Evaluation of financial aspects and energy performance indicators of residential real estate in the Netherlands


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Abstract
The introduction of the concept of sustainable building in the construction industry has led to different measures to reduce the environmental impact of building objects in the past decades. Because the built environment accounts for more than 40% of the total energy consumption in Europe (EC, 2002), energy saving techniques receive much attention. In the Netherlands the overall energy performance of houses can be calculated by three different indicators. In order to compare these Energy Performance Indicators (EPI) seven residential objects are evaluated. This study reflects on the financial efficiency of energy saving measures, techniques or technologies by introducing a new variable for the gains related to the value increase of houses. It is found that the energy performance of houses has gradually improved during the last century. The results of the financial analysis point out that the return on investments is high in Dutch real estate.

Introduction
This paper focuses on the energy performance of existing real estate in the Dutch residential sector. Especially older existing building stock, consisting of more than six million objects, offers many possibilities to reduce the energy use for example. Houses from before 1945 use on average 31% more natural gas than houses from the period 2000 to 2004 (SenterNovem, 2006). The increase in price of natural gas – the most common fuel for heating real estate in The Netherlands – has already led to the application of energy saving measures within the existing building stock. However, little has been written about the possibilities to come to a better energy performance in a financially efficient way. Therefore, in this paper three energy performance indicators and the financial aspects of energy saving will be considered in the framework of a case study. The goal was to develop a methodology that can be used to energetically and financially assess energy saving measures that better expresses the actual developments in the value of residential real estate.

Energy performance indicators for residential real estate
In the Netherlands three methods are in use to calculate the energy performance of residential real estate: EPC, EI\textsubscript{old}, and EI\textsubscript{new}.

1) Since the end of 1995 new residential building stock has to meet the so called Energy Performance Coefficient (EPC). The EPC is the result of an integral energetic assessment of a building and its installations made during the design phase. The EPC for new residential real estate objects is calculated as follows (NNI, 2004):

\[
EPC = \frac{Q_{\text{total;EPC}}}{330 A_{gr;EPC}} + \frac{1}{A_{ts;EPC}} C_{EPC}
\]

In which:
\(Q_{\text{total;EPC}}\) = yearly energy use of a house (MJ)
\(A_{gr;EPC}\) = total ground surface (m\(^2\))
\(A_{ts;EPC}\) = total thermal transmission surface (m\(^2\))
\(C_{EPC}\) = correction factor (-)

2) The Energy Index (EI\textsubscript{old}) is part of the Energy Performance Advice (EPA) procedure and calculates the energy performance of existing houses. In the EPA method the EI\textsubscript{old} is calculated by (Hoiting et al., 2004):

\[
EI_{\text{old}} = \frac{Q_{\text{total;EI old}}}{56 A_{ts;EI old}^2} + \frac{0.13}{A_{gr;EI old}}
\]

In which:
\(Q_{\text{total;EI old}}\) = yearly energy use of a house (MJ)
\(A_{gr;EI old}\) = total ground surface (m\(^2\))
\(A_{ts;EI old}\) = total thermal transmission surface (m\(^2\))

3) The implementation of the European Energy Performance Building Directive (EPBD) in the Netherlands made it necessary to develop a new Energy Index (EI\textsubscript{new}), which enables the certification of both new and existing buildings. The Dutch method uses this equation to calculate EI\textsubscript{new} (Blankestijn et al., 2006):

\[
EI_{\text{new}} = \frac{Q_{\text{total;EI new}}}{155 A_{gr;EI new}^2} + \frac{106 A_{ts;EI new}}{9560}
\]

In which:
\(Q_{\text{total;EI new}}\) = yearly energy use of a house (MJ)
\(A_{gr;EI new}\) = total ground surface (m\(^2\))
\(A_{ts;EI new}\) = total thermal transmission surface (m\(^2\))
Financial performance of energy saving techniques
The financial benefits of energy saving techniques can traditionally be calculated on the basis of the electricity price (€/kWh) and the natural gas price (€/m³). Also Return On Investment (ROI) methodologies can be applied. When the externalities, demolition costs and recycling costs of buildings or measures are incorporated in the calculations, one often speaks from Life Cycle Costing (LCC) methods (Gluch & Baumann, 2004). The total gains of a project can be calculated by using the Net Present Value, that corrects the value of the gains in a specific year for the inflation and/or interest rate.

A new additional variable for the yearly gains of energy saving measures is presented in the form of the value increase of the real estate object in which the measure is installed in Eq. (4).

\[
G_a = q_{e,a} c_{e,a} + q_{g,a} c_{g,a} \frac{V_a}{c_p} \frac{c_i}{d} 
\]

In which:
- \(\Delta q_{e,a}\) = change in electric energy use (kWh/year)
- \(c_{e,a}\) = electric energy price (€/kWh)
- \(\Delta q_{g,a}\) = change in natural gas consumption (m³/year)
- \(c_{g,a}\) = natural gas price (€/m³)
- \(\Delta V_a\) = change in value of real estate object (€/year)
- \(c_p\) = initial investment costs of energy saving measure (€)
- \(c_i\) = initial costs of installing energy saving measure (€)
- \(d\) = total depreciation on energy saving measure (€)
- \(V_a\) = value of house when installing measure (€)

The value increase of real estate offers opportunities to assign financial benefits to separate components of the buildings. The yearly financial benefits (\(G_a\)) of energy saving techniques will in that case increase from the point of view that the value of the building is the sum of its parts.

Results case study on energy performance indicators
The cases are chosen in such a way that they represent approximately hundred years of residential real estate development. Cavity walls, double glazing, insulation, and efficient natural gas boilers are some of the most important breakthroughs that were implemented. Table 1 shows data for seven case objects built in the period 1913-1992. The EPC and the EI_{old} computed by two programs (NNI, 2005, SenterNovem, 2003).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Object 1</th>
<th>Object 2</th>
<th>Object 3</th>
<th>Object 4</th>
<th>Object 5</th>
<th>Object 6</th>
<th>Object 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy for heating (MJ)</td>
<td>144,314</td>
<td>69,451</td>
<td>118,491</td>
<td>105,514</td>
<td>67,941</td>
<td>38,370</td>
<td>40,485</td>
</tr>
<tr>
<td>Additional energy (MJ)</td>
<td>2,935</td>
<td>4,909</td>
<td>3,397</td>
<td>3,489</td>
<td>4,098</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Heating water (MJ)</td>
<td>15,759</td>
<td>23,843</td>
<td>24,419</td>
<td>35,129</td>
<td>53,117</td>
<td>12,592</td>
<td>14,663</td>
</tr>
<tr>
<td>Energy for fans (MJ)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3,245</td>
<td>4,011</td>
</tr>
<tr>
<td>Energy for lighting (MJ)</td>
<td>7,051</td>
<td>5,796</td>
<td>8,182</td>
<td>8,390</td>
<td>9,871</td>
<td>5,666</td>
<td>7,004</td>
</tr>
<tr>
<td>Summer comfort (MJ)</td>
<td>1,070</td>
<td>1,230</td>
<td>1,616</td>
<td>4,284</td>
<td>1,481</td>
<td>1,558</td>
<td>4,745</td>
</tr>
<tr>
<td>Q_{total}; EPC (MJ)</td>
<td>171,129</td>
<td>105,229</td>
<td>156,105</td>
<td>156,806</td>
<td>335,508</td>
<td>61,431</td>
<td>70,908</td>
</tr>
<tr>
<td>Q_{total}; permitted (MJ)</td>
<td>51,583</td>
<td>40,829</td>
<td>57,396</td>
<td>59,836</td>
<td>63,419</td>
<td>38,161</td>
<td>49,369</td>
</tr>
<tr>
<td>EPC (-)</td>
<td>2.66</td>
<td>2.07</td>
<td>2.18</td>
<td>2.10</td>
<td>1.73</td>
<td>1.29</td>
<td>1.15</td>
</tr>
<tr>
<td>Energy for heating (MJ)</td>
<td>129,330</td>
<td>69,827</td>
<td>101,566</td>
<td>91,777</td>
<td>74,504</td>
<td>33,176</td>
<td>30,737</td>
</tr>
<tr>
<td>Additional energy (MJ)</td>
<td>1,138</td>
<td>814</td>
<td>1,242</td>
<td>1,260</td>
<td>1,397</td>
<td>1,811</td>
<td>2,110</td>
</tr>
<tr>
<td>Heating water (MJ)</td>
<td>18,509</td>
<td>16,505</td>
<td>15,402</td>
<td>13,932</td>
<td>12,562</td>
<td>19,478</td>
<td>24,289</td>
</tr>
<tr>
<td>Energy for lighting (MJ)</td>
<td>2,700</td>
<td>2,221</td>
<td>3,332</td>
<td>3,215</td>
<td>3,776</td>
<td>2,167</td>
<td>2,682</td>
</tr>
<tr>
<td>Q_{total}; EI_{old} (MJ)</td>
<td>151,677</td>
<td>89,366</td>
<td>121,342</td>
<td>110,184</td>
<td>92,240</td>
<td>56,632</td>
<td>59,818</td>
</tr>
<tr>
<td>EI_{old} (-)</td>
<td>1.11</td>
<td>0.95</td>
<td>0.95</td>
<td>0.86</td>
<td>0.84</td>
<td>0.85</td>
<td>0.62</td>
</tr>
<tr>
<td>Period of time</td>
<td>4-5-2006</td>
<td>6-7-2006</td>
<td>9-22-2004</td>
<td>6-1-2004</td>
<td>3-15-2005</td>
<td>3-4-2006</td>
<td>7-6-2005</td>
</tr>
<tr>
<td>Natural gas consumption (m³)</td>
<td>850</td>
<td>1,596</td>
<td>2,170</td>
<td>2,021</td>
<td>1,216</td>
<td>672</td>
<td>1,000</td>
</tr>
<tr>
<td>Electric energy use (kWh)</td>
<td>3,285</td>
<td>3,713</td>
<td>3,351</td>
<td>3,761</td>
<td>3,301</td>
<td>2,513</td>
<td>1,586</td>
</tr>
<tr>
<td>Q_{total}; Actual (MJ) period</td>
<td>40,225</td>
<td>66,689</td>
<td>84,563</td>
<td>81,061</td>
<td>52,510</td>
<td>31,498</td>
<td>39,120</td>
</tr>
<tr>
<td>Q_{total}; Actual (MJ) annual</td>
<td>124,406</td>
<td>67,241</td>
<td>84,563</td>
<td>81,061</td>
<td>53,989</td>
<td>28,317</td>
<td>not known</td>
</tr>
</tbody>
</table>

The EPC values range from 1.15 for the youngest house to 2.66 for the oldest house. Values of the EPC are higher for older objects with exception of case object 2. Thanks to the high performance glazing and a better isolated extension of the building at the rear side, this case object has an EPC of 2.07.

The EI_{old} values range from 0.62 for the case study object of 1992 to 1.11 for the case study object of 1913. The values of the EI_{old} do not follow the same sequence in energy performance per object as the values of the EPC. Especially the additional energy use and the energy needed for heating water influence the performance of the last two objects, which are connected to a district heating system. Although there is a signif-
There is not significant difference between the EPC of object 4, 5, and 6, their specific EI\text{old} of respectively 0.86, 0.84, and 0.85 are almost the same. The energy needed for heating water for house number 6 is estimated by the program to be much higher than for house number 4 and 5, because of the use of district heating.

The same aspect can also be noticed for object 2 and 3, where a significant difference in the results of the EPC transforms into equal EI\text{old} of 0.95. In this case the different definitions on the thermal surfaces for the EPC and EI\text{old} have resulted in other proportional relations.

In the nearby future the energy performance of houses will be expressed by Eq. (3). Making the assumption that $Q_{\text{total;EI\text{new}}} = Q_{\text{total;EPC}}$ and the calculation of the surfaces of the floor and building shell remains the same as within the EPC-method, then the results on EI\text{new} equal the values shown in Figure 1.

By using $Q_{\text{total;actual}}$ (given by Table 1) instead of the calculated values on the primary energy consumption, the actual performance of the house and its inhabitants can be reviewed. Figure 2 shows that the younger the building the better the EI\text{old} of the building and inhabitants.

**Results on financial analyses**

It may be clear that the financial benefits of energy saving techniques can be calculated more exactly after application than before application. This is the reason for using a set of existing houses in the case study. To gain insights in the fluctuations of the most important variables regarding energy saving investments, data on inflation, interest, house prices, natural gas prices, and electric energy prices of the past twenty years was used of Statistics Netherlands (http://www.cbs.nl) and the national land registry (http://www.kadaster.nl). This makes it possible to reflect on the benefits and costs of energy saving measures by using two examples.

1) At the beginning of 1996 object 2 was extended by 16.4 m$^2$. Although the main reason was to gain space for the inhabitants, the improvement of thermal comfort was an important side effect. With exception of the ground floor, the thermal resistance was significantly improved. The EPC was reduced from 2.85 to 2.07. The reduction on natural gas consumption is estimated to be 482 m$^3$ annually and the increase in electric energy use was theoretically 522 kWh per year. The investment costs of the project were €9,100.- in 1996. At this moment the value of the house is estimated at €118,000.-. The costs and benefits of this measure are visualised in Figure 3. Although the extension of the house was not initiated to lower the energy costs, it is shown that the gains of the lower natural gas consumption rose to almost €1,500.- in nine years time. The overall benefits surpassed the costs after 2002.

2) Roof insulation was installed in object 5 at the end of 1991. This measure focuses mainly on energy saving. The EPC was lowered from 1.90 to 1.73. The reduction on natural gas consumption is estimated to be 416 m$^3$ per year and the increase in...
electric energy use in the category ‘summer comfort’ is 41 kWh per year. The initial investment costs were 1,460.-, compensated by 438.- by a subsidy on thermal insulation of the energy company. The value of the house was at the beginning of 1992 84,900.-. Nowadays, the market value is 324,000.-, but this is only for a small part the result of the installed roof insulation. Figure 4 shows the costs and benefits of the installed roof insulation. In this case the benefits derived from saving energy account for a large part of the total benefits. The gains derived from the increasing value of the house seem to be of less importance than within the case of the extension of object 2. However, as long as house prices are increasing the payback period of energy saving measures will be shortened. From a traditional energetic perspective the insulation had a payback period of ten years. From the new perspective it paid itself back within half the time.

Conclusions
The energy analysis of the case objects shows that the energy performance of new houses is in general better than the energy performance of old houses. The forecasted energy performance expressed by the EPI's differs more from the actual total energy use of the object when this object is younger. In all cases the actual energy use was lower than the theoretical energy use derived from the calculations. It is possible to make an energetic assessment of the case objects by using the three EPI's. However, it is necessary to reflect on the actual energy use of the object and its owners.

The financial formula introduced a new variable on the financial gains of energy saving measures, that assigns the general value increase of houses in the Netherlands partially to the installed measure. When the variable is included, the payback period of energy saving measures or improvements of the energy performance rates can be significantly reduced as long as the value of residential real estate increases. When energy saving is a side effect of the applied measure, the introduced variable on the increasing value of real estate will contribute for a large part to the total gains.

The representativeness of the research will be further improved by adding extra case objects and by including more diversity and a larger quantity of energy saving measures to give more insights in the financial and energetic appreciation of energy saving measures.

The calculation of the ROI on energy saving measures traditionally involves the direct annual benefits on lowering the electric energy use and natural gas consumption. The indirect benefits derived from the increasing value of real estate can only be obtained by the owner when the house is sold. More insights are necessary in real estate development processes to assign these indirect benefits to stakeholders that bear the investment costs.

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