

# **The influence of end-user perception on the economic feasibility of sustainable building skin renovations**

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## **Abstract**

Considering the small addition in the housing supply of newly built dwellings, meeting sustainable goals in the Netherlands will have to come from the existing housing supply. TU Delft's Solar Decathlon 2014 design focuses on achieving a zero energy renovation that is both sustainable as well as attractive for inhabitants of the most frequent housing typology in the Netherlands, a row house. A strong emphasis in the design has been the expansion from the focus on energy efficiency and pay-back periods, towards the many potential added values in comfort, space, aesthetics and end-user involvement. After the competition the design as market product has been tested and further research has been performed. Even though this has not resulted in a viable market proposition yet, many benefits of a broader value proposition have become evident both in the form of market value and end-user value.

Key words: post-war terraced housing, zero energy renovation, sustainable building skins, quality perception, economic feasibility, Prêt-à-Loger.

## 1. Introduction

### 1.1 Ambitions of the Delft Solar Decathlon 2014 team

TU Delft's Solar Decathlon 2014 team, Prêt-à-Loger, set out to not only create a design capable of generating energy, reducing energy demand and creating innovative solutions, but most of all to create a more sustainable future through making a difference for those that actually live in a terraced home. In order to counteract processes that induce environmental exhaustion, there ought to be less focus on constructing new buildings and a stronger emphasis on improving the existing building stock. The challenge of our design was therefore creating a project that would achieve affordable goals where it matters most: in the existing housing supply. Our approach therefore consisted of an existing row-house covered with a second skin that boosted the appearance and comfort, increased the total living space and made the dwelling energy neutral. This approach both reduces the consumption of natural resources and preserves the current urban DNA with the emotions and memories that inhabitants have developed.



Figure 1 : Existing row-house with the second skin

### 1.2 Renewal versus renovation

Discussion exists on how sustainability and integration within the building level should take place. Problems arise since many participants focus on the construction of new buildings, which can induce decisions that generate demolition and reconstruction. Not only does this exhaust natural resources, it will lead to a higher energy consumption than necessary. In the Netherlands, 45% of the entire Dutch energy consumption is related to the construction and the exploitation of the built environment (van Eck, 2008, pp. 16).

The Netherlands has witnessed a growing number of demolitions over the last years, higher than in neighboring countries (van der Flier & Thomsen, 2010, pp. 3). This high number of demolitions causes three main problems:

- (1) demolition waste with its ecological consequences
- (2) Social problems when groups of residents are moved between neighborhoods and the existing social cohesion is disrupted
- (3) The increasing volume of capital loss due to demolition and reconstruction (van der Flier & Thomsen, 2010, pp.3).

On top of that, the entire process of demolition and reconstruction requires a lot of other resources as well, such as people, time, materials and energy. In addition, an immense logistical problem is created because temporary housing for all these 'homeless' families will have to be provided. And lastly, the emotional bond that families have with their home is broken and the historical, social and urban structure is eradicated. All these arguments show that demolition and reconstruction is not a favorable, nor a realistic option. In order to extend the lifespans of these dwellings, they will therefore need renovations that make them sustainable, future-proof and protected against price increases of conventional energy sources.

### 1.3 Towards a sustainable housing supply

The Netherlands, as well as all EU member states, have agreed to a goal of 80% reduction of greenhouse gas emissions by 2050 (CPB, 2011). With 19200 million kg of CO<sub>2</sub> the housing sector contributes to about 12% of the total CO<sub>2</sub> emission (CBS, 2015). A significant proportion of the reduction required to meet the goal of 80% reduction will amongst others have to come from the housing sector. As currently not even 1 % of the total housing supply is replaced per year (CBS, 2015b) this highlights the importance of reductions in existing households.

As a result the Dutch government has initiated the *Energiesprong* platform. The platform was brought to life by the ministry of Internal Affairs and Kingdom Relations to create large scale supply and demand for buildings without energy bills. The organization aims at creating the changes that are deemed necessary in the process and approach of the construction sector within the built environment. One of the main achievements of the *Energiesprong* has been the signing of the '*Stroomversnelling*' deal in which 175 parties of different housing related industries have agreed to strive for the creation of so called '*Nul-op-de-meter*' renovations, which are renovations where the end user on average has an energy bill that equals zero (Energiesprong, 2015b).

After starting in 2013 the first goal was creating a 1000 prototype renovations until December 2014 and continuing with the creation of 11.000 renovations by December 2016. Building on the knowledge and expertise that has been generated in the first phases, the final goal is the realization of 111.000 renovations by 2020 (Energiesprong, 2015a). In practice it seems these goals have been ambitious, nonetheless progress has been made. At the start of 2015 a total of a 150 renovations have been realized (Doodeman, 2015), although this is a considerable number regarding the timespan, it is not high enough to reach the planned 1000 prototypes.

### 1.4 Expanding the focus

The focus of Dutch building professionals in energy efficiency is mainly on technical solutions and affordability. This focus can lead to neglecting aspects such as image, architecture, communication and in general a more demand oriented approach (van Hal, 2011). For inhabitants the energy use and technical improvements are rarely the main motivation for refurbishment. Although the reduction of energy expenses is of interest to inhabitants, energy expense itself is not considered a major problem. The perception of the neighborhood and the home in the form of comfort, quality of space, social security, appearance and cost of renovation are considered most important by inhabitants (Nieboer, Tsenkova, Gruis, & van Hal, 2012). Expanding the value proposition of energy neutral renovations beyond technical and efficiency related aspects towards what inhabitants find most relevant could contribute to more powerful drivers in the process towards creating energy efficient housing (see figure 2).

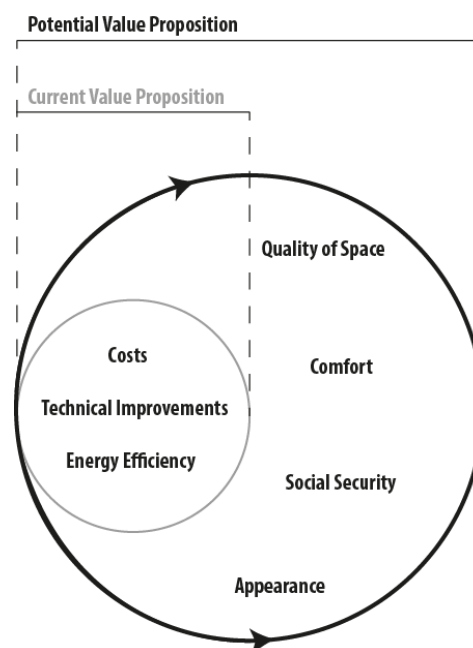


Figure 2: Potential value proposition expansion

## 1.5 The most common housing typology in the Netherlands

In the Netherlands a majority of 61.2% of the residents inhabit semi-detached row (terraced) houses (Eurostat, 2012). The typology of these row houses is not only limited to the Netherlands, but it is a typology that can be found all over North-western Europe, totaling 36 million (see figure 3). Approximately half of these row houses have been built as a response to the post-war shortage that required fast, inexpensive housing solutions for the pre-dominant middle class in the period between 1946 and 1975. This fast and cheap housing solution represents in the Netherlands alone already a total number of 1.4 million post-war dwellings which do not satisfy the present-day demands in terms of energy efficiency (Heijnen & Ham, 2004). Although these dwellings have provided a pleasant living environment to its families for many decades, they entail more shortcomings next to energy inefficiency, namely; an uncomfortable indoor climate due to poor insulation and a lack of space. As previously addressed the themes relevant for the inhabitant in such a renovation extend beyond costs onto many other qualities. This should be taken into consideration, when aiming for successful sustainable renovation of these row-houses.

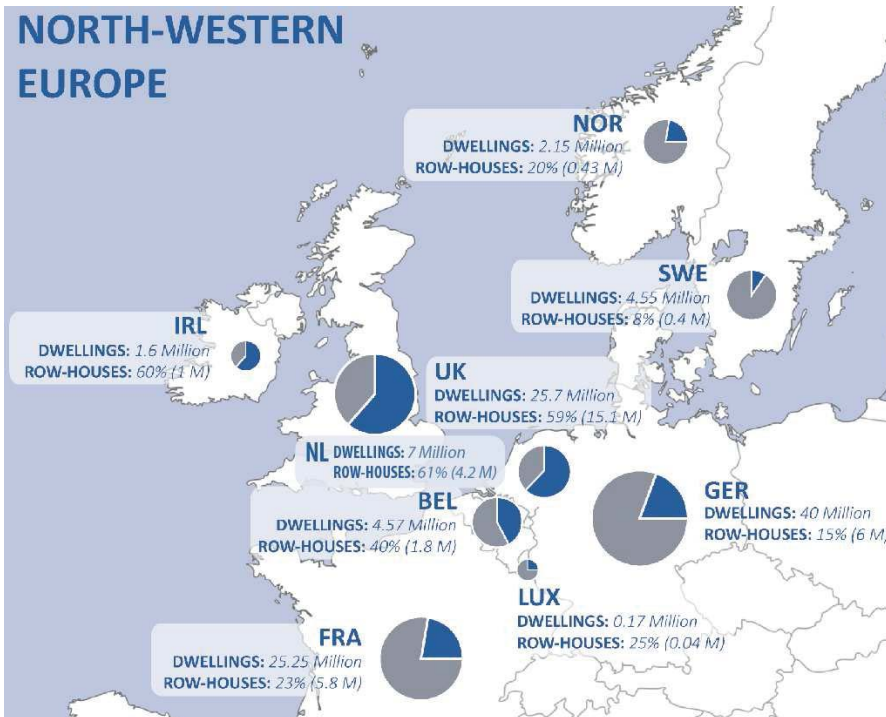


Figure 3: Row housing in Europe (Bellstedt, 2014)

## 2. Prêt-à-loger, TU Delft's Solar Decathlon 2014 entry

As the ambitions towards sustainability are considerable amongst others in the housing sector, relying on efficiency in new buildings will not be enough. Solutions are needed dealing with the existing supply and its problems. The most often seen housing typology is the row house in the Netherlands which was selected as focus of the TU Delft Solar Decathlon design. By creating a renovation that is not only efficient but attractive for inhabitants as well, the design can make a difference for the Dutch housing stock.

### 2.1 The Prêt-à-Loger Design

For the Solar Decathlon 2014 competition in Paris the team tackled the challenge of creating a renovation for terraced housing that would solve its energetic issues while respecting and building upon the people living in these houses. The renovation design can be categorized into three main components:

- The basis of the solution in the form of a second skin, consisting of a greenhouse and extra insulation ;
- Installations required for energy efficiency and ;
- Several components that allow for customization by the inhabitant in the form of a 'Toolbox'.

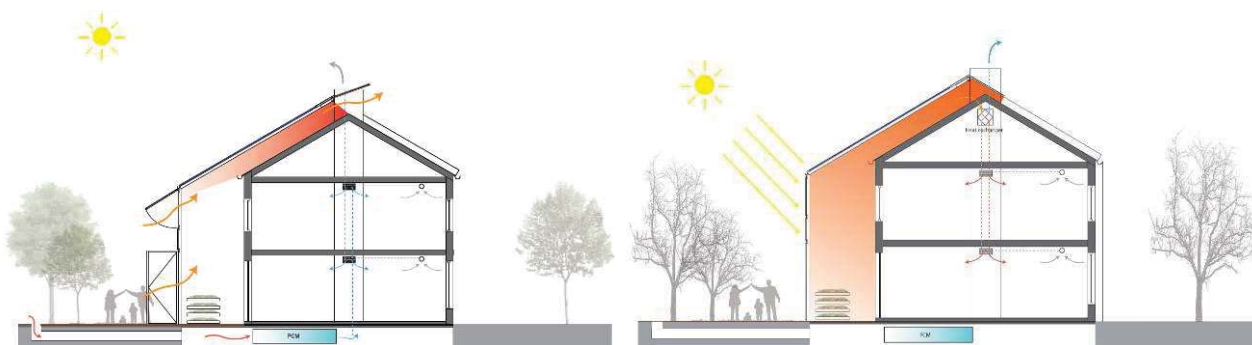
The second skin allows the house to retain its energy and create a more comfortable and spacious interior climate. The installations increase the house's performance and overall comfortability. The toolbox allows end-users to give a personal touch to their renovation, ensuring that their home really stays their home.



### 2.1.1 The second skin

One of the main features of the second skin is a greenhouse that, based on the orientation of the dwelling, is placed on the side of the sun, creating a second skin over the existing building. This second skin creates additional floor space at ground level and creates several energy reduction possibilities. The buffer this second skin creates reduces energy losses of the existing house and the hot air created in the greenhouse can accumulate at the top where it can be used for ventilation or the generation of hot water. The intermediate climate provides a comfortable space to reside in throughout the year. The roof of the greenhouse consists out of semi-transparent solar panels, generating electricity while still allowing the space underneath to have natural lighting. This second skin extends over to the other side of the house as well, where it reduces energy loss through an extra layer of insulation and if required the replacement of glazing and the door.

Due to the extra floor space the greenhouse provides there is the possibility of creating a winter garden, which is an attractive and unique selling point to the renovation. Where most other designs in sustainable housing renovation focus solely on improving insulation and adding installations, the inhabitants of the Prêt-à-Loger design receive more quality in the form of additional space. The façade of this space can be fully opened at ground level while the façade on the 1<sup>st</sup> level and the top of the greenhouse can partially open to allow for airflow when ventilation is required. This additional space can therefore serve as a winter garden in winter, an extension of the living room during spring and autumn and as a garden during summer (see figure 4).



*Figure 4: Prêt-à-Loger design in summer(left) and winter(right)(TeamDEL, 2014)*

On the North side, the second skin consists of an extra layer of insulation, stuck against the existing façade and covered with a strip of composite material resembling ordinary bricks. Optionally, people can replace their windows, window frames and doors as well to improve insulation standards.

### 2.1.2 Installations

Depending on the requirements of the home and the inhabitants a variety of installations can be incorporated into the design. Solar panels, heat panels, balance ventilation, heat pumps, heat recovery units, fully electric kitchen appliances and PCM boxes are amongst the installations available for selection. The greenhouse in combination with the right selection of installations creates a so called 'Nul-op-de-meter' house, a fully electric house without the need for external energy consumption totaled over a year. This principle works using the electricity grid as buffer, allowing the user to overproduce in summer and use the grid in winter.

### 2.1.3 The toolbox

Market research has shown that the emphasis of end user demand is on space and comfort, while sustainability does not score very high (TheChoice, 2014). This does not imply that the opportunities for sustainable solutions are limited however. It shows that it is important to seek integration between sustainable solutions and solutions that contribute to user experience, together creating an interesting selection of possibilities. Such a selection can contribute towards energy efficiency while respecting budgetary possibilities, creating additional value of the home, increasing comfort for the user and adding additional space.

Possible solutions are incorporated in the 'toolbox'. Within this toolbox several materials and products are included providing a broad range of solutions of varying budget, sustainable impact, and end-user qualities.

An example are the solar panels, where several options exist in both the amount of panels and the aesthetics and transparency of the panels (influencing the price), or the use of balanced ventilation systems improving the interior climate. The priority for toolbox components is that they improve the ease of use of the house or improve its perceived quality to make the renovation tangible for inhabitants, creating involvement in sustainability and their renovation. The possibility for people to be able to participate in the process by being able to select from different solutions creates interactivity while the pre-selected list of solutions keeps it tangible and comprehensible. This changes the process of energy efficient renovations from a process where a single design is blueprinted onto a street of houses towards a process where inhabitants are able to select from standardized options to fit their own specific demands and budget. Furthermore the toolbox allows for the expansion or upgrading of parts of the renovation, for instance when technology has developed or new inhabitants move in.

This toolbox has been applied to an existing family house to experience what the application would mean in reality, which was later on translated into a design fitting the Solar Decathlon competition demands (see figure 5). The toolbox which was used for Prêt-à-Loger offered a set of possible sustainable attribute packages ranging from €60.000 up to €150.000. During the competition the most elaborate package with all the top attributes was used which resulted in a house that was not only energy neutral, but is even capable of offsetting redundant energy to the grid. If a resident would opt for the cheapest possible toolbox package, this will not result in a completely energy neutral house but an 80% energy neutral house. This is the lower boundary. This boundary has been determined due to the fact that improving the house to an energy neutral house entails a lot of extra costs. To make the entry level more or less accessible for most households, a discussion about the importance of energy neutrality is important. In the Prêt-à-Loger toolbox the advantage is that all attributes can easily be replaced, offering the possibility for an increase of the future energy efficiency.



Figure 5: Toolbox implementation during the competition (TeamDEL, 2014)

#### 2.1.4 The importance of careful renovation

Throughout the time spent inside the house, inhabitants have not just been making use of the house as a product, but have also made it their home. The approach Prêt-à-Loger proposes, allows for the creation of highly energy efficient renovations while consciously dealing with the identity and existing qualities of homes, carefully balancing between protecting the existing and renovating. This approach has resulted in the design shown in figure 6. The ultimate goal of the design is to improve the interior climate, the energy consumption and the lack of space and improving the quality of the house without losing the characteristics of what makes a home.



Figure 6: Prêt-à-Loger pavilion (SolarDecathlon, 2014)

## 2.2 The design as market product

As the design has always focused on being a solution that could be viable in reality, a small group of the students participating in the project decided to try and create a market version of the design. By approaching the sponsors of the project and other market parties the discussion shifted from trying to make a great Solar Decathlon entry towards creating a market viable renovation. What we had learned from the competition is that many people, such as inhabitants, housing associations and construction companies, were very excited about the design that was created. Up to this day there are several group visits per week in the house, which is currently exhibited at the Green Village area of the TU Delft. This area will exhibit all kinds of sustainable initiatives developed by students and employees of the TU Delft. It seems that the extension of the value proposition we proposed is something considered very positive (see figure 7).

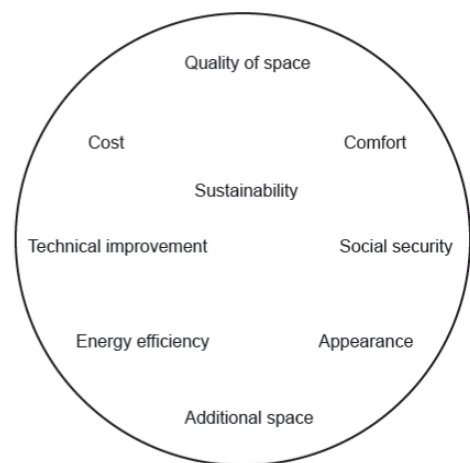


Figure 7: Prêt-à-Loger value proposition

### 2.2.1 Market value

The positive reactions resulted in many people stating they would be interested in applying the renovation to their home, combined with a key question: how much will it cost me? Although calculations have been made regarding the feasibility of the design they have always been based on assumptions and collaboration with practice would be required to take the next step into offering the renovation. Sustainable renovations offered in the Stroomversnelling deal are offered to the end-user at €45.000,-, which is based on a reduction of €175,- energy costs per month stretched over 30 years (Energiesprong, 2015a). In practice it is not possible to realize such renovations at cost price however, let alone profitable for private parties. Estimates are that renovation would be around €90.000,- euros after semi-industrialized production can pick up. Our design is slightly more expensive at an estimated €100.000,-, but this additional expense was offset by the increase of value because of the additional space. During the competition it was still unclear how much of an added

value Prêt-à-Loger would be. After the competition, the Prêt-à-Loger house has been appraised by a group of 10 appraisers, who compared it with the original house in Honselersdijk. The Prêt-à-Loger house was appraised €37.000 higher than the original house, whereas other '0-op-de-meter' dwellings were only valued €5.000-€10.000 higher than their neighbours. An important notion is that the higher the initial value of the house is, the larger the absolute market value increase will be. Hence it looks like these kind of sustainable renovations are more lucrative in more expensive neighbourhoods.

The Prêt-à-Loger house hence creates favorable economic conditions for homeowners when compared to other sustainable renovation solutions. According to the Rabobank (van den Berg, 2015), these kind of economic details help making risk assessments for sustainable renovations. In the end it all comes down to the fact that an expected increase in market value allows more favorable interest rates on loans for the homeowners (van den Berg, 2015), making these kind of sustainable renovations more attractive. The exact attributes responsible for this higher market value could not be given, however the appraisers reckon this mainly had to do with the extra quality in the form of thoughtful design, extra space and improved comfort. One of the authors of this article is currently researching how these different attributes influence the end-user's perception of a dwelling's value.

### 2.2.2 Costs

After the competition, collaboration was initiated with one of the largest contractors in the Netherlands, which was a main sponsor of the team, to see whether the design could be affordable and if they would start offering the design as part of their portfolio. They were amongst the parties of sufficient scale to realize the quantities that were believed to be necessary to sufficiently reduce costs. It quickly became evident that even though the design was highly competitive regarding the price/quality balance compared to other energy neutral renovations, zero energy renovations in general were not yet an attractive proposition. Although much has happened in the Stroomversnelling deal, propositions are not being realized at a price attractive for parties not willing to make considerable investments in zero energy innovations. At the moment the target price is still €45.000,- while in practice the housing associations are paying €85.000,- to contractors for zero energy renovations. On top of this contractors are paying the additional costs (e.g. for development of the design), which are only known to the contractor (Doodeman, 2015). It is likely initial versions of the Prêt-à-Loger would require an investment comparable or slightly higher than current projects.

### 2.2.3 Added value/tenant appreciation?

An often heard argument is that zero energy renovation is not at the economic optimum. The contractor the team collaborated with, was focusing on a concept where they would realize two 80% reduction renovations for the price of a single zero energy renovation, ultimately leading to a situation where our design was not matching their vision or portfolio.

Although the design has up to this point not led to the application on actual housing we believe there are valuable lessons to be learned from the project. The more extensive exploration of potential added values of energy efficient renovations can lead to a much more attractive proposition. Such value can often be realized at marginal or even without costs, creating a much stronger drive behind energy efficient measures. Such a position is much more attractive for public parties, stimulating energy efficiency, and private parties, which are able to realize additional revenue and profit and finally the inhabitants, able to improve their home.

## 3. Focus on quality

### 3.1 Improving quality

The potential added value that has to be sought in other things than only energy efficiency and a reduction of energy costs, such as quality of space and appearance, are closely related to the term quality. Although the financial benefits and the improved energy performance are very important for the financial feasibility of sustainable renovations, residents are often more focused on the extra quality a sustainable renovation can offer them (van Eck, 2008). A higher quality can also trigger a higher willingness to pay among residents, which benefits both the demand and supply side of this industry. In addition, a higher general willingness to pay could also lead to beneficial long term effects, such as a higher resale value and a shorter negotiation time.



### 3.1.1 Willingness to pay

Faro Architects, a Dutch medium sized architecture firm conducted a research to the effect that different attributes have on the perceived quality of a house. These were not only attributes focused on improving the sustainability, but also attributes such as details, ornaments, colors or the amount of green used in the garden. Faro Architects arrived to the interesting conclusion that certain sets of attributes triggered a relatively high willingness to pay among residents. Not all of these attributes were expensive, making them serious considerations to add them to sustainable renovations. Ideally these attributes such as a different color of brick or ornaments in the facade are included during moments of large maintenance. This way the costs can be kept at relatively low levels. According to Jurgen van der Ploeg (2014), owner of Faro Architects, the glasshouse used in the design of Prêt-à-Loger is a typical example of an attribute that adds much more than only an improvement in the energy performance. This is the kind of attribute that also adds quality in terms of more comfort, extra space and appearance. He is very clear on his thought.

### 3.1.2 Market value increase

With all the sustainability upgrades that current housing faces for the next decades, a focus on adding extra quality could increase willingness to pay among residents, it could increase societal support and together this could lead to a higher popularity and hence higher value of the dwelling. This could be very interesting for both housing associations and private homeowners, as both of them benefit from higher market values at a resale moment. The figure below shows that quality can play a very central role in the willingness to pay of residents for sustainable renovations. When quality of the product is increased, it is expected that a market value increase follows. An expected market value could have a positive influence on the investment capacity and the fundability, as money providers such as banks put you in a lower risk profile or even increase your maximum loan-to-value. Hence the quality approach in combination with energy efficiency is an interesting mindset, as it both reduces short term cost and energy consumption, but also increases long term benefits and customer satisfaction (van den Berg, 2015).

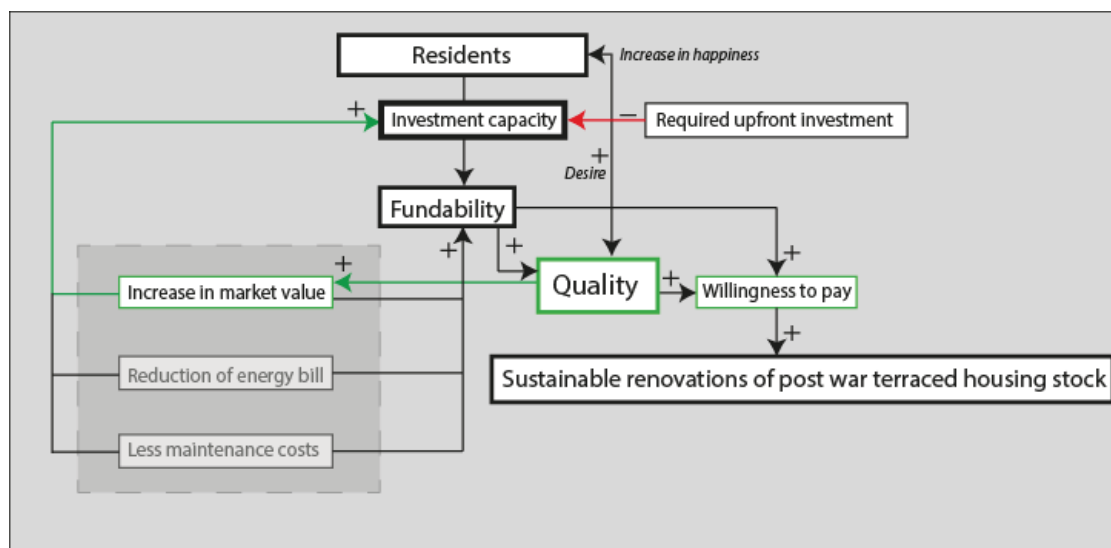


Figure 8: quality can improve the investment capacity and the fundability, through a positive feedback loop caused by a market value increase (van den Berg, 2015)

The focus on quality is also very important, as the reduction of the costs on the energy bill are often not sufficient to pay back the investment (Dekker, 2014). Furthermore, a focus on the reduction of the energy costs over a longer period indirectly assumes that the energy costs remain equal, or would even increase, to make the investment financially attractive. It is complicated to predict how energy prices will develop, although an upwards trend can be identified (IEA, 2014), therefore focusing on increasing the overall quality of a dwelling in combination with an improved energy efficiency seems the more sustainable approach..

## 4. Conclusion

As current approaches for the sustainable renovation of the Dutch post-war terraced housing stock are deemed economically challenging and customer satisfaction is not optimal, it is clear that a different mindset has to be adopted in order to achieve the goals of the Stroomversnelling or the 80% emission reduction of 2050. Whereas current approaches focus mainly on the reduction of energy costs, there should be more focus on the potential added value that can be included in a sustainable renovation, such as an improved appearance, improved comfort or extra space.

This can be achieved by offering the demand side (the residents) a selection of most popular attributes in the form of a toolbox which could be part of a sustainable renovation, which reduces the energy costs and boosts the potential added value through extra quality as well. The challenge with this new value proposition resides in the interaction between the additional quality and the marginal costs. Although the solution presented by Prêt-à-Loger scored very high on both reduction of energy costs and the addition of extra quality, it fell short in practice on the cost aspect.

Future proposals for sustainable renovations in this market segment will have to face the challenge to balance the extra quality and costs to an optimum, while further reducing the costs. If these cost reductions can be achieved and more quality is brought in the form of a flexible package (toolbox) of options, we are convinced that the Dutch housing sector can make a big leap towards becoming more sustainable.

Research into the possibilities of increasing the value propositions of energy efficiency in the building industry could provide additional insight in how energy efficiency goals can be achieved. Market research has shown that the motivations for sustainable renovation are often very broad and extend beyond financial and sustainable arguments. Although research exists on the drivers of sustainable renovation a more detailed investigation of such mechanisms in practice would prove highly valuable.

## 5. Acknowledgements

The writing of this paper could not have taken place without the incredible effort of the 55 students of the DEL Solar Decathlon team, its many sponsors, the design and construction of the Prêt-à-Loger pavilion and the Solar Decathlon organization. Therefore we would sincerely like to thank all of these people for the direct and indirect contributions.

## 6. Literature List

- Bellstedt, C. (2014, 30 September 2014). "Town with a Skin - Retrofitting Dutch Heritage." Retrieved 20-05-2015, from <http://www.symbioticcities.net/index.cfm?id=65416>.
- van den Berg, D. (2015). A different approach to the improvement of the fundability of sustainable renovations for private homeowners. Real Estate & Housing. Delft, TU Delft.
- CBS. (2015). Emissies van broeikasgassen, berekend volgens IPCC-voorschriften: Centraal Bureau voor de Statistiek.
- CPB. (2011). Analyse Routekaart 2050, Op verzoek van het ministerie van Infrastructuur en Milieu. Den Haag: Centraal Planbureau.
- Dekker, T. (2014). Interview about Rabobank's view on sustainable renovations. D. van den Berg. Delft.
- Doodeman, M. (2015, 24-02-2015). Gedachtegoed Stroomversnelling is bij Woonwaard snel geland. Retrieved 05-06-2015, from <http://www.cobouw.nl/nieuws/algemeen/2015/02/25/gedachtegoed-stroomversnelling-is-bij-woonwaard-snel-geland>
- van Eck, A. (2008). De 'Willingness to pay' voor een energiezuinige nieuwbouwwoning. Real Estate & Housing. Delft, TU Delft. Master.
- Energiesprong. (2015a). Deal De Stroomversnelling: 111.000 huurwoningen naar energienota=0. Retrieved 15-06-2015, from <http://energiesprong.nl/blog/deal-de-stroomversnelling-111-000-huurwoningen-naar-energienota0/>
- Energiesprong. (2015b). Wat is het? Retrieved 15-06-2015, from <http://energiesprong.nl/over-ons/wat-is-het/>
- Eurostat. (2012). Distribution of population by dwelling type, 2012 (% of population). from [http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Distribution\\_of\\_population\\_by\\_dwelling\\_type,\\_2012\\_\(1\)\\_\(%25\\_of\\_population\)\\_YB14\\_II.png](http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Distribution_of_population_by_dwelling_type,_2012_(1)_(%25_of_population)_YB14_II.png)
- Heijnen, R., & Ham, M. (2004). Upgrading of post-war row houses in The Netherlands on the area of usable area and thermal resistance. Eindhoven: Technische Universiteit Eindhoven.
- IEA. (2014). WEIO. from <http://www.iea.org>
- Nieboer, N., Tsenkova, S., Gruis, V., & van Hal, A. (2012). *The Netherlands unsettled times for energy efficiency*. New York City: Routledge.
- SolarDecathlon. (2014). Photos. Retrieved 07-06-2015, from <http://www.solardecathlon2014.fr/en/photos>
- TeamDEL. (2014). Project Manual #5. Delft: TU Delft.
- TheChoice. (2014). Propositie & Potentie, slimme verbouwing. In opdracht van Energiesprong, Platform 31.
- van Hal, A. (2011). Anders denken, anders doen. *Building Business*, 22-25.