Session 6.9: Transforming Green Market – Green Economics (2)

Economic and Sensitivity Analysis of Net Zero Energy Refurbishment of Terraced Houses

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ABSTRACT

Post-war terraced houses, built en masse for the European middle-class, remain a major consumer of energy, significantly affecting the performance and quality of the residential stock. Prêt-à-Loger is a net zero energy refurbishment (NZER) concept addressing 1.4 million post-war Dutch terraced houses and possibly some other 30.6 million spread throughout North-Western Europe. By applying an integrated external renovation system (called “the skin”), the house becomes energy neutral while at the same time the living quality and the durability of the house are improved, and extra space is added. This non-invasive renovation project competed at the Solar Decathlon Europe 2014, winning five prizes, among which the first in sustainability. Despite the easy and fast applicability, the financial aspect still presents a serious barrier for large-scale implementation of this and other energy neutral renovation concepts.

The research summarised in this paper firstly identifies the economic factors that can boost the investment in energy neutral refurbishments, on the basis of interactions with public and local authorities, private companies, research institutes and end-users. Secondly, it studies the economic potential of the NZER and the relative importance of the identified factors with Monte Carlo simulations. Different cases are considered to address the situation of single homeowners as well as housing associations needing to refurbish multiple dwellings.

The increase of total rent after renovation for the housing association case and the energy prices for the homeowner case are the most influential factors together with the capital expenditures; the maintenance cost and increase of property value are also relevant elements that can be affected by the right design choices. For the Prêt-à-Loger solution, for instance, a higher increase of property value is registered in comparison to other energy neutral renovation concepts. These findings provide an important support and inspiration for designers and decision makers operating in the field of deep energy retrofit.

Keywords: net zero energy refurbishment, green economics, Monte Carlo simulations

1. INTRODUCTION

Energy use in buildings represents about 40% of Europe’s total energy consumption and CO2 emission (European Commission, 2008). About 70% of buildings are over 30 years old and about 35% are more than 50 years old (Poel et al., 2007), while less than 1% of new constructions is added in any given year. Given the fact that buildings are long-term assets, designed to function for at least 50 years, we can foresee that 75 - 90% of those standing today will remain in use in 2050. These same buildings will form the means to achieve the required 80% reduced energy consumption compared to the 2008 levels (European Commission, 2010). Aiming at high standards of energy efficiency is essential for residential buildings, since they account for 70% of the building floor space (Itard et al., 2008). Within the residential typologies, the post-war terraced houses remain a major consumer of energy, significantly affecting the performance and quality of the residential stock. Around a quarter of Dutch housing consists of terraced houses built between 1946 and 1975. They have a poor energy performance, experience moist and mould problems and offer too little living space by modern-day standards (van den Dobbelsteen et al., 2015).

Prêt-à-Loger is a net zero energy refurbishment (NZER) concept addressing 1.4 million post-war Dutch terraced houses and possibly some other 30.6 million spread throughout North-Western Europe (Bogers et al., 2014). By applying an integrated external renovation system (called “the skin”), the house becomes energy neutral while at...
the same time the living quality and the durability of the house are improved, and extra space is added. This non-invasive renovation project competed at the Solar Decathlon Europe 2014, winning five prizes, among which the first in sustainability. Despite the easy and fast applicability, the financial aspect still presents a serious barrier for large-scale implementation of this and others energy neutral renovation concepts.

Over the past few years, the government in The Netherlands has stimulated the development of so-called "Nul-op-de-meter" ("zero-on-the-meter", i.e. net zero energy) renovation concepts for terraced houses. The organisation coordinating this initiative, the Stroomversnelling, proposed a target price for these renovations of €45,000 for the private sector, based on savings of energy costs. Because of subsidies related to this fixed target-price, cost benefits on energy savings are often taken as a main criterion by builders to decide which renovation measures will be taken. However, based on current construction methods, builders are still unable to create a renovation achieving both the energy reduction as well as the target price.

In this paper, all financial factors for energy neutral refurbishment of terraced houses are explored. The economic potentials of the NZER and the relative importance of the identified financial factors are then analysed with Monte Carlo simulations (MCS). These allow for a sensitivity analysis of the considered variables, showing the relative impact they have on the value of the refurbishment. Awareness of the relevance of the economic factors can support decision-making and the design phase, which will help create feasible renovations.

2. METHODOLOGY

This section summarises firstly the renovation type considered, then the approach used to identify the financial factors, and lastly, the methodology adopted to perform the MCS.

2.1 Renovation type

For this analysis, the Prêt-à-Loger solution is considered. This is because such a renovation differs from other concepts present on the market, which are not believed to be financially attractive yet. Prêt-à-Loger achieves a higher increase in post-renovation property value, key factor to determine the business case. The issues addressed by the Prêt-à-Loger solution are high energy bills, moisture problems and lack of living space. To preserve the original house, the renovation is designed as a non-invasive construction. An outer skin allows the inhabitants to live in the house during the renovation (hence the name Prêt-à-Loger: ready to inhabit). The skin integrates a number of measures to make the house energy neutral: roof, cavity wall and crawlspace insulation, mechanical ventilation system with heat recovery and phase changing materials (PCMs) in combination with a greenhouse.

![Figure 1: Prêt-à-Loger climate design functioning in summer (left) and winter (right)](image)

A smart domotic system controls all installations in the house and provides information about its performance to inhabitants. The insulation, heat recovery and green roof are meant to reduce energy losses through the skin, while the greenhouse harvests the energy from the sun, producing electricity, hot water, and warm air, while also collecting rainwater, and producing food. In spring and autumn the greenhouse can be used as living space, during winter as a rough-climate winter garden buffer zone, and in summer it becomes an open covered terrace connecting the garden and the living room.
2.2 Financial factors

The financial factors were identified by means of interaction with public and local authorities, private companies, research institutes and end-users. The conditions created today by local subsidies and regulations for investments to take place were also considered.

2.3 Monte Carlo simulation

Monte Carlo simulation is a method to solve complex problems by varying parameters within statistical constraints. Each variable is assigned a range rather than a specific value, which allows carrying out analyses when variables bear a certain degree of uncertainty. The Excel application called Oracle Crystal Ball was used to perform the simulations. By defining variable inputs in terms of realistic range of possible values, Crystal Ball performs thousands of calculations, each time using a different randomly selected value based on a specific probability distribution function. In this case, a beta-PERT distribution was chosen as it allows giving a minimum, a most likely and a maximum value. The input variables and the related ranges are given in Table 1 and described in section 3.1. The Net Present Value (NPV) is chosen as output variable, being the most commonly used discriminator for the business attractiveness of a project. A sensitivity analysis on the NPV was performed to study the weight of the variables used as inputs in the model.

2.3.1 Cases

For the simulations, four energy neutral renovation cases are considered:

- Privately owned house with and without greenhouse addition;
- Rented house with and without greenhouse addition.

For each case, two sets of simulations were performed: one assuming realistic variable inputs as shown in Table 1, the other altering the mid value by plus 5% (maximum value) and minus 5% (minimum value) to test the effective influence of each variable independently from its actual uncertainty. All variables shared across the two cases, such as renovation costs or maintenance costs, were kept constant. This is a conservative assumption because when a housing association decides to renovate or maintain part of their buildings, it is likely to do it in bulk, achieving lower renovation costs per housing unit with respect to a single homeowner.

To avoid repetition in the methodology and results sections, the most relevant input variables are explained in section 3.1.

3. RESULTS

3.1 Financial factors

The relevant financial factors identified in the first part of the research are explained in this section as input variables. These are part of the result but also of the methodology adopted for the MCS.

Renovation costs: The reference minimum value for the renovation costs is related to the one suggested by the Stroomversnelling, which takes into account an average Dutch energy expense of €175 per month, expressed in a mortgage that adds up to €45,000 over a 30-year period. Construction companies are striving to get close to this target, but still cannot achieve it. A price of €80,000 was chosen as mid value for the renovation with greenhouse (€60,000 for the case without greenhouse) as this is the closest price for energy neutral renovation of terraced houses that construction companies have achieved so far. This price, however, is still hardly available for private homeowners, while it can be accessible to housing corporations refurbishing more dwellings simultaneously. €100,000 is about the price any (terraced house) household can find on the market, but it is considered not attractive enough.

Property value: The appraised value depends on the type of renovation and the specific location of the house and is normally estimated using previous evaluations or by comparing it to similar interventions. Various aspects, such as floor area and aesthetics, drive this increase of value. For NZER the value increase will also originate in part from the energy savings and changed maintenance requirements, although incorporating any kind of energy
intervention in real estate evaluation is a practice still in its infancy. The increase of property value can potentially contribute to the initial capital to finance the renovation. Dutch banks are allowed to provide a loan to value (LTV) of 106% for NZER opposed to a 102% LTV for normal mortgages. A real-estate evaluation of the Preß-a-Loger renovation done by ten different brokers estimated an increase in property value of €37,000 approximately (mainly because of the greenhouse in the backyard – circa 15 m² of additional surface), against the €5,000-10,000 estimated for the average energy neutral renovations that can be found on the market.

Mortgage: As mentioned before, banks can provide a mortgage with a loan to value up to 106% when the property undergoes a deep energy retrofit. Furthermore, Dutch legislation allows banks to provide an additional sum in the form of a mortgage potentially up to €27,000 for energy retrofit, on top of the loan to income. Finally, the Dutch government provides a partial refund on interest paid on housing mortgages (Belastingdienst, 2016).

Loan interest rate and duration: At present, Dutch banks require an interest rate of circa 2% for a fixed mortgage plan (Trading Economics, 2016). The values for the loan duration are chosen considering usual practice for loans (amount and years packages offered by banks) as well as the life span of installations needed for the NZER. The Dutch government refunds part of the interest paid on the mortgage for the first 30 years, and therefore a loan longer than 30 years would not be considered attractive for a house renovation. Thus this value is used as upper bound in the simulations.

Energy performance compensation: Under certain conditions, housing associations are allowed to charge residents with the so-called Energie Prestatie Vergoeding (EPV) (Energylinq, 2016). This energy performance compensation is a monthly fee that may be charged by the landlord to the tenant if the property meets certain energy efficiency standards. The EPV is the (new) part charged in addition to the rent and service charges. For this analysis the three possible EPV values of 1.0, 1.2 and 1.4 €/m²/month are applied (Coen and Stutvoet, 2015).

Rent increase: Similarly to the property value, the rent could also be increased within market and legislation limits. It should be noted however that with regards to affordability of social housing a rental increase for housing corporations might not be applicable. If the EPV is applied, energy performance cannot influence the increase of rent (Coen and Stutvoet, 2015). The pre-renovation rent value is taken from AEDES (2016).

Maintenance difference: New installations like PV panels, heat exchangers and heat pumps will introduce new maintenance costs. Over the course of a 30-year mortgage, these installations have to be replaced at least once. On the other hand, the renovation itself makes up for overdue maintenance. Furthermore, a smart design in combination with the right choice of materials could potentially reduce the cost of general maintenance. Maintenance costs are taken from AEDES (2016).

Future value: For simplicity, the future value of the variables used in the simulations is calculated using an average inflation rate (EUROSTAT, 2016b). The discount rate is assumed to be zero because investments from homeowners and housing associations are more for savings and energy performance than for economic returns.

Tax implications: The property tax in the Netherlands oscillates approximately between 0.075% and 0.250% of the market value of the property itself (Cijfer Nieuws, 2015). An increase in property value implies an increase in the property tax.

Energy bills: The calculation of the energy cost is a combination of the average consumption rate (Milieucentraal, 2016) and the average energy prices (EUROSTAT, 2016a).

3.2 Sensitivities

Table 1 shows the range used as input for the MCS, while Figure 2 and 3 show the NPV sensitivities for each case. The sensitivity analysis for the NPV is shown from Figures 2 and 3 for the housing association and homeowner cases, respectively. For almost all cases, the biggest impact on the NPV (43 to 65%) is given by the renovation cost. The revenue sources of increase of total rent (including the EPV, which is de facto an increase of rent) for the housing associations (17 to 30%) and energy bills for the homeowners (17 to 53%) also play an important role. Other variables such as the increase of property value (1 to 12%), the increase of maintenance (2 to 11%) and the loan interest rate (1 to 6%) have limited but non-negligible influence on the NPV of the renovation.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Low</th>
<th>Mid</th>
<th>High</th>
<th>Unit</th>
</tr>
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<tbody>
<tr>
<td>Renovation cost w/o greenhouse</td>
<td>40,000.00</td>
<td>60,000.00</td>
<td>80,000.00</td>
<td>€</td>
</tr>
<tr>
<td>Renovation cost w/ greenhouse</td>
<td>50,000.00</td>
<td>80,000.00</td>
<td>110,000.00</td>
<td>€</td>
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<td>Loan interest rate</td>
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<td>2.7</td>
<td>3.5</td>
<td>%/year</td>
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<td>Loan duration</td>
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<td>25</td>
<td>30</td>
<td>Year</td>
</tr>
<tr>
<td>Increase of m2 (only w/ greenhouse)</td>
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<td>7</td>
<td>20</td>
<td>m²</td>
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<tr>
<td>Increase of property value w/o greenhouse</td>
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<tr>
<td>Increase of property value w/ greenhouse</td>
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<td>27,000.00</td>
<td>40,000.00</td>
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</tr>
<tr>
<td>Increase of maintenance</td>
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<td>500.00</td>
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<td>€</td>
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<tr>
<td>Increase of rent</td>
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<tr>
<td>EPV</td>
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<td>14.40</td>
<td>16.80</td>
<td>€/year</td>
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<tr>
<td>Electricity cost</td>
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<td>€/year</td>
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<tr>
<td>Gas cost</td>
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<td>1,300.00</td>
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<td>€/year</td>
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<td>Tax refund on mortgage</td>
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<td>Inflation rate</td>
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<td>€/m²/year</td>
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</tbody>
</table>

Table 1: Variables and related ranges used for the Monte Carlo simulations.

![Figure 2: NPV sensitivity for the housing association case.](image2)

![Figure 3: NPV sensitivity for the homeowner case.](image3)
4. CONCLUSION

Reducing the cost for energy neutral refurbishment is a relevant and well-understood problem among the involved parties. The sensitivity analyses performed in this study indeed suggest that the initial investment is the financial factor that influences the business case the most. Housing associations have higher chances of improving their business case by accessing to lower prices when refurbishing a large number of dwellings. Increase of rent for the housing associations and reduced energy bills for the homeowners are the most influential sources of revenue when evaluating the feasibility of the NZER. For private homeowners, it is also beneficial to address aspects such as increase of property value, reduced financial risk, and improved living quality.

The Prêt-à-Loger concept has resulted in a higher increase of post-renovation building value, which makes the renovation attractive and more feasible (e.g. due to the higher loan to value). Energy cost abatements and fluctuations in the energy prices strongly influence the return of investment. It follows that improving the living comfort, which affects the increase of property value, becomes even more important when performing energy related upgrades, as this could reduce the dependence of the renovation on the energy market.

REFERENCES