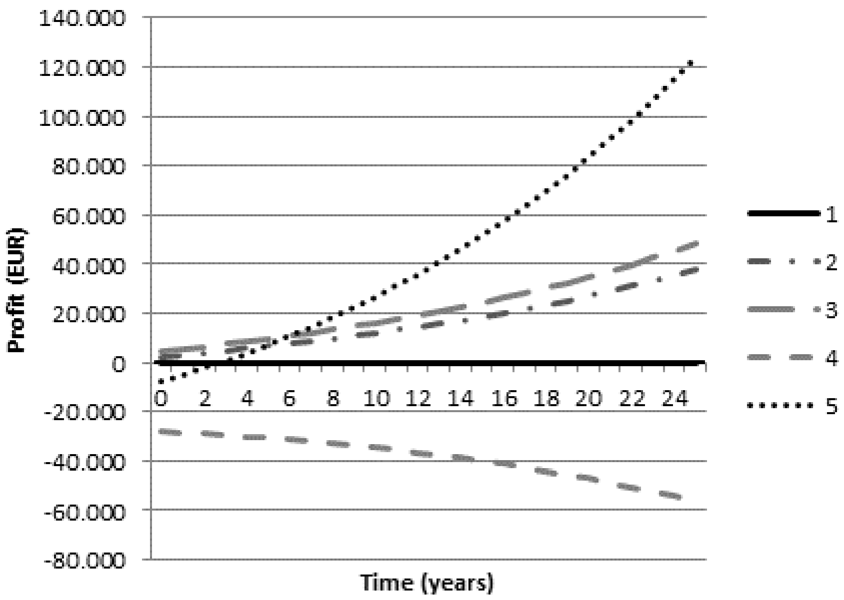
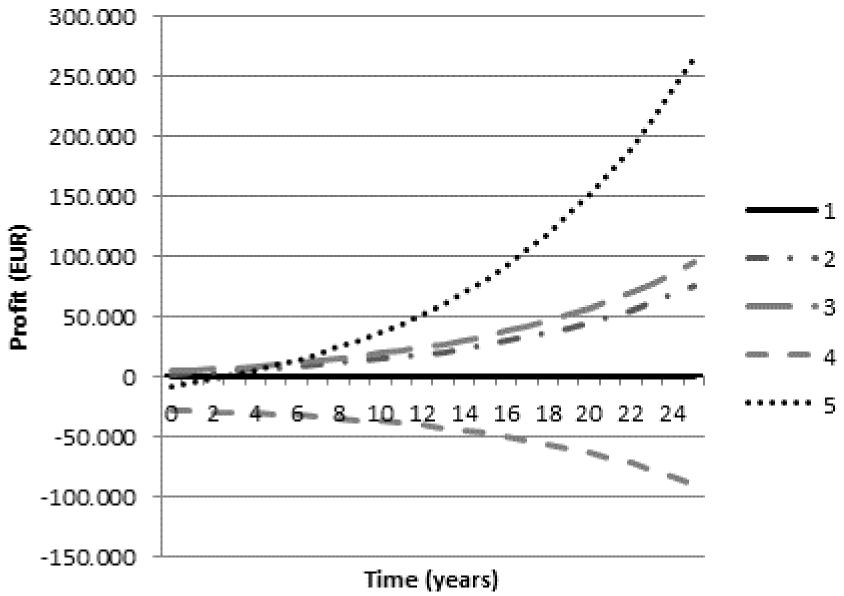


Figure 5. Economic results of the heating systems – Annually increasing energy prices with 15%



5.2. Ecologic results

The EPB software has been used to calculate the different ecologic footprints of all five alternative heating systems. As indicated earlier, the K-value refers to the global thermal insulation capacity of a building or installation (the lower the value, the better its insulation characteristics), while the E-level measures the energy efficiency of a building or installation under standard circumstances (the lower the E-level, the more energy friendly). Table 3 provides an overview of the K-value and E-levels for the different heating systems.

Table 3. K-value and E-level for the five space heating systems

67. Heating system	68. K-value	69. E-level doctor*	70. E-level ap. 1*	71. E-level ap. 2*	72. E-level ap. 3*
73. Condensing heating unit on fuel oil with radiators	74. 45	75. 92	76. 85	77. 85	78. 96
79. Condensing heating unit on natural gas with radiators	80. 45	81. 91	82. 84	83. 84	84. 95
85. Condensing heating unit on natural gas with underfloor heating	86. 45	87. 89	88. 82	89. 82	90. 92
91. Electric heating system with radiators	92. 45	93. 145	94. 136	95. 137	96. 154
97. Heat pump with underfloor heating	98. 45	99. 73	100. 65	101. 65	102. 74

** The E-levels refer to the individual E-levels of the doctor's practice and the three apartments, where apartment 3 is the rooftop apartment (which explains its more negative ecologic impact).*

The results in Table 3 indicate that the K-value for all alternatives is equal. This is not surprising, given the fact that the analyses have been performed under the 'ceteris paribus' hypothesis, i.e. all other things (amongst which the insulation characteristics of the building) remaining equal.

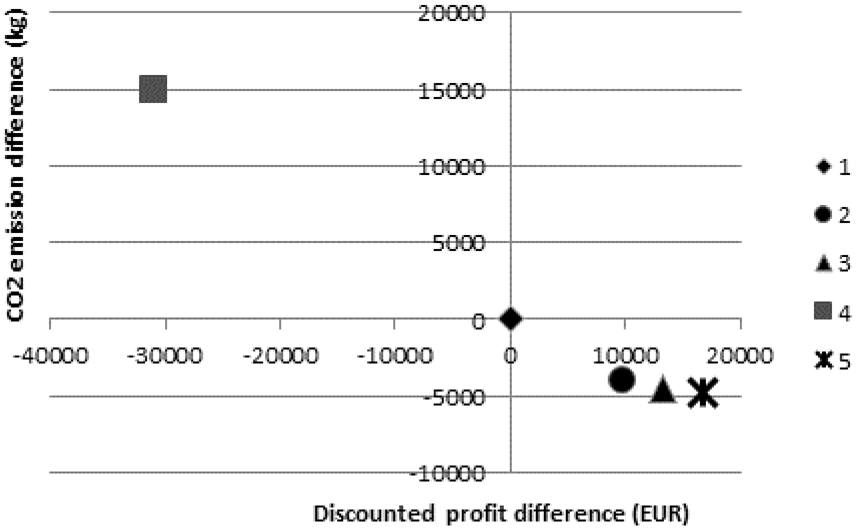
The results of the E-levels clearly indicate that the space heating systems with condensing heating units yield very similar results, while the electric heating system has by far the most negative ecologic impact and the system with heat pump and underfloor heating is the best performing one. If the ecologic footprint, measured by E-levels, would be the only determinant in the decision making process, the heat pump alternative should clearly be preferred. The latter is also the only system fulfilling the maximum E-level of 80 for building application filed between 01/01/2010 and 31/12/2011.

Furthermore, systems with underfloor heating tend to perform better than systems with radiators.

5.3. Eco-economic results

The last analysis combines both the economical and ecological aspects in a single overview, being the yearly CO2 emission (in kg) as determined by the EBP software, the economic results with the condensing heating system on fuel oil with radiators as reference system, and the changing energy prices over time. As depicted in Figures 6 till 10, this eco-economic analysis confirms what could be extracted from all previous individual analyses, i.e. that the heating system with a heat pump and underfloor heating outperforms the other systems in both ecologic and economic regard over a 25-year period (which is about the estimated lifetime for all systems).

Figure 6. Scatter plot of the eco-economic results – Annually decreasing energy prices with 5%



6. Conclusions and implications

This study aimed to evaluate different space heating systems by means of a case study in a new housing project. Five different systems have been evaluated on both economic as well as ecologic outcomes, and under various scenarios of energy price evolutions. The results yield three main outcomes. Firstly, the more classical heating systems, based on electric heating systems with radiators, are by far the worst systems in terms of economic and ecologic impact. This outcome has been observed under all energy price scenarios. Secondly, space heating systems with underfloor heating outperform systems with radiators, again both with regard to economic and ecologic parameters. Thirdly, despite its higher initial investment, the heating system with a heat pump and underfloor heating yields significantly better results than all other systems. This is mainly driven by its low operational costs (given its low annual energy consumption needs).

Clearly, the subsidies and monetary penalties have a substantial impact on the results and vary over different countries and even regions or cities. Therefore, the same analyses have been run excluding these elements.

References

Audenaert A., De Boeck L., Geudens K., & Buyle M. (2012). Cost and E‑level analysis of different dwelling types and different heating systems with or without heat exchanger. *Energy, 44*(1), 604-610.

Audenaert A., De Boeck L., & Roelants, K. (2010). Economic analysis of the profitability of energy-saving architectural measures for the achievement of the EPB-standard. *Energy , 35*(7), 2965-2971.

Audenaert, A., De Cleyn, S. H., & Vankerckhove, B. (2008). Economic analysis of passive houses and low-energy houses compared with standard houses. *Energy Policy, 36*(1), 47-55. doi:10.1016/j.enpol.2007.09.022

Badescu, V. (2002). Model of a space heating system integrating a heat pump, photothermal collectors and solar cells. *Renewable Energy, 27*(4), 489-505.

Comakli, K. (2008). Economic and environmental comparison of natural gas fired conventional and condensing combi boilers. *Journal of the Energy Institute, 81*(4), 242-246.

European Environmental Agency. (2007). Annual European Community Greenhouse Gas Inventory 1990–2005 and Inventory Report 2007.

Eurostat. (1999). Energy consumption in households. 1996 survey.

Gustavssona, L., & Joelsson, A. (2007). Energy conservation and conversion of electrical heating systems in detached houses. *Energy and Buildings*, *39*(6), 717-726.

Harvey, L. D. D. (2009). Reducing energy use in the buildings sector: measures, costs, and examples. *Energy Efficiency*, *2*, 139-163.

Hughes, L. (2010). Meeting residential space heating demand with wind-generated electricity. *Renewable Energy*, *35*(8), 1765-1772.

Jaber, J. O. (2002). Prospects of energy savings in residential space heating. *Energy and Buildings*, *34*(4), 311-319.

Kroetz, K. M., & Friedland, A. J. (2008). Comparing costs and emissions of northern New England space heating fuel options. *Biomass and Bioenergy*, *32*(12), 1359-1366.

Monahan J., & Powell, J.C. (2011). A comparison of the energy and carbon implications of new systems of energy provision in new build housing in the UK. *Energy Policy*, *39*(1), 290-298.

Marcos, J. D., Izquierdo, M., & Parra, D. (2011). Solar space heating and cooling for Spanish housing: Potential energy savings and emissions reduction. *Solar Energy*, *85*(11), 2622-2641.

Meier, H., & Rehdanz, K. (2010). Determinants of residential space heating expenditures in Great Britain. *Energy Economics*, *32*(5), 949-959.

Rehdanz, K. (2007). Determinants of residential space heating expenditures in Germany. *Energy Economics*, *29*(2), 167-182.

Stepanov, V., Starikova, N., & Stepanova, T. (2000). Indices for estimation of energy conservation in space heating. *Energy and Buildings*, *31*(3), 189-193.

Xi, C., Hongxing, Y., Lin, L., Jinggang, W., & Wei, L. (2011). Experimental studies on a ground coupled heat pump with solar thermal collectors for space heating. *Energy*, *36*(8), 5292-5300.

Appendix 1 Material characteristics, insulation values and coefficient of the permeability of total solar radiation energy

This appendix provides an overview of the material and installation characteristics used in the new housing project. These values have been used to calculate the E-levels and K-values by means of the EPB software.

Opaque materials

Isover	Mupan Façade Mineral Wool	λ = 0.032 W/mK
Isover	Party-wall	λ = 0.033 W/mK
Roof insulation	Mineral wool	λ = 0.034 W/mK
Roofmix concrete	Cement screed	λ = 0.087 W/mK
EPDM	Foil (rubber parts)	λ = 0.170 W/mK
Eternit	Natura-plates	λ = 0.407 W/mK
Isobet	Cement screed	λ = 0.085 W/mK

Masonry

Facade brick	Wienerberger – terca	Brons rustiek	λ = 1.180 W/mK
Porotherm Thermobrick	Porotherm	Thermobrick	λ = 0.260 W/mK

Windows

Saint-Gobain (vertical windows)	Climaplus Ultra N	U = 1.1 W/m²K	g = 0.42
Saint-Gobain (roof windows)	Sky-Lite K18	U = 1.6 W/m²K	g = 0.18

Window frames

Reynaers	CS 86-HI	U = 1.20 W/m²K

Curtain wall

Reglit – Lamberts Linit	g = 0.63	U = 1.8 W/m²K	Glass surface = 56.31 m²

Adjustable supply vent

Renson – Invisivent	q1,2Pa = 52.7 m³/hm	L0,2Pa = 0.066 m	U = 3.9 W/m²K
	q1,10Pa = 59.8 m³/hm	L0,10 = 0.066 m	U = 3.9 W/m²K

Heat generating installations

Viessmann Vitodens 222-F	Condensing kettle	Natural gas	Test efficiency at 30% part load = 1,09	Kettle inlet temperature at 30% part load = 30°C
Viessmann Vitoladens 300T	Condensing kettle	Gas oil	Test efficiency at 30% part load = 1,03	Kettle inlet temperature at 30% part load = 30°C

Heat pump

Viessmann Vitocal 220G	Coefficient of performance = 4.5	Temp. increase = 35.0°C	Electric power = 17.2 kW