A COST-BENEFIT MODEL TO EVALUATE ENERGY SAVING MEASURES IN OFFICE BUILDINGS

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Abstract: The objective of this study is to evaluate potential energy-saving measures in office buildings by preparing a cost-benefit model. The reach of this model includes all non-renovated office buildings in Flanders. The measures are chosen based on findings of a literature review. There is decided to include 7 energy-saving measures and 1 renewable energy system in the model. A costbenefit analysis is a method to determine the return on investment. The mathematical model is established using the Excel software. In a cost-benefit model, the benefits of the investment are compared to its cost. The benefits are the savings that the investment realizes. The profitability of the measures is evaluated based on the results. The payback time is the output of the model. In the mathematical model, the payback period is calculated with and without financial aid. The model also allows to calculate the results for combinations of measures. To be able to test the mathematicalmodel, a case study is applied. It concerns an older office building in Antwerp, the district house. The data from this building are entered into the model to get a realistic representation of the payback periods for the applied measures. According to these results, the economical most efficient measure is the implementation of insulation in the roof. The payback period is just over one year. The least cost-effective measure is the replacement of double glazing through high efficiency glazing. The investment cost is very high and the payback time is slightly more than 47 years. However, various combinations of measures are advisable. When adjusting the building envelope by adding insulation, the current gas consumption is reduced by approximately 10%. In combination with replacement of the boiler, the payback period is approximately 6,5 years. When placing a photovoltaic system, the financial aid has much influence on the payback time. Without the contributions the payback time is about 19 years. With the contributions, it is about 7 years.

Key-Words: cost-benefit model, energy, energy-saving measures, office buildings; payback time

1 Introduction

Energy conservation is increasingly important. Harvey L.D.D. [1] gives an overview of the literature on energy conservation. Overall, the savings are realized by optimizing the shape of the building, improving the building envelope, improving the efficiency of individual installations and the use of alternative energy systems. New buildings and renovations are being treated. The size of the energy savings in commercial buildings depends on the characteristics of the existing building, the climate, the internal heat gain and the occupancy rate. In this paper the developing of a mathematical model to evaluate the measures in office buildings is discussed. Renovation with application of energy efficiency measures is supported by the government through the offering of incentives and tax relief. Also the premiums. operators distribute network Although human behaviour is also very important in energy saving, this is not taken into account of this model, because it's a very subjective parameter [2]. In this mathematical model the payback period of energy-saving measures will be calculated with and without these contributions. The model is applied to a case study, the district house of Antwerp.

2 Cost-benefit analysis

The developing of a cost-benefit analysis is a method to determine the return on investment. The costs of implanting energy efficiency measures are the investment costs. The benefits will be the savings. The payback time will be the output of this model.

The established mathematical model of this thesis is based on an existing calculation model [3]. Thus investment costs and cash flow savings will determine the cost benefit of an energy efficiency measure.

2.1. Energy-saving measures

Energy-saving measures which can be applied in office buildings, are examined during a literature study. Based on this study, the measures are adopted in the calculation model.

Papadopoulos M. [4] examines the feasibility of some measures applied in different residential buildings in Greece. The measures are improving the heating system and better insulation of the building envelope.

G. Verbeeck [5] focuses on finding the optimum balance between investment costs and energy savings. A hierarchy of energy-saving measures is derived from the results. The ranking is as follows: insulation of the building envelope, better glazing, an energy-efficient heating system and the use of renewable energy [6-7].

Cakmanus I. [8] studied an office in Turkey. The study deals with the current HVAC systems and the existing glazing. By making the HVAC systems more energy-efficient, the energy consumption is reduced. The existing glazing is replaced by better thermal insulation glazing with blinds. This will reduce the electricity consumption for cooling.

The use of solar energy by installing photovoltaic cells obtains an energy yield. Audenaert A. [9] evaluates the installation of grid connected photovoltaic systems for companies in Flanders, based on an Excel model.

The following measures are discussed in the mathematical model: the implementation of insulation in the building envelope, the replacement of windows, placing of awnings, the replacement of the boiler, relighting and the use of photovoltaic cells. Premiums and other tax benefits are obtained by the network operator, the federal government and the Flemish Community [10].

2.2. Case study: District house Antwerp

A case study is used to test the model. Data from this case study is entered in the model to set a realistic representation of the results.

The case study must meet certain conditions. The building must be an office and may not have been renovated at least the last ten years. This also applies to the heating and the cooling system. These conditions are imposed because then the profitability of several combinations can be evaluated.

The energy-saving measures applied in the model are based on a condition measurement

and the Energy Performance Certificate. Both are conducted in the year 2009. The Energy Performance Certificate indicates that the building annually consumes 316,06 kWh/m². This is 12,5% higher than a similar building. Advices on the building envelope, the heating system, the cooling system and lighting are given.

3 The mathematical model

This chapter deals with the operation of the Excel model. Also, the formulas are briefly explained. The mathematical model contains 11 tabs: front page, information office building, premiums, roof insulation, wall insulation, floor insulation, transparent components, replacement boilers, relighting, photovoltaic cells and cost-benefit summary. Each worksheet will be discussed separately. The gray boxes in each tab must be completed to obtain a correct calculation.

3.1. Front page

On this worksheet, the data from the client – who would apply the measures - and the details of the site - the building where the measures would be applied- have to be entered.

3.2. Information office builling

This worksheet contains data on buildings which are necessary to calculate the energy savings and/or the energy yields. The data is already entered in this tab so that it will not be needed to enter the data in the following worksheets to complete these. This worksheet contains three frames namely 'Building Information', 'Temperature Data' and 'Other '.

The input parameters under 'Building Information' are the number of opening hours per day and the number of working days in the week, the heating period and the cooling period. These periods are determined best by the users of the building. The current glazing, the type of heating and the network operator are to be indicated. If the building is heated with gas, the current efficiency of the boiler must be specified.

The indoor temperature, de outside temperature during the winter and outside temperature during the summer must be entered under 'Temperature data'. The energy prices, the discount rate and the annual energy price increases are the input parameters under 'Others'.

3.3. Premiums

On this worksheet the premiums are shown. The first frame shows the premiums distributed by the network operators AGEM, Eandis, Infrax, GHA and DNBBA. The amounts that are shown are the contributions valid for 2011. The bonuses awarded by the Flemish government and the Belgian community have to be filled in. The parameters differ from situation to situation.

3.4. building envelope insulation

Three types of insulation are treated in the model: roof insulation, wall insulation and floor insulation. It is divided over three worksheets. Through a not or poorly insulated building envelope, there is a lot of heat loss. The heat losses will be reduced by adding insulation and energy savings will be achieved.

• Roof

In the calculation model the possible presence of a flat roof and a sloping roof are taken into account. The input parameters are located under 'Data roof' and under the two frameworks for the investment costs. The surface of the roof, the current U-value and the new U-value are the input parameters under 'Data roof'. The new U-value is the current U-value of the roof with implementation of the added insulation. It is advisable to isolate to a maximum U-value of 0.333 W/m²K or a minimum total R-value of 3 m²K/W. There is no annual maintenance charge for insulation. This apllies to all insulation.

• Facade

The outer wall is often a cavity wall in Belgium. The U-value of a cavitywall may amount to a maximum of 0,6 W/m²K under the new energy performance regulation. The U-value can be reduced by providing more insulation. The total wall area, the current U-value and the new U-value are the input parameters under 'Data wall'. The new U-value is the U-value of the wall with implementation of the added insulation. [11]

• Floor

There is also heat loss downwards through the floor. This heat loss is different from a floor above the ground than a floor above a basement or a floor above the outdoor environment. The U-value of a floor may amount to a maximum of 0,4 W/m²K under the new energy performance regulation. In old buildings, the U-value of the floor is usually not enough. If placing floorheating chosen when is insulation renovating. should be applied to reduce the heat loss downwards to a minimum. This is not easy with existing buildings, especially to floors above the ground. It is easier to achieve that for floors over a basement. There is room for insulation on the underside of the floor. The isolation of a full ground floor is more difficult. Existing pipelines under or in the floor should be taken into account. In office buildings there is usually a basement or garage under the building. It is assumed that the installation of floor insulation in office buildings entails no major demolition.

3.5. Transparent components

When renovating the windows there is the choice to either replace the windows or to replace the windows and to place awnings. This calculation takes into account to only place blinds. This can be advantageous if the windows (glazing and window profile) have already been renewed.

First, an inventory has to be made of the windows in the current situation. The inventory consists of the place (facade), the number, width, height and current U-value. The window areas are automatically calculated. These data are entered under 'List windows'. Besides these data, the new U-value has to be filled in this framework..

Large glass windows lead to heat gain in winter. The solar radiation transmitted through the glass, heats the room. In summer this can lead to overheating of the room. By installing an awning, the solar gains are limited. When sunlight falls on a window, a part of the radiation is reflected, another part is transmitted and another part is absorbed by the glass. The absorbed fraction is converted into heat and radiated to both sides of the glass. The total rate of energy that enters through the glass is the g-value. The use of sunscreens will reduce the transmitted fraction. The F_c-factor of the awning is often used to characterize the thermal performance of the blinds. This is equal to the ratio between the g-value of the awning and the glazing and the g-value of the glazing alone. The thermal performance is better when the F_c-factor is low.

3.6. Replacement of the boiler

Energy is saved when the current boiler is replaced by a boiler with higher efficiency. Gas consumption will be reduced. Both the current and the new state of the boiler is listed on the worksheet in the boxes provided. The useful power is obtained by multiplying the efficiency with the gross power of the boiler. Each boiler will have a weight percentage by dividing the capacity of the boiler by the total capacity of all the boilers. This weight percentage indicates the contribution of the boiler to the total heating capacity of the building. The weighted average efficiency of the boiler is determined by the weight percentage. The difference in efficiency and the current gas consumption are the parameters to calculate the energy savings.

The boiler capacity should not be oversized or under-dimensioned. Therefore, the boiler output required is calculated based on the transmission losses. These losses are calculated with a minimum outside temperature of -10 °C. The boiler capacity is equal to the sum of all transmission losses. This sum must be less than the installed capacity of the boiler. The boiler is under dimensioned when that power is much higher. If it is much lower, the boiler is oversized.

3.7. Relighting

Relighting means the replacement of lamps and fixtures, installation of a control system, installation of a motion detection and using different lighting techniques. A part of the overall energy savings can be achieved by performing a relighting. First, the current state of lighting has to be known. When the current state is known, it can be optimized and made more energy-efficient. The new state follows. The results are obtained by subtracting the details of the new state from the data of the current situation. The energy savings can be calculated with these results.

3.8. Photovoltaic cells

A PV system consists of a series of panels and peripherals. The panels form solar modules. In these panels solar cells convert sunlight into electricity. Converters supply power to the grid. Under 'Data panels' the input parameters are the data relating to the roof and solar panels. The gross roof area is the area of the roof where solar panels can be placed. The details of the panels can be found at the suppliers and the technical sheets. The losses that are to be charged, are losses to shade, losses of direction, aging losses, maintenance losses and inverter losses. The losses to shade and losses caused by the direction may be reduced by a good choice of place on the roof. Panels facing south bring more energy than panels facing north. The aging losses are an annual energy loss. After 20 years the panels convert less sunlight into electricity than in their first year. The maintenance losses are dependent on external circumstances such as the weather. The losses of the inverter are mentioned on the technical sheet of the inverter.

The investment costs depend on the net roof area. The price per m² of the panels is obtained from suppliers. Installation costs are divided into a fixed price and a variable price.

Unlike the other measures, solar panels yield energy. For a more realistic representation of the energy yield, the aging losses are taken into account.

3.9. Cost-benefit summary

On this worksheet the payback and discounted payback period of each measure is shown in both frames, see Table 1, and on a figure, see Figure 1. In this framework, the total energy savings, the total cash savings, the total investment cost and the premiums associated with any measure are shown. The data on the graph takes into account the energy price increases and the discount rate.

Measure	
investmentcost	€
gas energy savings	kWh
electricity energy savings	kWh
gas money savings	€
electricity money savings	€
premium	€
payback time	year
discounted payback time	year
payback time premium	year
discounted payback time premium	year

Table 1: Result measure



Figure 1: Payback period measures

In a summary table, see Table 2, all measures are shown with their investment costs, their savings or yields, their payback time without and with premiums. In the first column (On/off), the number 0 or 1 has to be entered. When entering 1, the measure is selected in the combination and the corresponding values are shown. When entering 0 the measure is not included and the values remain 0. Below this frame a figure, see Figure 2, is displayed with the discounted payback period of the selected combination of the measures taking into account the energy price increases.

Summary cost-benefit analysis										
On (1)	Investment	İ	Sav	rings/yields	PBT (year)			PBT with	premiums (year)
/off(0)	Measure	Costs (€)	Gas (€)	Electricity (€)	PBT	D-PBT	Premiums (€)	Annual premiums (€)	PBT	D-PBT
0 or 1	Roof insulation									
0 or 1	Wall insulation									
0 or 1	Floor insulation									
0 or 1	Replacement windows									
0 or 1	Placing awnings									
0 or 1	Replacement boiler									
0 or 1	Relighting									
0 or 1	Photovoltaic cells									
Total investment			Total	savings/incomes			total premium			

 Table 2: Summary cost-benefit analysis





4 Result case study

The mathematical model is used to evaluate energy-saving measures. A case study is applied to test the model. Relighting is not dealt with in the model because of not sufficient information on the existing lighting. The data are extracted from the building plans, a study by Electrabel in 2002 and the annual report of 2009 prepared by Electrabel.

4.1. Building information

The week program is from Monday to Friday from 6 am to 19h. The number of opening hours is 13 hours per day and the number of working days is 5 days a week. The heating period is 30 weeks and the cooling period is 12 weeks. These numbers are determined by the users of the building. The offices have large windows facing south. The existing glazing is double glazing. The building is heated by gas boilers with an efficiency of 83%. The network operator is Eandis.

The average outdoor temperature during winter is 5°C. The outdoor temperature during summer is 30°C. The comfort temperature is set at 22°C. At night and on weekends, the indoor temperature is set at 15° C.

The price of electricity [12] amounts 21 eurocents per kWh during peak hours and 16 eurocents per kWh during off-peak hours. The cost of gas [13] is 5,78 eurocents per kWh. The prices are standard prices of Electrabel. The price of electricity has risen 4,28% in 2010 compared to 2009 according to data from VREG. The gas price has risen 7,74% in 2010 compared to 2009 [14]. The discount rate is set at 4,86% [15].

4.2. Measures

• Building envelope insulation

The district house consists of several connected dwellings. The part being treated, consists of two buildings. One building has a fully pitched roof and the other building consists of a pitched roof and a flat roof. The total area of the pitched roof is 258 m². The surface of the flat roof is 1.073 m². The current

U-value of the pitched roof is 5,45 W/m²K. Glass wool insulation with a thickness of 12 cm and a λ -value of 0,035 W/mK will be applied. This corresponds to an R-value of 3 m²K/W which is necessary to obtain the premium of the system operator. The flat roof has a U-value of 0,47 W/m²K. Insulation is already present in the flat roof. The new U-value of the pitched roof is 0,31 W/m²K.

The price for the investment is 28,19 euro/m² [16]. The total investment is 7.273,79 euro. The total annual energy saving is 84.869,89 kWh. With a boiler efficiency of 83% and a gas price of 5,78 eurocents/kWh, the total cash saving for roof insulation is 5.910,22 euro per year. The network operator gives a premium of 4 euro/m² and the city of Antwerp gives 6 euro/m². The conventional payback time is 1,2 years. The payback period is less than 1 year if the premiums are charged.

The total facade area is 771,4 m². The wall surface without the transparent components is 429,52 m². The walls of district house consist of cavity walls. According to the study by Electrabel in 2002, the U-value is 1,76 W/m²K. This corresponds to a cavity composed of an inner wall with a thickness of 19 cm and an outer wall with a thickness of 9 cm and an uninsulated cavity of 5cm. For the renovation is assumed that PUR insulation will be sprayed into the wall. The insulation thickness is 5 cm and the λ -value is 0,028 W/mK. The new U-value is 0,42 W/m²K.

The price for injecting polyurethane insulation in the cavity is estimated at 25 euro/m². The total investment cost is 10.738 euros. The energy saving is achieved by reducing the heat loss during the heating period. The energy saving is 36.732,46 kWh per year. With a boiler efficiency of 83% and a gas price of 5,78 cents/kWh, the total annual cash saving for insulation is 2558,00 euro. The network operator provides a premium of 4 euro/m². The total premium is 1.718,12 euro. The conventional payback time is 4,2 years without taking into account the premium and 3,5 years with taking into account the premium.

The floor area is 1536,5 m². The current Uvalue is 1 W/m²K. To meet the requirements of the energy performance regulation, the new Uvalue has to be 0,4 W/m²K. The insulation is made from hard polyurethane panels of 40 mm and a λ -value of 0,024 mK/W. The new U-value is 0,375 W/m²K.

The price for the polyurethane panels is 19,12 euro/m². The total investment cost is 29.374,81 euro. Energy is saved due to less heat loss during the heating period. The energy saving is 61.508,02 kWh per year. The total annual cash saving is 2558,00 euro. The conventional payback time is just under 7 years.

• Transparent components

The windows consist of an aluminium window profile and ordinary double glazing. This gives a current U-value of 3,2 W/m²K. The windows will be replaced by a plastic window profile -PVC - and high-efficiency glazing. The new U-value is 1,4 W/m²K. The glass as well as the profiles will be replaced. The total window area is 341,88 m².

The price for high-efficiency glazing is 130 euro/m². The price for PVC window profiles is 250 euro/m² [17]. The investment cost for the windows is 129.912,50 euro. There will be less heat loss during the heating period. The total gas saving is 39.414,77 kWh per year which means an annual money saving of 2.744,79 euro. The network operator Eandis gives a premium of 10 euro/m² when replacing double glazing in high-efficiency glazing. The total premium is 3418,75 euro. The conventional payback time is about 47 years. The life span of windows should be taken into account. If a good choice is made, the return on investment can be achieved during the life span of the material. It is also important in determining the profitability of a measure.

In the current situation there is no sunscreen available. The F_c -factor is 1. New outdoor blinds with a Fc-factor of 0,3 will be installed. The g-value of the current situation is 0,8. The new g-value is 0,18. By using blinds in the summer, the radiation is limited. The space is less warm and thus less cooling is needed. The electricity saving is 16.119,75 kWh per year. This gives a money saving of 3385,15 euro per year. The price of the blinds is 176,30 euro/m². Multiplied by the window surface, the investment cost is 60.271,54 euro. The conventional payback is 17,8 years.

• Replacement of the boiler

On the technical level there are two boilers each with a boiler efficiency of 83%. The boilers were installed in 1990. Since then they have not be changed. Each boiler has a capacity of 144 kW. For the new state two condensing boilers are fitted with an efficiency of 96%. The new boilers will be obtained from the same manufacturer as the existing boilers. There is opted for condensing boilers, because then the system operator and the Flemish Government give financial aid. The cost of a boiler is 13.440,68 euro. The placement cost is 2688,14 euro for both boilers. The total investment is 29.569,50 euro. The average gas consumption from 2007 to 2009 amounts to 2.029.494.88 kWh. The difference in efficiency is 0,135. The energy saving is 274.827,43 kWh per year. The annual cash saving is 15.885,03 euro.

The network operator provides a premium of 9 per kWth with a minimum of 125 euro and a maximum of 5400 euro. Without the premium, the conventional payback time is 1,9 years and with the premium the payback time is 1,5 years. Gas consumption will decrease with 13,5%.

Based on the transmission losses the boiler capacity is under-dimensioned. The necessary current capacity is 302,06 kW. The installed capacity is 288kW. Since this is too little and this model does not take into account the ventilation losses and the infiltration losses, it is recommend to apply the measures to the building envelope. This reduces the transmission losses and the necessary capacity of the boiler [18].

• Photovoltaic cells

First, the surface area available for solar panels is determined. The area is 100 m² for the district house. A PV system is provided consisting of hybrid solar cells with a lifespan of 25 years. The surface of one solar panel is 1,26 m². 79 panels can be placed. The peak power of the cells is 240 W_p/m^2 . The performance guaranteed after 10 years is 90%. The loss by the aging effects is 1% per year. The loss due to the direction is 3%. The panels are facing south and the slope is approximately 35 degrees. Maintenance losses are estimated at 0.05%. The loss by shading is estimated at 8%. Two inverters with a yield of 97,5% are chosen. The loss by the inverters is 2,5%.

The cost of solar panels is estimated at 970 euro/m². The maintenance cost is 966,18 euro. The total investment cost is 97.584,35 euro. The first year the yield is 27.779,01 kWh. By the age loss of 1% per year, the total yield after 25 years is 611.781,45 kWh. The average annual yield is than 24.471,26 kWh. This gives an annual cash yield of 5.138,96 euro. Green energy certificates worth 330 euro per 1.000 kWh of electricity generated, will be presented by the Flemish Government for a period of 20 years. The total premium exceeds 165.330 euro. This represents an annual premium of 8.065,20 euro. The conventional payback time is 19 years without taking into account the premium. With the premium the payback time is only 7,4 years. With the contributions this measure is cost-effective.

• Summary

A summary of the measures with their investment cost, the annual savings and the total netto income after 20 years without and

with energy price increases are given in Table 3. The total netto income is the total saving after 20 years minus the investment cost. The price increase of gas and electricity has a positive impact on the payback time and on the income after 20 years. Figure 3 shows the discounted payback period for each measure taking into account the energy price increases.

Placing blinds and installing photovoltaic cells are viable due to the price increase. The replacement of windows, however, remains unprofitable. Roof insulation has the lowest payback time. Replacing the boiler has the highest income after 20 years and the payback period is very low. Both measures are certainly advisable. The placement of insulation in the cavity wall and the application of floor insulation are cost-effective.

Placing blinds also affects the thermal comfort of the users. The job performance is lower with a poor thermal comfort. Improved working conditions lead to increased productivity. Economically, this is also important in addition to saving energy [19]. Placing blinds should not be based solely on the payback period. The improvement of thermal comfort should also be taken into account.

Measure	Investment (€)	Annual savings (€)	Income after 20 years without energy price increase (€)	Income after 20 years with energy price increase (€)
roof insulation	7.273,79	5.910,22	68.031,75	100.994,42
wall insulation	10.738,25	2.558,00	21.854,67	36.121,22
floor insulation	29.374,81	4.283,33	25.201,61	49.090,75
replacement windows	129.912,50	2.744,79	-94.939,55	-79.631,22
placing awnings	60.271,54	3.385,15	-17.139,39	25.382,83
replacement				
boiler	29.569,50	15.885,03	172.830,96	261.425,50
photovoltaic cells	97.584,35	5.188,96	-32.105,79	32.446,84

Table 3: Summary measures district house Antwerp



Figure 3: Payback period measures district house Antwerp

In Table 4 a summary is given of each measure taking into account the financial aid. The implementation of roof insulation and the replacement of the boiler are still advisable. The installation of floor ans wall insulation are cost-effective. Replacing the windows remain not-advisable even with premiums. Installing photovoltaic cells on the other hand is recommended. During 20 years 8065,20 euro is annually produced by the green energy certificates. The financial measures are important in areas of renewable energy. When renovating the building envelope, the premiums of the operator does not have much influence on the payback period. It may provide a motivation for applying the renovation measures. Figure 4 shows the discounted payback period of measures taking into account the energy price increases and the premiums.

Measure	Investment (€)	Annual savings (€)	Premiums (€)	Income after 20 years without energy price increase (ε)	Income after 20 years with energy price increase (€)
roof insulation	7.273,79	5.910,22	2.580,00	70.611,75	103.574,42
wall insulation	10.738,25	2.558,00	1.718,12	23.572,79	37.839,34
floor insulation	29.374,81	4.283,33	/	25.201,61	49.090,75
replacement windows	129.912,50	2.744,79	3.418,75	-91.520,80	-76.212,47
placing awnings	60.271,54	3.385,15	/	-17.139,39	25.382,83
replacement boiler	29.569,50	15.885,03	5.400,00	178.230,96	266.825,50
photovoltaic cells	97.584,35	5.188,96	8.065,20	70.657,67	135.210,30

Table 4: Summary measures with premiums district house Antwerp



Figure 4: Payback period measures with premiums district house Antwerp

4.3. Combinations of measures

When all the measures are selected, the total investment cost is 364.724,73 euro. The total cash saving is 39.905,47 euro. Figure 5 shows the discounted payback time of this combination with and without taking into account the premiums. This figure shows that the payback period without contributions is approximately 10,5 years. After 20 years the income is 425.830,33 euro. With contributions the payback period is approximately 8,5 years. In this case, the income is 541.710,66 euro. The combination is advisable.



Figure 5: Payback period combination of all measures district house Antwerp

The economically most profitable combination is the combination of applying insulation to the building envelope and the replacement of the current boiler. This combination has the lowest investment cost and is 76.956,35 euro. The annual cash saving is 28.636,57 euro. Figure 6 shows that the discounted payback period is about 3 years. The financial aid has little effect on the payback time. The income after 20 years is 447.631,88 euro. The current gas consumption will be reduced by 24,5%.



Figure 6: Payback period economically most profitable combination district house Antwerp

5 Conclusion

The mathematical model is based on an existing model prepared by Dotsenko V. [1]. This existing model offered no overview and was not user friendly. The new model is simplified compared to the previous calculation by setting the measures each on a separate tab. The fields to be filled, are colored gray. This makes the structure more clearly and keeps an overview for the user.

The calculations were adjusted and improved. A new selection of the most useful measures were made. In the future omitted measures can added complete the be to model. A further innovation is that the transmission loss through the building envelope can be calculated. Based on the transmission loss the boiler capacity is calculated. The investment in replacing the current boiler is dependent on that capacity. The lower the capacity, the lower the purchase cost. The boiler capacity should be well adjusted to the needs of the building. In this model, only the transmission loss is calculated. Ventilation and infiltration losses were not integrated in this model.

The discount rate and the evolution of the energy prices are future values and difficult to be predicted. Their impact, however, is big on the results. The price of gas and electricity have a positive impact on the payback period. When the prices rise each year, the cash savings will rise. On the other hand if the prices drop, the decrease has a negative influence.

The financial aid that is distributed over several years, has a major impact on the payback time. Because the green energy certificates are awarded over a period of 20 years, the installation of photovoltaic cells is viable.

In the renewed computational model, the financial support for the region of Flanders is integrated. This may be extended in the future to Belgium.

Replacement of double glazing in highperformance glass is economically not viable. The investment cost is very high and the annual energy saving is low. Insulating the building envelope - except the replacement of the windows - in conjunction with replacing the current boiler is economically the most profitable combination. The investment is low and the annual cash savings are large. Energy consumption decreases about 24,5%. The financial aid has no significant impact.

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