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ECONOMIC ANALYSIS OF THE PROFITABILITY OF ENERGY-SAVING ARCHITECTURAL MEASURES FOR THE ACHIEVEMENT OF THE EPB-STANDARD

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ABSTRACT

Energy consumption in the residential and service sector makes up 20% to 40% of the total final consumption in developed countries. Due to e.g. population growth and higher comfort requirements it is highly likely that this energy consumption will continue to increase. As such, energy efficiency in buildings has become a key goal in any energy policy. Europe relies on the Energy Performance of Buildings Directive (EPBD) converted by Flanders into the 'Energy Performance and Interior Climate' (EPB). This study seeks the economically most profitable combination of insulation - facade, roof, floor and glazing - taking into account this Flemish EPB-standard. Therefore a scenario-analysis is conducted using the EPB-software Flanders and a self-designed Excel file for calculating the most important profitability criteria. Based on these criteria the most profitable combination is determined for a maximum E-level of 80. Using a reference point for three types of dwellings studied, the scenario-analysis shows that for the half-open dwelling the insulation of roof and floor becomes more important whereas for the open dwelling it is the insulation of facade and roof. Further on we can conclude that the EPB-policy should distinguish between the dwelling types and should take on more stringent values for the U-level.

1. INTRODUCTION

Energy challenges are ranked on the top of the world agenda. [1] identified the following four main challenges: the increasing oil scarcity, the security of supply, the environmental degradation and the growing energy requirements in the developing countries. In Europe the growing realization to cope with these challenges existed already for a longer time. Whereas the focus in Europe used to be at the supply side of the energy market, the focal point has now moved to managing the demand for energy. The most important example of this shift can be found in the issue of the Energy Performance of Buildings Directive (EPBD) in the context of the Kyoto Protocol, aiming at decreasing energy demand. Despite this favourable evolution, we must note the supply side deserves further attention (see e.g. [2] and [3]).

Zooming in on the demand side of energy, [4] conclude that the residential sector is responsible for around 25% of the total final consumption in Europe. Further on [4] state that due to improved legislation and new materials a lot of progress has been made in terms of energy-efficient and environmentally friendly buildings but a rising standard of living and working and the introduction of new equipment such as air conditioning, can cause a further rise in energy consumption in buildings despite being more efficient. The results of [5] are in the same line. They state that the share of buildings, both residential and commercial, lies between 20% and 40% of the total final energy consumption in developed countries. Moreover they point out the following additional reasons for a rise in energy consumption of buildings: population growth, higher comfort requirements and increasing time spent in buildings. Energy efficiency in buildings is therefore a primary objective in any current energy policy.

Apart from energy efficiency, we have the emission of greenhouse gases when producing and consuming energy [6]. It appears now that insulation of buildings (insulation improvements) is the most cost-effective measure relating to this emission [6].

Therefore, this study focuses specifically on this most cost-effective component, namely the insulation of new constructions in the residential sector. It seeks to identify the economically most interesting combination of insulation - facade, roof, floor and glazing - taking into account the Flemish EPB standard using a scenario-based analysis. Related studies can be found in [7], [8] and [9]. The main difference with our paper relates to the region where these studies are applied and/or the 'client' for which these studies were carried out. In [7], the study applies to three European climate zones; in [8] they focus on the 'Brussels Capital Region'. [8] and [9] are studies performed by government order. Our study intends to find out the economical most profitable combination of isolation (given a representative installation-technical placing) for the Flemish citizen.

The paper is organized as follows. In section 2, we briefly touch the legal framework. Section 3 clarifies the methodology used followed by the results in section 4. Section 5 concludes the paper with the most important highlights of the analysis.

2. LEGAL FRAMEWORK

Europe has issued the Energy Performance of Buildings Directive (EPBD) in the context of the Kyoto Protocol. This directive aims to improve the energy performance of buildings in the European Union by promoting cost-effective solutions. The EPBD imposes upon member states the following commitments: minimal energy performance requirements, calculation procedure, certification, inspection of boilers and air conditioning and requirements for experts and inspectors.

In Belgium, the regions are responsible for the conversion of this directive into their legislation. Flanders has translated this in the 'Energy Performance and Interior Climate' (EPB). The EPB is applicable to new construction and renovation projects for which a building permit must be submitted. Table I represents the EPB requirements.

Section	Requirement
Insulation	Maximum K 45 and maximum U-values
Indoor climate	Ventilation and reduction of risk of overheating
Energy performance	Building application filed till 31/12/2009: maximum E 100
	Building application filed upward of 01/01/2010: maximum E 80

TABLE I: EPB REQUIREMENTS

The K- or insulation level of a dwelling is the overall level of thermal insulation. It takes into account the heat losses (through external walls, roofs, floors, windows) and the shape and size of the dwelling. The lower the K-level is, the better.

Each structural element of the dwelling is subject to maximum U-values (see Table II). The U-value or heat transfer coefficient, expressed in W/m^2K , is the insulation value of a structural element of the dwelling (facade, roof, floor, and window). The U-value corresponds to the amount of heat flowing from inside to outside per second, per square meter and per degree temperature difference. The lower the U-value of a structural element is, the better it keeps the heat inside.

The E- or energy level is a measure of the energy consumption of the dwelling. The lower the E-level is, the more energy efficient the home is.

The ventilation requirement is as follows: per square meter of floor space, a nominal inflow and outflow rate of 10 m^3/h per person has to be achieved. Furthermore a minimum flow rate, in cubic meters per hour, applies to the rooms. To ensure the flow of air, minimum sizes apply to the grids under doors.

Structural element	U-value (W/m^2K)	
	Until the end of 2009	From 2010 onwards
Facade	0.6	0.4
Floor	0.6	0.6
Roof or attic	0.4	0.3
Glazing	1.6	1.6

TABLE II: MAXIMUM U-VALUES FOR EACH STRUCTURAL ELEMENT

3. METHODOLOGY

The aim of the study is to identify the economically most profitable combination of insulation (facade, roof, floor and glazing), both in terms of thickness and U-values. To accomplish this, a scenario-analysis is conducted using the EPB-software Flanders and a self-designed Excel file for calculating the most important profitability criteria (payback period, net present value and internal rate of return).

3.1 EPB-software Flanders

The EPB-software Flanders calculates the characteristic annual primary energy consumption, the E-level and the K-level. This is a complex work requiring architectural data, installations and sanitary ventilation. The energy consumption consists of the energy needed for heating, cooling, hot water and auxiliary energy reduced with the energy generation by photovoltaic panels and cogeneration. Remark that only the energy needed for heating and cooling will change in our study since only insulation of the dwelling changes.

In Table III, the insulation materials used in the structural elements (facade, roof and floor) are presented together with their minimum and maximum thickness and thickness in between (represented by the step size in Table III) used for building up the different scenarios. For the floor we used expanded polystyrene (EPS) and not polyurethane (PUR) since pre-analysis revealed that although its lower insulation value, EPS succeeded in broadly reaching the maximum U-values (as given in Table II) and thereby resulting in a lower investment cost (PUR is more expensive). As a result, all possible values of the three structural elements given in Table III combined with the three options for the glazing (U2.9, U1.4 and U1.1) gives 450 combinations to analyze for each type of dwelling.

Structural Element	Min. thickness (cm)	Max. thickness (cm)	Step size (cm)	Material	Lambda (W/mK)
Facade	0	20	5	MW (Mineral wool)	0.041
Pitched roof	0	24	6	MW	0.041
Floor	0	20	4	EPS	0.040

TABLE III: INSULATION MATERIAL PER STRUCTURAL ELEMENT AND ITS THICKNESS

Each possible combination of insulation for facade, roof, floor and glazing (i.e. each scenario) corresponds with an investment cost and characteristic annual primary energy consumption (i.e. an energy cost). To allow an economic analysis, a comparison basis is needed. This basis is obtained by analyzing reference dwellings. Since the scenario-analysis will be performed for the three main types of dwellings present in Flanders (the townhouse, the half-open dwelling and the open dwelling), we will have three reference dwellings. The properties of these reference dwellings are represented in Table IV.

Characteristics	Dwelling type		
	Townhouse	Half-open dwelling	Open dwelling
Orientation	front north, back south	front north, back south	front north, back south
Built-on ground	73.50 m ²	73.50 m ²	73.50 m ²
Sheltered volume	546.2 m ³	546.2 m ³	546.2 m ³
Area of heat loss	238.38 m ²	311.44 m ²	384.50 m ²
E-level	110	116	121
K-level	63	66	68
U-values	Not satisfied	Not satisfied	Not satisfied
Insulation	5 cm facade, 6 cm roof, 0 cm floor	5 cm facade, 6 cm roof, 0 cm floor	5 cm facade, 6 cm roof, 0 cm floor
Glazing	U = 2.9 W/m ² K	U = 2.9 W/m ² K	U = 2.9 W/m ² K
Heating	central, natural gas	central, natural gas	central, natural gas
Ventilation	free inflow, mechanical outflow	free inflow, mechanical outflow	free inflow, mechanical outflow
Air tightness	12 m ³ /hm ²	12 m ³ /hm ²	12 m ³ /hm ²

TABLE IV: CHARACTERISTICS OF THE REFERENCE DWELLINGS

Each scenario (i.e. each possible combination of insulation for facade, roof, floor and glazing) generates an investment cost for insulation and an energy cost. Each of both costs will then be compared with the

corresponding costs for the reference dwelling and their difference will serve as input for the economic analysis. Note that only those scenarios that meet the E- and K-level standards will undergo the economic analysis, i.e. a calculation of three profitability criteria: payback period, net present value and internal rate of return. As builders attach the most importance to the payback period, the best combination of insulation will be based on this criterion. While determining the best combination, the maximum U-values for each structural element are not taken into account to allow the assessment of the current policy of these U-values. The economically most profitable combination of insulation is determined for the future (from 2010 onwards), i.e. an E-level of 80.

3.2 Profitability criteria

As already mentioned before, the three profitability criteria we will use are payback period, net present value and internal rate of return. For a definition of these well-known criteria, we refer to the literature (see e.g. [10]). Taking into account Section 3.1 and the definition of these criteria, the following inputs are required:

- **Duration:**
We fix the duration at 30 years which can be considered the time the dwelling is used for one generation. The same duration can be found in [9] and [11].
- **Investment cost and tax percentage:**
The investment cost for facade, floor and roof is determined by multiplying the following factors: price per square meter of the insulation material, number of layers and number of square meters used of the insulation material. The price per square meter for facade, floor, roof and glazing is given in Table V. These prices are taken from the form of unity prices 2008 composed by the architect's and engineer's firm Aspen.
The tax percentage (on this investment cost) is 6% for dwellings > than 5 years and 21% for dwellings < 5 years. For this last category, there is a temporary decrease in the tax percentage to 6% on a bracket of 50000 EUR. However, we will not take this decrease into account because of the temporary character and because we do not know how much of these 50000 EUR can be assigned to insulation investment costs.
- **Discount rate:**
We choose for a discount rate of 5.12%, which is the mortgage interest rate on 30 years taken from [12].
- **Energy price:**
Since for the scenario-analysis we rely on heating with natural gas, we should rely on the price of natural gas. This price consists of three components: the energy price, the net tariffs and the federal surcharge, all expressed in cEUR per kWh. Using the rate 'Basisaanbod' (from April 2009) from Electrabel, Sibelgas being the distribution network operator, the total variable cost is 5.62809 cEUR per kWh. The growth rate for the natural gas price is assumed to be 5%, being the average growth rate of household's natural gas prices between 2000 en 2007 [13].

Material	Price (EUR/m ²)
Facade: MW (5 cm)	9.00
Floor: EPS (4 cm)	5.60
Roof: MW (6 cm)	6.77
Double Glazing U2.9	90.80
HR+ glazing U1.4	108.90
HR++ glazing U1.1	118.00

TABLE V: PRICES OF INSULATION MATERIALS

Given these inputs, we can easily calculate the profitability criteria by the following formulas:

- **Payback period (PB):** calculates the exact time needed to recover the investment costs with (future) cash flows

$$I = \sum_{t=0}^{PB} CF_t (1+d)^{-t}$$

- **Net present value (NPV):** represents the value that the investment generated during its lifetime (i.e. its duration)

$$NPV = \sum_{t=0}^{29} CF_t (1+d)^{-t} - I$$

- **Internal rate of return (IRR):** represents the actual return of the investment

$$I = \sum_{t=0}^{29} CF_t (1 + IRR)^{-t}$$

In all formulas t represents year t ($t=0..duration$) with the duration equal to 29. I is the **additional investment cost** in insulation, i.e. the difference between the investment cost with tax included (see the inputs) and the investment cost of the reference dwelling. CF_t is the cash flow in year t (in our study this cash flow is equal for all t) and equals the **value of the energy savings** due to the additional investment in insulation. This value can be calculated by multiplying the energy savings (in kWh) and the energy price (see the inputs). d is the discount rate (see the inputs).

4. RESULTS

For the results we expect that for the same investment cost, a combination of insulation investment for facade, roof, floor and glazing will result in higher energy savings than an investment in the insulation of one structural element (façade or roof or floor or glazing) for the following reasons: there is a decreasing marginal improvement in U-values for insulation in one of each structural element and there are different heat losses for each structural element.

The investment cost (IC) and energy cost (EC) for the reference dwellings and the economically most profitable combination of insulation for all dwelling types and their corresponding values for the profitability criteria given an E-level of 80, are given in Table VI.

Type	Profitability criteria and components for most profitable combination of insulation					
	I (EUR)	CF (EUR/year)	PB (year)	IRR (%)	NPV (EUR)	
	IC (EUR)	EC (EUR/year)				
Townhouse	3286.20	459.72	7.17	21.85	10279.47	
Half-open dwelling	3582.59	1267.98				
	5247.94	590.09	8.93	17.83	12164.71	
Open dwelling	4378.22	1513.51				
	7652.46	741.82	10.37	15.57	14237.79	
	5173.84	1760.39				
	Most profitable combination of insulation, related U-value, E-level and K-level					
	Facade (cm)	Roof (cm)	Floor (cm)	Glazing	E-level	K-level
	U-value	U-value	U-value	U-value		
Townhouse	10	18	8	1.1	80	31
	0.34	0.29	0.30	1.1		
Half-open dwelling	10	24	12	1.1	80	31
	0.34	0.22	0.23	1.1		
Open dwelling	15	18	12	1.1	80	30
	0.24	0.29	0.23	1.1		

TABLE VI: ECONOMICALLY MOST PROFITABLE COMBINATION OF INSULATION

The most important conclusions that can be derived from Table VI will be discussed in Section 5.

5. CONCLUSIONS

This study focuses on the most cost-effective component related to the emission of greenhouse gases in a sector with high energy consumption, namely the insulation of new constructions in the residential sector. It seeks to identify the economically most interesting combination of insulation - facade, roof, floor and glazing - taking into account the Flemish EPB-standard by using a scenario-based analysis given an E-level of 80.

From this analysis (see Table IV), we can derive the following main conclusions.

- We observe an increasing additional investment cost (I) for the half-open dwelling compared to the townhouse and for the open dwelling compared to the half-open dwelling. The reason is very simple: the townhouse has two external walls adjacent to a heated space, the half-open dwelling one and the open dwelling none. As a consequence with the half-open and open dwelling one need

to insulate respectively one and two extra external walls leading to an increasing investment. At the same time, an increasing additional investment cost also generates increasing energy savings (CF) for the half-open dwelling compared to the townhouse and for the open dwelling compared to the half-open dwelling.

- The payback period is between 7 and 11 years which is on average 3 times lower than the duration (30 years). The internal rate of return is located between 15% and 22%, rendering an extremely high actual return for an almost riskless investment in insulation. The net present value is positive indicating a netto positive return of the investment.
- For the half-open dwelling the floor and roof insulation become more important whereas for the open dwelling the floor and facade insulation play a bigger role.
- The more stringent E-level has resulted in more stringent U-values (see Table II). However, especially for the floor and glazing for all types of dwellings and for the facade for the open dwelling, these more stringent U-values do not suffice. Indeed, the obtained values are 31% till almost 62% below the maximum U-values. This asks for revising the EPB-policy concerning the U-values and depending on the dwelling type. We are confident that this can be interesting material for future research, requiring a more profound study.

REFERENCES

1. Doriana, J.P., et al. (2006), Global Challenges in Energy. In *Energy Policy* 34: p. 1984-1991.
2. Reymond, M. (2007), European Key Issues Concerning Natural Gas: Dependence and Vulnerability. In *Energy Policy* 35: p. 4169-4176.
3. Weisser, H. (2007), The Security of Gas Supply - a Critical Issue for Europe? In *Energy Policy* 35: p. 1-5.
4. Poel, B., et al. (2007), Energy Performance Assessment of Existing Dwellings. In *Energy and Buildings* 39: p. 393-403.
5. Pérez-Lombard, L., et al. (2008), A Review on Buildings Energy Consumption Information. In *Energy and Buildings* 40: p. 394-398.
6. McKinsey & Company, (2007), A Cost Curve for Greenhouse Gas Reductions. In *The McKinsey Quarterly* 1: p. 35-45. [Online], Available: http://www.epa.gov/air/caaac/coaltech/2007_05_mckinsey.pdf. Consulted: [28 April 2009].
7. Petersdorff, C., et al. (2005), Cost-Effective Climate Protection in the EU Building Stock. [Online], Available: http://www.eurima.org/uploads/Documents/documents/cost_effective_climate_protection.pdf. Consulted: [28 April 2009].
8. Verbeeck, G., et al. (2005), Technisch-Economische Analyse van de Rendabiliteit van Energiebesparende Investeringsen. [Online], Available: http://www.leefmilieubrussel.be/uploadedFiles/Contenu_du_site/Professionnels/Themes/L%C3%A9nergie/Le_logement_collectif/Les_outils_URE/24_Eindrapport.pdf?langtype=2067. Consulted: [28 April 2009].
9. Verbeeck, G., et al. (2008), Studie naar de Economische Haalbaarheid van het Verstrengen van de EPB-Eisen bij Residentiële Gebouwen. [Online], Available: <http://www2.vlaanderen.be/economie/energiesparen/epb/doc/economischehaalbaarheidstudieresidentieel.pdf>. Consulted: [28 April 2009].
10. Meredith, J.R., et al. (2006), Project Management: a Managerial Approach. John Wiley & Sons.
11. Tommerup, H., et al. (2006), Energy Savings in Danish Residential Building Stock. In *Energy and Buildings* 38: p. 618-626.
12. Immotheker, (2009), Overzicht van de Gemiddelde Rentestanden voor Woonleningen in België. [Online], Available: http://www.immotheker.be/Immotheker3/Site_v3/Default.aspx?WPID=333&MIID=115&MSIID=151&L=N. Consulted: [28 April 2009].
13. FOD economie, (2009), De Aardgasprijzen voor Huishoudelijk Gebruik. [Online], Available: http://economie.fgov.be/energy/energy_statistics/Statistics_nl_022.htm. Consulted: [28 April 2009].