Investigating the business case for a zero-energy refurbishment of residential buildings by applying a pre-fabricated façade module

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Abstract

The ambition to renovate the post-war building stock to an energy-neutral quality is getting a lot of attention from social housing corporations and other institutional owners, financial organizations, and users. An effective renovation plan must significantly improve the current energy performance of a target building towards nearly zero-energy levels. A number of facade solutions have been developed in recent years to solve the problem of large-scale renovation of housing. In the Netherlands, several exemplary renovation projects have the ambition to achieve an energy-neutral objective. One such project is the 2ndSkin Façade refurbishment approach for post-war residential buildings.

Nevertheless, the market intake of such renovation is currently very slow, as housing associations are reluctant to invest the increased cost of a zero-energy refurbishment, despite the energy savings and ongoing benefits for the occupants.

Within the framework of the research project 2ndSkin, this paper presents a prefabricated and integrated façade module that provides the possibility to improve energy performance up to zero-energy use, while ensuring minimum disturbance for the occupants, both during and after renovation. Based on the proposed integrated refurbishment solution, the study presents a financial breakdown of this case-study concept – including options to lower the initial investment – in order to outline a more attractive business case. Firstly, three design variations, ranging from a standard external insulation upgrade to a zero-energy renovation, are compared, using a range of positive, average, and negative values for a series of financial and economic parameters. Subsequently, the financial performance of a zero-energy renovation investment is calculated for three different apartment properties with diverse market values, to determine the circumstances that can justify an energy renovation investment.

The analysis showed that, for properties with an intermediate to high market value, the investment can be attractive under current economic and market conditions, but this attractiveness drops significantly for lower-cost properties such as social housing. The study objective is to develop both the technical solution and the related business case to support the implementation of zero-energy refurbishment strategies into diverse real estate market tiers of the residential building stock.

Introduction

The ambition to renovate the post-war building stock to an energy-neutral quality is getting a lot of attention from social housing corporations and other institutional owners, financial organizations and users. Studies have reported that huge potential for energy savings, improved health and comfort of the occupants', elimination of fuel poverty, and job creation lay in the technical upgrade of the existing buildings stock, but both rate and depth of renovation need to increase (BPIE 2011). The Energy Agreement for Sustainable Growth (SER 2013) (in accordance with the Energy Performance of Buildings Directive adopted by the European Union (DIRECTIVE 2010/31/EU) to improve the Dutch building stock to energy neutral) indicates that 300.000 dwellings have to be renovated in the Netherlands annually.

The post-war building stock, which represents 33 % of all residential buildings in the Netherlands (CBS 2015), is particularly relevant for refurbishment. Despite its varied mix of construction types, from traditional to modern, from low rise to high-rise, it has the common characteristic that the buildings were generally poorly insulated at the time of construction, and are therefore in need of renovation in the near future (Itard and Meijer 2008). Due to the circumstances of its development, the post-war housing stock has specific characteristics in terms of neighbourhood design, building construction, and common shortcomings. Moreover, being 50 years old, the building envelope has reached its original end-of-life, while the building's load-bearing structure is still generally sound (Andeweg, Brunoro et al. 2007).

An effective renovation plan has to significantly improve its current energy performance towards nearly zero-energy level. A number of facade solutions have been developed in recent years to solve the problem of large-scale renovation of housing (Sijpheer, Borsboom et al. 2016). In the Netherlands, front-running housing associations have the ambition to achieve a zero-energy renovation approach, which balances a reduced energy demand during the building's operational phase against locally generated electric and thermal power. Some façade solutions are hence oriented towards energy neutrality (Stroomversnelling, 2013),

However, few renovation solutions address the complexity of multi-family rental dwellings and, more importantly, the effect of user behaviour on the operational performance of the buildings. Studies have shown that even though many improvements have been applied, they mostly consist of basic maintenance and shallow renovation. More or deeper energy renovation measures are required (Filippidou, Nieboer et al. 2016). Previous experiences (Winter 1993, Silvester 1996) have shown that there is still an enormous challenge to fulfil the ambition of making the porch apartment energy neutral for an affordable price, and in a manner which is acceptable for the residents, while there are still significant barriers in terms of financing, lack of information, and user acceptance (Matschoss, Atanasiu et al. 2013).

In this context, the "2ndSkin" project brings together different stakeholders within the building industry, aiming at integrating their expertise and objectives into an innovative building retrofitting concept that achieves zero energy use of a dwelling, while also offering strategic up-scaling possibilities. The hypothesis of the project is that zero-energy refurbishment can be promoted, and its rate increased, through the application of prefabricated façade modules, which reduce installation time while minimizing disturbance to the occupants. The focus of the 2ndSkin project is on low-rise, multi-family residential buildings, accessed by separate stairwells per 6-8 apartments in a three to four story configuration. This type of building represents about 300.000 houses in the Netherlands (Platform31 2013). Nevertheless, the concept of the renovation can be applicable in apartment blocks of other than the post-war period, increasing significantly the impact of the solution with a potential target of 875.000 apartment blocks in the Netherlands (Voorbeeldwoningen 2011).

The proposed solution consists of prefabricated modules, in order to reduce construction time and support upscalability. To meet the requirement of zero-energy consumption, the solution consists of three basic elements: a) increasing the thermal resistance of the building envelope, including walls, windows and roof; b) installing heat recovery ventilation, to reduce energy demand for heating while providing adequate indoor air quality (IAQ); and c) the use of photovoltaic (PV) panels to generate energy. Figure 1 presents a detailed section of the façade module, showing the prefabricated sandwich insulation panel, and the location of the ventilation pipes. The proposed renovation solution results in the required characteristics of the envelope, in terms of thermal resistance and infiltration, as well as providing an updated building services' performance. The proposed renovation strategy has the potential to deliver the zero-energy target, under specific conditions for orientation, number of storeys, and PV panels' layout. The building-related energy consumption for heating can be covered due to the reduction in demand enabled by the façade upgrade (Konstantinou, Guerra-Santin et al. 2017).

Nevertheless, the market intake of such renovation strategies is currently very slow, as housing associations are reluctant to invest the increased cost of a zero-energy refurbishment, despite the documented energy savings and related benefits for the occupants. The holistic application of prefabrication modules (integrating both the building envelope and building techniques) is more complex than traditional models, and is often only used in subsidised demonstration cases. In other words, while it is technically possible, it is not yet widely economically feasible (BPIE 2016). It is therefore imperative to find new ways of reducing the impact of initial investment costs, capitalize on collateral benefits, and create successful business cases.

To address this issue, the paper discusses the proposed integrated refurbishment solution. The study presents a financial breakdown of the case-study concept, including alternative building envelope upgrade options, in order to provide insights for a more attractive business case. The study objective is to develop both the solution and a business case to support the implementation to zero-energy refurbishment in the Dutch building stock.

Method to investigate the business case

The present study aims at discussing refurbishment solutions towards a zero-energy objective. To this end, several steps are followed, including comparing refurbishment solutions, not only as technical options, but, most importantly, with regards to the business case that each option can result in.

First, we look at three design variations. The three design variations to be compared were developed taking into account the building industry practice, ranging from a standard external insulation upgrade to zero-energy renovation. The zero-energy objective will be further referred as to NOM, which is the acronym for "Nul op de meter" (Zero on the meter). This suggests that the resulting energy demand after renovation, including both building and user related energy consumption, should be compensated by energy generated on site. Thus, the final balance of energy delivered to the household will be zero.

Subsequently, a feasibility analysis in two stages is conducted. The first stage considers different scenarios, including a no-renovation scenario – in which the building remains in its current state – and calculates their performance according to a range of economic parameters. Finally, in the second stage, it estimates the financial performance of a zero-energy renovation investment on real estate properties with different market values. The next sub-sections analyse the steps in more detail.

REFURBISHMENT SOLUTION VARIATIONS

In order to be able to compare different options and provide insights on how the technical solution can affect the business case. The first variation includes the upgrade with external insulation finishing system (EIFS), which is currently a standard solution, while the other two variations suggest the application of the 2ndSkin panel, as described in Figure 1. More specifically, the variations are described below:

- *Traditional exterior renovation*. A common solution for the upgrade of the envelope is the application of an exterior insulation system, such as extruded polystyrene boards attached to the wall. Thus, the first variation suggests such a solution to achieve an advanced thermal performance of the envelope. New windows are also installed, as well as roof insulation. A mechanical ventilation system with heat recovery, individual for each apartment, is installed. The ventilation units are placed outside of the apartments, possibly on the balcony. The heating system is not retrofitted and the existing gas boiler and radiator system will be used.
- *2ndSkin NOM-ready*. In this case, the 2ndSkin prefabricated panel is applied to upgrade the building envelope. The thermal conductivity achieved is similar to the previous option. A central mechanical ventilation system with heat recovery is installed on the roof. The air supply ducts run in the prefabricated façade module and exhaust ducts in the existing ventilation shaft. This option is referred to as "NOM-ready" because, even though it is not a zero-energy renovation, it provides the first steps towards this goal.
- *2ndSkin NOM*. The zero-energy (NOM) refurbishment variation is similar to the previous variation, but it also includes upgrade of the heating system with the use of an air-to-water heat pump and the installation of photovoltaic (PV) panels. This option has the potential to achieve zero-energy consumption, as previous studies have shown (Konstantinou, Guerra-Santin et al. 2017), depending on orientation and PV layout.

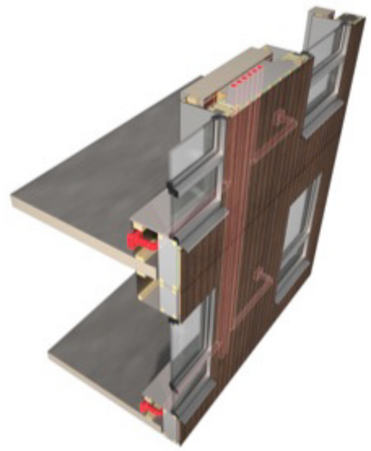
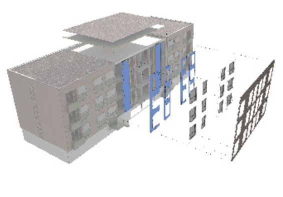
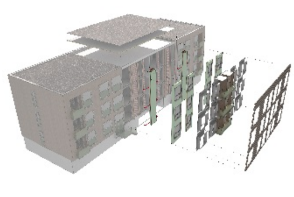
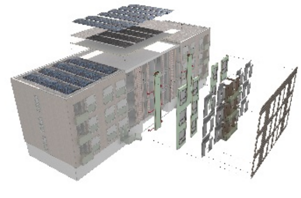


Figure 1. Detailed 3d section, showing the integration of ventilation channels within the prefabricated façade panel.

Table 1 provides an overview of the three variations. The energy demand and the energy generation has been calculated and analysed, taking into account different scenarios of households and behaviour (Guerra-Santin, Bosch et al. 2016, Konstantinou, Guerra-Santin et al. 2017). The energy was calculated with dynamic building simulations, carried out with Bink software (BINKSoftware 2015). In the table, the average value for energy demand is presented. Design options 1 and 2 have the same energy demand, as similar values for the building envelope are as-

Table 1. Summary of the three design variations.

	Traditional insulation from the outside	**2ndSkin NOM-ready**	**2ndSkin NOM**
			
Façade	External insulation and finishing system (EIFS) 190 mm, with brick cladding, Rc 6.5 New high performance windows U 0.8	2ndSkin prefabricated panel Rc 6.5 New high performance windows U 0.8	2ndSkin prefabricated panel Rc 6.5 New high performance windows U 0.8
Roof	● Roof insulation sandwich panels Rc 4.5	● Roof insulation sandwich panels Rc 4.5	● Roof insulation sandwich panels Rc 4.5
Building services	Existing gas boiler Mechanical ventilation system with heat recovery	Existing gas boiler Mechanical ventilation system with heat recovery	● Pv-panels, 255 Wp Air-to-water heat pump for heating (all-electrical system) Mechanical ventilation system with heat recovery
Energy Use	3,421 kWh/dwl/yr	3,421 kWh/dwl/yr	0 kWh/dwl/yr

sumed. The differences in production and installation between an external insulation system and the prefabricated module do not affect the energy demand. For the zero-energy case, the best option for energy generation is considered, in which case the energy demand, including heating demand, electricity consumption and domestic hot water (DHW) can be covered by the available energy generation (Konstantinou, Guerra-Santin et al. 2017).

FINANCIAL FEASIBILITY STUDY

A preliminary financial feasibility study of the proposed zero-energy solution, elaborated for our previous publication (Konstantinou, Guerra-Santin et al. 2017), showed an average internal rate of return of 4% per year. The study took into account certain conditions such as energy-inclusive rental contracts, and a steadily increasing cost of energy according to recent pricing trends. In order to expand the scope of this analysis, investigate the different design possibilities, and account for a wider range of economic parameters, this follow-up study is divided into two stages:

Stage 1. analyses the performance of the three types of renovations on an average model apartment using a range of positive, average, and negative values for a series of financial and economic parameters. The results are compared against a similar study elaborated for a "No renovation" strategy, in which no corrective action is taken. All four scenarios consider equivalent life-cycle cost parameters over a study time of 30 years. Further detail is provided below. This stage will work as a sensitivity analysis to identify the most relevant factors determining the performance of a renovation investment. It will also identify renovation models which are more attractive, and which have the highest chance of success under the uncertain economic conditions of the future.

Stage 2. applies "average parameters" to three different apartment properties with identical floor areas but diverse market values (eg. properties in different areas of the city of Rotterdam), and calculates the financial performance of a zero-energy renovation investment on each property by comparing the calculated internal rate of return values for each scenario. The goal of this stage is to develop a result matrix to indicate which properties can independently justify an energy renovation investment, and which would require external support to establish a feasible business case through, for example, low-cost subsidies or sustainability grants.

Stage 1. Sensitivity analysis methodology

In the sensitivity analysis stage the value of the property has been set as constant, with a median value of 130,00 Euros per apartment (more details on this figure in the following section). A range of positive, average and negative values have then been established for a series of micro- and macro-economic parameters such as general inflation rate and organizational cost of capital. Table 2 presents an overview of the study parameters explained below.

Study and renovation parameters concern fundamental project attributes such as expected service-life and cost of renovation:

- Time of study – The time-span of the study has been set to 30 years. Having established this value, through meetings with institutional property owners, as the average project planning timeframe from both a technical and a financial perspective.
- Cost of renovation – Reflects four strategies for renovating an apartment unit: A no renovation benchmark in which no intervention is done; A traditional, exterior renovation, in which a significant portion of the construction is done on-site; A NOM-ready 2nd Skin package, with pre-fabricated all-electric components but without photovoltaic energy generation; And a NOM 2nd Skin package with pre-fabricated components, photovoltaic energy generation, and heat-pump, which offers calculated energetic neutrality. Data for these (preliminary) values has been provided by the project's partner contractor. The difference in cost between the NOM-Ready and the NOM renovation strategies, which could seem too narrow, is due to a large portion of the budget being allocated to activities which have to be performed in both renovation scenarios. Site preparation and preliminary works, façade fabrication and installation, and roof insulation, which collectively add up to more than €40.000 per apartment, are all costs which must be incurred for both 2nd Skin scenarios, leaving a €20.000 budget for installations in the NOM-ready variation, against €26.000 in the NOM strategy.
- Industrial parameters are related to the effect of production processes on the cost of renovation per living unit.
- Economy of scale reduction – This value takes into account one of the main advantages of a 2nd Skin renovation strategy – pre-fabrication – by applying a cost reduction range based on a volume of 1,000 renovated units. This factor reflects the industrial effect by which, when producing a large number of identical or highly similar products, a lower cost per unit is achieved though more effective production processes or more widely distributed overhead costs. The range from a negative 0 % to a positive 10 % has been determined - after interviews with a series of contractors and suppliers in the Dutch construction sector – as a standard industry – wide estimation. The traditional renovation strategy, being non-prefabricated, has been calculated to have no economy of scale reduction.

Property parameters concern real estate market variables attributed to the modelled property apartment. These include factors such as market value, attractiveness and occupancy rate, and projected rental income.

- One-time market value increase after renovation – Represents the immediate increase in value of an externally renovated apartment unit. Most of this perceived increase in value can be attributed to the aesthetic reconditioning of the façade, more than the energy label improvement. This range has been established through interviews with housing associations and real estate experts, who attribute a value increase of 20 % to 25 % for a property renovated both internally and externally. Since the 2nd Skin model only deals with exterior improvement we have applied only a portion of this value increase, ranging between 5 % and 11 % of the initial market price (Greco, Konstantinou et al. 2016).

Table 2. Overview of study conditions set for both stages of the sensitivity analysis, as described in the section above. Each one of the four "Renovation scenarios" is analysed according to three "Study scenarios" which reflect Negative, Average, and Positive market conditions.

Renovation scenarios	Key parameters	Value range			
Study parameters	Time of study (Years)	30			
Renovation parameters	Renovation strategy	**No renovation**	**External renovation**	**2nd Skin NOM-Ready**	**2nd Skin + PV NOM**
	Renovation cost	€0	€-55,000	€-60,000	€-66,800

Study scenarios	Key parameters	Negative	Average	Positive
Industrial parameters	Economy of scale reduction (1,000 prefabricated units)	0 %	5 %	10 %
Property parameters	Market value of apartment unit (pre-renovation)	€75,600	€130,000	€175,500
	Market value increase after renovation (one time)	5 %	8 %	11 %
	Value trend of apartment unit (with renovation)	2 %	4 %	6 %
	Value trend of apartment unit (without renovation)	-2 %	0 %	2 %
	Occupancy rate before renovation	65 %	75 %	85 %
	Occupancy rate after renovation	75 %	85 %	95 %
	Rent per unit per month (exclusive)	€540	€920	€1,240
	Rental profit per unit per year (Rent - 20% (Admin + OPEX))	€5,184	€8,832	€11,904
	Rent increase per apartment (with renovation)	2 %	4 %	6 %
Economic parameters	Rate of Inflation	0,25 %	2 %	3,50 %
	Energy price increase (per year)	2 %	4,5 %	7 %
Financial parameters	CAPEX (Capital Expenses)	6,0 %	4,0 %	2,0 %
	Non-Energy OPEX (Operational Expenses)	10,0 %	15,0 %	20,0 %
	OPEX savings after renovation	5,0 %	15,0 %	25,0 %

- Value trend of apartment – In the case of a renovated property, this range represents the average increase in real estate value for the area of Rotterdam (Rabobank, 2016). With a small upward and downward range to account for different regions within the city. A non-renovated property from the post-war period is considered to be reaching the end of its original service life (50 to 60 years), and therefore calculated to be dropping in value every year due to its increasing technical obsolescence. Even if the real estate value of the area where it is located has a generally upward trend.
- Occupancy rate – Based on values from housing associations, only a certain fraction of their properties can be calculated to be rented out (and therefore generating income) at any given time. This value fluctuates according to general supply and demand trends in the area, but can also be positively affected by a renovation investment, as a property with better functional and aesthetic qualities will be more competitive in the rental market.
- Rental income – From the perspective of the housing association (potential investor), the rental income represents the final balance generated by each apartment unit. Considering the rent price per unit minus operational and administrative expenses. This value depends on the market value of the property (and will therefore have an effect on Stage 2 of this study). Energy is not included into what would be considered as "Cost of living" from the tenant's perspective, as it is currently general practice for tenants to pay for energy independently. This removes renovation incentives from the housing association, as will be discussed further in the conclusion section of this paper.
- Rent increase – This parameter represents the potential of increasing the price of rent after renovation of the apartment unit. The value range will be used to determine the impact such a rise could have on the overall performance on the investment. However, especially in the case of social housing, regulatory restrictions prevent rent increase beyond a limited threshold.

Economic parameters include wider macroeconomic behaviour such as fluctuations in energy prices and the national rate of inflation.

- Rate of Inflation – Net present value for the calculations is based on an expected average rate of inflation of 2 % per year, with a maximum of 3.5 % and a minimum of 0.5 %, according to historic data for the Netherlands from the last 20 years (tradingeconomics.com, 2016)
- Energy price increase (per year) – Energy prices, in the Netherlands, have increased at an average rate of 4.5 % per year over 15 years up to 2012 (CBS, 2012). This is a considerable rate when compared with the 1.5 % yearly increase in the Consumer Price Index over the same period. Long-term performance of this value is difficult to determine, but a ±2.5 % range has been given to represent spikes and slowdowns according to historic data.

Financial parameters refer to smaller scale, investor-specific financial indicators such as capital/financing costs and operational expenses.

- CAPEX – Financial expenses related to the Cost of Capital for a housing association acting as investor. Since the cost of capital is determined by the specific organizational and financial structure of the company, for example the ratio of funds acquired from equity (capital invested by shareholders) against those acquired from debt (capital borrowed from third parties), this value can vary widely according to the particular institution making the investment. The range used reflects the fiscal advantages of the housing company as a provider of social housing, the low opportunity costs generated by current low-interest rates which render alternative investments unattractive, and the leverage of institutional real estate owners with broad property portfolios. The sensitivity of this value will be discussed further in following sections.
- OPEX – Operational expenses (excluding energy) related to maintenance and administration of the property, this is expressed as a percentage of the property value according to data from Stanford University Land and Buildings (Megan Davis, Regina Coony et al. 2005). A small OPEX reduction is applied to renovated properties to reflect the reduction in maintenance costs after renovation.

An analysis has been done for each renovation model, as well as for a scenario in which no renovation takes place. To reduce complexity, ranges of values will be applied in combination, so that three financial performance scenarios will be described per renovation model: A negative, or worst-case scenario, in which all parameters are counterproductive to the investment; an average, or expected scenario, with median parameters reflecting minimum deviations from recent economic data; and a positive, or best-case scenario, in which all economic and property parameters are beneficial to the investment. It is important to note that the terms "negative" and "positive" are determined, in this case, from the specific perspective of the investor. So that, for example, a rapid increase in the price of energy is considered a "positive" effect, as it enhances the incentive for renovation. Rapid energy increases, however, could be caused by factors which would be deemed negative from an ecological or socio-political perspective.

Stage 2. Property analysis methodology

Considering the cost of a renovation is mainly determined by the surface area of the façade intervened, it can be assumed that renovating apartments with a higher initial market value will be more attractive, from an investment perspective, than renovating apartments with a lower initial value. This due to the fact that the cost of renovation (which in this case can be considered a constant for apartments with the same floor and façade area) will be lower relative to the value of an apartment in a higher-value, inner-city area, than in a social housing project in a marginalized neighbourhood. Stage 2 of our sensitivity analysis explores the impact of such differences by applying average values – from the parameters established in Stage 1 – to three similar apartments with different initial market values.

For this study. we have collected examples from one of the main Dutch real estate residential retail websites, Funda.nl, and cadastral analysis data from Kadasterdata.nl. These sources are deemed to provide an accurate overview of the market value, book value, and recent trend of apartments in different areas of the city of Rotterdam. The study focuses on apartments with a surface area of 65 m^2, a typical size for a two bedroom apartment from the post-war period, with market values per square meter of 1,300 Euros (social housing in suburban areas), 2,000 Euros (median value), and 2,700 Euros (high-end, inner city location).

Rental cost per apartment is correspondingly calculated per square meter according to the market value of the property, to determine the expected income per year from each property according to the diverse market levels they represent. Energy and non-energy operational expenses are assumed to be the same for all apartments, considering identical liveable areas and number of occupants.

A study will be done for each property value, to determine the expected Internal Rate of Return delivered by owning, managing and renting out each type of property.

INVESTMENT PERFORMANCE AND SENSITIVITY ANALYSIS FOR DIFFERENT REFURBISHMENTS SOLUTIONS AND APARTMENT TYPES

This section of the paper describes the process followed to evaluate diverse renovation models on different apartment types according to the parameters established in the methodology section above. It also presents initial observations in terms of parameter impact, feasibility of each strategy and comparison amongst different strategy combinations. The goal of this study is not to determine the exact financial behaviour of any particular investment and renovation strategy, but rather to describe the relative attractiveness of one option over another and, if needed, propose solutions that could increase the feasibility of the (otherwise) least attractive strategies. This study will be divided into two stages, corresponding to those established in the previous section:

Stage 1. Sensitivity analysis

This section analyses the projected cash-flow of the four intervention strategies (No renovation, Traditional renovation, 2ndSkin NOM-ready, and 2ndSkin NOM), according to the variables established in the methodology section. The study is done over a 30 year period, and applied to an apartment with a median market value. The cash-flow is divided into three main sections:

Expenses – Including direct renovation costs such as the initial investment required for renovation, and projected energy consumption values per apartment. These values describe current average energy used per unit in the case-study building, or are based on digital simulations of renovated apartments according to each renovation strategy (Guerra Santin, Silvester et al. 2015). Other expenses include financial costs linked to ownership of the property – such as cost of capital and operational expenses – and financial costs linked to the renovation investment.

Income – Includes projected added value both immediately after renovation, as well as due to its general real estate value increase trend over time. Rental income according to expected occupancy rate, and operational expenses reduction due to technical retrofit of the property are also taken into account.

Total balance – showing the expected overall performance of the investment.

Each value has been calculated according to pessimistic, average, and optimistic scenarios, for which Min/Max/Average charting has been used. Figure 2 shows the results of this calculation for our two extreme scenarios: No renovation and 2ndSkin NOM.

As can be seen from the values above, the most determinant costs are linked to capital expenses (CAPEX) incurred from ownership of the property and, when applicable, from additional investment in renovation. As mentioned before, CAPEX values are linked to the specific nature, history and performance of each individual investor, making it impossible to determine an accurate cross-industry range. The values used represent an intermediate range, lower capital costs are not credible under current economic conditions, while higher capital costs will render all business cases unfeasible.

On the income side, most of the generated gains come from the projected value increase trend of the property, as well as from rental income. The two graphs above show that, regardless of the increase in costs resultant from investing in a renovation project, intervention increases the chances of a positive final performance. A significant portion of this positive result can be attributed to the projected increase in rental price and occupancy rate, as well as the expected increase in real estate value of a retrofitted property.

Strategy comparison for average parameters

A direct comparison between the four possible strategies, according to negative, average, and positive scenarios, provides effective arguments in favour of retrofitting action. Looking at the average, or expected economic behaviour, as shown in Figure 3, we find all renovation strategies lead to positive returns. The rate of return per strategy is not significant in this particular stage of the analysis. The non-renovated apartment, on the other hand, shows a negative overall performance. This means that, even with significantly lower CAPEX costs, the non-renovated apartment is likely to perform financially poorly due to its expected drop in real estate value caused by its increasing technical obsolescence. Likewise, rental income could be realistically expected to drop due to a lower occupancy rate, a lower rental price, or both factors combined, resultant from the lower desirability of the property by potential tenants. This effect could be exacerbated in areas with a high volume of non-renovated properties, as the low real estate value of the properties leads to lower rental profit, which in turn leads to lower capital availability for renovation, in an ongoing vicious cycle.

Running the same analysis for negative and positive economic parameters, summarised in Figure 4, we find that, in the case of a pessimistic scenario, all strategies perform poorly and lead to overall losses. However, the difference between strategies is relatively small. In contrast, an optimistic scenario leads to wins across all strategies, with a clear advantage for all renovated models which perform as much as three times better than the non-renovated option.

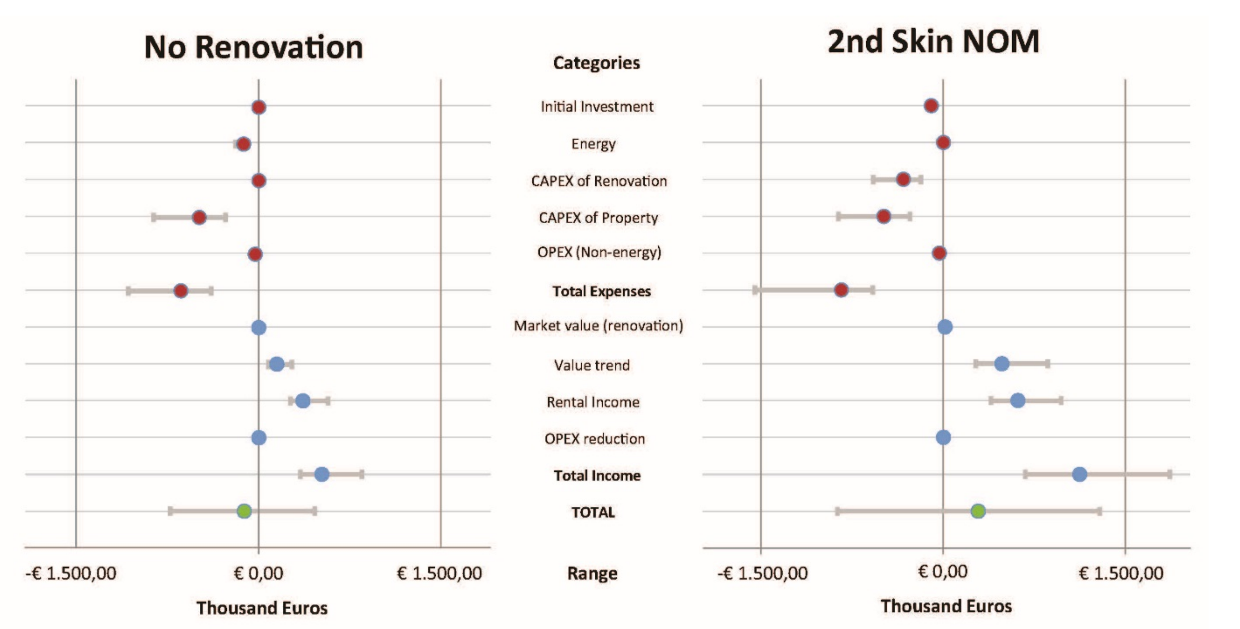


Figure 2. Financial breakdown, over a 30-year period, of a non-renovated apartment, and one renovated according to a 2nd Skin NOM strategy.

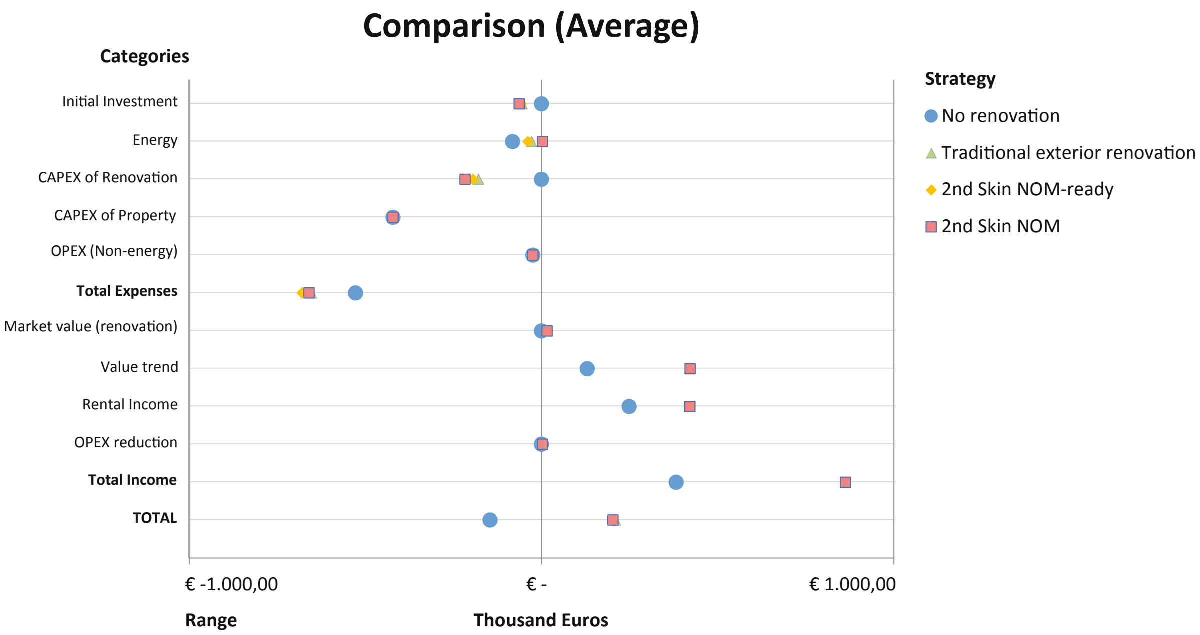


Figure 3. Comparison graphs showing the performance of the four distinct renovation strategies on an apartment with a median market value.

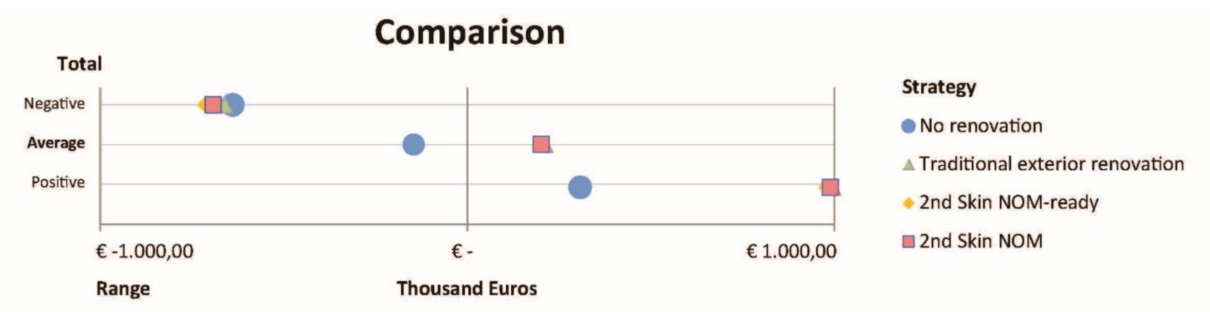


Figure 4. Total balance (Income-Expenses) for each renovation strategy, on a median-valued apartment, based on Negative, Average and Positive scenarios.

In other words, apartment renovation can be seen as a form of future-proofing a rental property portfolio. In an average or positive economic setting renovated properties will perform significantly better than non-renovated models. On the other hand, in a negative economic scenario, the additional capital invested into the apartment renovation will lead to only a minor additional loss when compared with the non-renovated model. The investment's upper limit is, therefore, significantly larger than its lower one.

Stage 2. Property analysis and investment performance

This section describes the average expected performance of a full 2ndSkin NOM renovation package applied to three comparable apartments with diverse market values (as described in the methodology section above). The three apartments have the same size and characteristics, were built during the same post-war period, and are in similar maintenance conditions. The main factor determining their value is their location within the city of Rotterdam, based on data gathered from real estate data platforms (Funda 2016, Kadasterdata 2016).

This stage looks at the expense and income balance over a 30-year period based on the same cash-flow concepts described in the previous section. The results are summarised in Figure 5. As expected we can see that - using average economic parameters in all cases – a renovated, high-end property will generate a rate of return of just below 5 % per year (not an unattractive figure compared to current return rates for alternative investments). Meanwhile, an apartment with a median market value will result in a rate of return of just 3.4 %, and a social-housing level investment will produce a disappointing 0.5 % yearly rate.

Such figures are concerning, as they economically justify the reluctance of housing associations and other institutional property owners to invest on deep energy renovations of their current portfolio. While a functional retrofit can, as observed in Stage 1 of this study, provide additional resilience to steadily moderate macro-economic parameters as those experienced in Europe in recent years, a deep retrofit, with a high initial investment requirement, is increasingly difficult to justify as the starting market value of the target property decreases.

In order to propose initial solutions to this problem, we have adjusted the parameters to reflect the impact of an external economic incentive. Such incentives could be, among others, state-sponsored subsidy programmes for NOM energy renovations, low-cost financing from public or private investment institutions in the form of green bonds or sustainability credits, or direct investment payback schemes such as Energy Performance Contracts, in which the cost of the energy renovation is paid off directly from the yearly energy savings generated by it. The depth and effectiveness of the renovation, in this last case, could improve the credit-rating of the investor's property, gaining him access to even further decreased capital costs.

In the case of a one-time subsidy for NOM-grade renovations, the impact of the sponsoring is positive but, in most likelihood, not determinant. Even a subsidy covering 25 % of the initial renovation cost leads to an overall Internal Rate of Return, for a social housing apartment, of 2 % per year; significantly better than the original 0.5 % but probably not enough to render the investment more attractive for the housing association. Access to low-cost credit, however, is seen to have a much more positive effect on the long-term performance of the investment. Low-cost, publicly or privately funded "green" credit, with an interest rate of 2.5 % (instead of the average 4 % assumed as average throughout this study), immediately increases the IRR of NOM-ready renovation strategies across the whole apartment value range: to 4.3 % for social housing, 7.3 % for median, and 8.7 % for high-end properties. Access to a full amount of low-cost capital in the form of green loans is, according to our range of parameters, more beneficial in the long run than acquiring a free, but partial, one-time support.

Energy Performance Contracting strategies, though beyond the scope of this study, are expected to show even more positive effects than the alternatives mentioned above, as they entirely remove capital commitments from the property owner, while still giving him access to the full advantages of a renovated property. The Energy Service Company (ESCO) becomes, in this scenario, the party responsible for covering the capital costs of the energy renovation investment, removing capital expenses related to the renovation from the housing association's balance sheet.

These and other financing strategies will be further discussed in future papers, and will support the ongoing development of a solid business model for exterior energy efficient renovations using our 2nd Skin strategy.

Conclusion

In the context of the urgent need to renovate the existing building stock, the present study investigates the business case for a zero-energy refurbishment solution for residential buildings. The proposed solution consists of prefabricated modules, in order to reduce the construction time, that integrate high insulation for wall and windows, together with ventilation pipes. In this way, both the envelope and the building services are upgraded. Furthermore, energy generation is necessary to reach the zero-energy target, energy is generated with PV cells on the roof and potentially on the façade.

For the purpose of this investigation, three variations of refurbishment solutions were taken into account. The first one improves the building envelope with a traditional external insulation solution, while the other two apply the prefabricated façade module. The difference between the latter two is that one of them includes the PV panels to generate energy and reaches the zero-energy target. This is important for the financial analysis because it determines the performance of the investment and its initial payback time.

The feasibility analysis took into account different scenarios for both property parameters such as the market value and the rent increase, and financial parameters such as the Capital expenses (CAPEX) and the Operational expenses (OPEX) related to maintenance and administration of the property. The first stage of the analysis included a sensitivity analysis for the

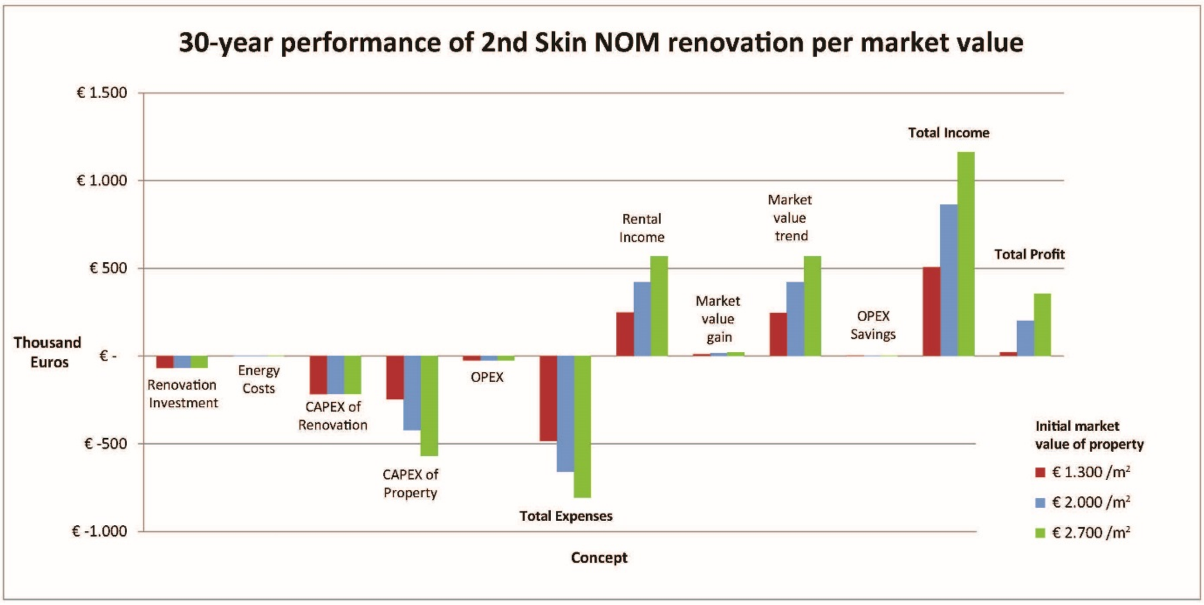


Figure 5. 30-year cash-flow overview for a 2nd Skin NOM renovation on three apartments with identical floor areas but diverse market values (e.g. due to location).

different parameters according to pessimistic, average, and optimistic scenarios, for which Min/Max/Average charting has been used (Table 2). The results showed that capital expenses (CAPEX) linked to additional investment in renovation is the most determinant factor.

This methodology shows that, when considering parameters beyond the energy savings, a positive financial performance can be achieved. The study demonstrated that the renovation increases the chances of a positive internal rate of return, despite the increase in costs resultant from investing in a renovation project. This is due to the expected increase in rental price and occupancy rate, the decrease in energy consumption, as well as the projected increase in real estate value.

Moreover, an expense and income balance over a 30-year period based on the different cash-flow scenarios was carried out for the third design variation, the 2ndSkin NOM renovation package. The analysis concluded that such a renovation has a more attractive business case for market properties, rather than for social housing. The outcome of this study illustrated the conditions under which an energy renovation investment can be most attractive, proposing strategies to facilitate decision-making such as energy-inclusive rental contracts or Energy Performance Contracting for housing associations. It also highlights, if our initial proposition proofs to be correct, the impact of property value before and after renovation on the overall feasibility of such an investment.

Additional research on the topic of zero-energy renovation would include the validation of our initial assumptions. This can be achieved by additional surveys and interviews with stakeholders. Furthermore, it is crucial for the application of such deep renovation solutions that the cost of the investment is decreased. To this end, the potential of different production processes, technologies and materials, as well as prefabrication strategies should be further investigated and exhausted. Finally, supply chain management and organization will play a determinant role in the development of a more efficient retrofitting environment.

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