



Prêt-à-Loger: Zero-Energy Home with Maximum Living Quality Increase

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ABSTRACT At the Solar Decathlon Europe 2014 (SDE2014) competition (Versailles, France), the team from the Delft University of Technology (TU Delft) took a stance by not constructing a new-built house but demonstrating the energy renovation of a typical Dutch terraced house. Around a quarter of Dutch housing consists of terraced houses built between 1946 and 1975, which have a poor energy performance, endure moist and mould problems and to modern-day standards offer too little living space. Nonetheless, inhabitants cherish these homes; almost everyone in the Netherlands once spent a part of their life in them.

The TU Delft team chose a real house as the reference for their retrofit design, the home to one of the students' grandfather and father, currently vacant. All actual features, unfavourable as they are, were taken as the basis: few existing houses are optimally designed for energy neutrality. The team worked on a gentle plan that enables inhabitant to stay in the house during intervention. Hence the name Prêt-à-Loger, ready to live in.

Basis of the Prêt-à-Loger concept is a new skin around the house: thermal insulation in the façade and roof, a greenhouse structure to the south-east, and phase change materials in the crawlspace. The smart and bioclimatic design ensures the use of local circumstances, optimised by an intelligent application of modern technology.

The eye-catching feature, the greenhouse, integrates several elements of the house's climate design. Its greatest importance however lies in the added value to the dwellers: in spring and autumn it can be used as living space, in winter it is a winter garden buffer, and in summer it can be fully opened, becoming the terrace to the garden. The garden was redesigned with the help of NL Greenlabel, a foundation that promotes sustainable gardening.

At SDE2014 Prêt-à-Loger was awarded five prizes, among which the Sustainability award, based on the holistic perspective on people, planet and prosperity in the everyday life of common people. This is also reflected by the many public visits to the project. The house was rebuilt on the TU Delft campus, serving demonstration, educational and research purposes.

KEYWORDS: sustainable building; terraced house; retrofitting; zero-energy; living quality.

1. Introduction

The Solar Decathlon is an international student competition for homes that can function entirely by renewable energy. It was initiated in order to demonstrate new, sustainable directions for the design of houses (US Department of Energy, 2014). The houses are constructed on site and assessed by ten criteria, hence the name. Since 2010 the American competition got its European version. The Solar Decathlon Europe 2014 (SDE2014) competition was held in Versailles, France, in June/July 2014, specifically addressing local issues of the teams partaking. As one of the finalists, the team from the Delft University of Technology (TU Delft) chose to take on the challenge to improve existing homes, rather than new ones. Research revealed that around 20% of Dutch housing consists of terraced houses built between 1946 and 1975 (SenterNovem, 2008), which have a poor energy performance, endure moist and mould problems and to modern-day standards offer too little living space. Demolition and sustainable new construction therefore seem a logical option, but with 1.4 million of these houses in the Netherlands alone (millions more in other parts of North-Western Europe), this would entail a relentless operation and massive destruction of capital. Moreover, there is preciousness involved. Inhabitants turn out to cherish these homes; almost everyone in the Netherlands once spent a part of their life in them.



Fig. 1: The reference dwelling, located in Honselersdijk, Western part of the Netherlands.

This is why the TU Delft team chose a real terraced house as the reference for their retrofit design (Fig. 1). It was the former home to one of the students' grandfather and father, a typical example from 1960. Over time it has become obsolete, for it lacks space, comfort and consumes around € 175 each month for energy. In accordance with Stroomversnelling, a public-private programme to stimulate energy renovation of dwellings, the annual net energy



consumption should be brought to nil ('zero at the meter') by measures that do not exceed the former expenses for energy. So inhabitants pay an equal amount of domestic expenses but get a better, more sustainable home in return (Platform 31, 2013).

The team stayed true to the actual situation of the house. All realistic features were copied in the prototype retrofit version, including all construction properties, garden sizes, opaque side, and the relatively unfavourable south-east orientation. The team wanted a plan that enables the inhabitants to keep living in their home, to be solved by 'The Skin', a collection of interventions to the outer skin, both roof, façades and ground floor. The Skin thus improves both the spatial and the climate performance of the existing house, without touching the quality of a home. Hence the name Prêt-à-Loger, ready to inhabit.

2. Design method

In line with the design method taught at TU Delft and coached and supervised by faculty advisors, students approached the retrofit challenge by means of 'smart & bioclimatic design'. This is a design approach that utilises the local characteristics in the sustainable design of a building (Dobbelsteen & Linden, 2007). Students are taught to first analyse the climatic, natural and technical circumstances before translating these into boundary conditions for the architectural design and eventually optimising the local features by smart technology. In that sense it takes a pragmatic stance to 'bioclimatic design' (Yeang, 1996), which tries to avoid technology and 'smart architecture' (Hinte et al., 1999), that predominantly seeks a technological approach.

In the case of Prêt-à-Loger, smart & bioclimatic design helped to conceive an integrated energy system for the house. Most striking features of these are the well-deliberated thermal post-insulation, the efficient soil/PCM-stabilised ventilation system and, most novel, the solar glasshouse. This addition merges well with the surroundings: Honselersdijk is part of the Westland area between Rotterdam, The Hague and Delft, characterised by horticulture, demonstrated by extensive greenhouses for food and flower production.

From the beginning, it was clear to the students that presenting a sustainable home to people (in terms of its technical performance) has no added value if it does not improve the quality of living. Indoor climate conditions will be improved by common energy retrofitting strategies (post-insulation, window replacement and renewal of building services); the Prêt-à-Loger team wanted to give dwellers something extra, to render the home attractive for a long time to come. The solution for this is found in the four-seasons' functionality of the solar glasshouse and in the sustainable garden. Thus, the Prêt-à-Loger team pursued a balance between what should be preserved (home) and what should be improved (house).

3. Building design

The Skin consists of interventions to four surfaces of the house: roof, two façades and ground floor. Part of the interventions are passive measures to reduce the energy demand. The roof gets thermal post-insulation from the inside and a vegetated roof is added to the north-west slope. The typical Dutch facade from the 1960s consists of two gables, a load-bearing inner limestone gable (10 cm) and an outer brick gable (10 cm), separated by a cavity (5 cm). In modern-day houses this (wider) cavity is filled with thermal insulation material; back in 1960 it was kept void for ventilation purposes only. On the cold north-west elevation the outer gable is replaced by a 20-25 cm layer of insulation, finished by brick slips that make the wall look as its origin. The warm south-east wall cavity (also 5 cm) is filled with thermal insulation, and a glasshouse is added to the skin.

The soil has a relatively constant temperature, corresponding with the mean temperature of the local climate. Therefore, the plan was to introduce soil collectors for air drawn into the house before it passes a heat recovery unit. At the SDE 2014, digging into the ground however was not allowed, which the team solved by introducing phase change material (PCM) batteries in the crawl space of the house. In summertime, air passing through these PCMs is cooled before entering the home.

The smart glasshouse is a combined passive and active feature of Prêt-à-Loger. PV-cells are integrated in the glazing for the house's entire electricity production. A plate collector, connected to a heat pump boiler, is placed between the old and new roof, producing hot water and cooling the PV cells, which therefore become more efficient. The glasshouse provides the house with energy year round, contributes to the climate performance of the house, and (not least) provides extra space.



Fig. 2: Prêt-à-Loger at the SDE 2014 in Versailles, showing a cross-section through the neighbours.



1. In winter it remains closed and functions as a passive heat buffer, both for hot water and for ventilation via a heat exchanger. It functions as a winter garden, through which inhabitants enjoy green and produce food during winter.
2. In spring and autumn it is also mostly closed yet boasts a comfortable temperature, because of which it can serve as living space. The dwelling can be ventilated directly via operable windows and doors, using the preheated air from the glasshouse.
3. In summer it opens up completely by the folding door, becoming a part of the garden. In hot periods two sets of operable window hatches at the top and front allow a chimney effect incited draft that provides cooling, while at the same time optimising the performance of the solar panels. The hatches can be operated by the house's domotics system, either manual or automatic.

4. Other sustainability measures

The climate system described above led to a very good energy performance at SDE2014, and simulations predict net zero energy use during a full year. Tests and measurements are currently executed to validate these simulations (Xexakis & Dobbelsteen, 2015). Next to energy, Prêt-à-Loger took into account a myriad of sustainability aspects.

Water: rainwater is infiltrated through permeable materials (e.g. Olivine gravel and garden borders) or buffered (vegetated roof on the north-west side, up to 32 l/m², and borders, capable to buffer 90%), or collected, stored and used for toilet flushing, cleaning and irrigation (2,000 litres, at least 18% of freshwater savings).

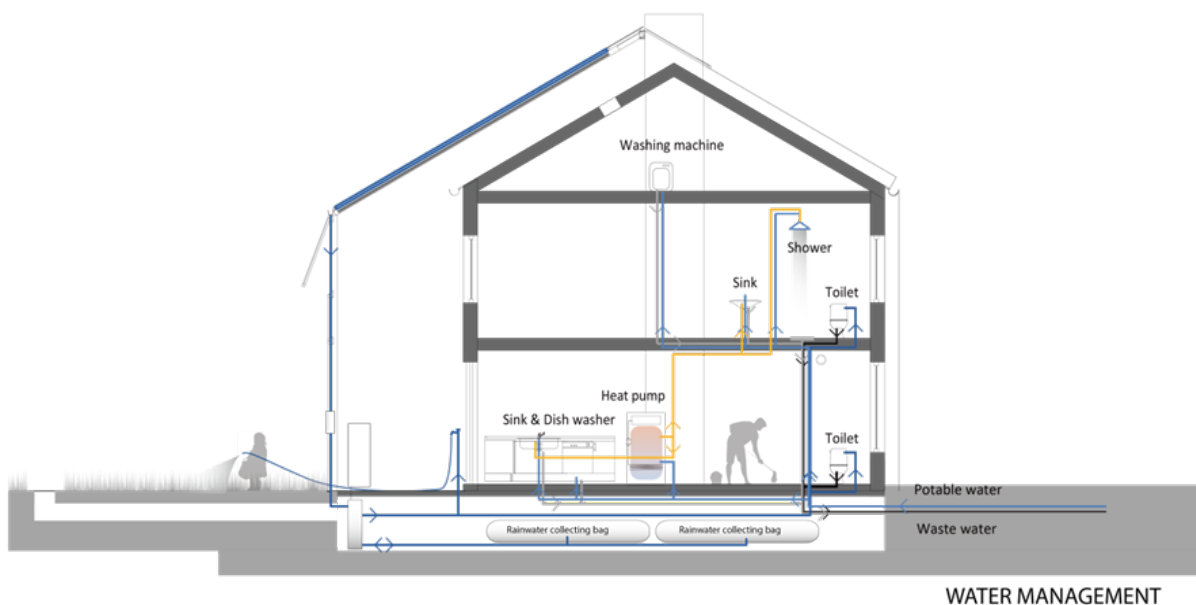


Fig. 3: Prêt-à-Loger water system

Biodiversity and food: there is use of local organic plants, flowers and trees in the garden; local and environmental friendly materials are used; vegetables and herbs grow in the private garden and glasshouse.

Waste: the house has a waste management system; waste is prevented during construction; prefabricated elements are used, such as the glasshouse; materials in the Skin are reused or recycled by 80%.

5. Collaboration and partnerships

In order to kick-start the project's collaboration with the market the TU Delft team put together a committee of recommendation, consisting of leaders in the sustainability and building sector, for instance chairs of branch organisations in the building industry. Partnerships were pursued with companies who could support in kind (products, hours) or cash. With the Dutch ministry of Internal Affairs on board, in spite of the national building crisis, an extensive group of companies decided to support Prêt-à-Loger. After the final green light given by the university (six months before the competition start), pressure-cooker sessions were organised for the Prêt-à-Loger team and its partners, in order to achieve specific results at the end of the day. These proved to be very intense but effective and fun too. The preparation and construction stage were done in an intensive process of collaboration.

6. Communication

Prêt-à-Loger actively sought publicity to communicate and discuss with the intended audience. Visiting fairs, organising events, presenting the project to interested parties, and using social media were means to facilitate an active discussion about Prêt-a-Loger's concept, vision and design. Public presentations played a big role in communicating the story behind the project and receiving valuable feedback. With around 25 events throughout the country and with a wide range of public, from citizens of Honselersdijk and highschool children to seasoned professionals, the word was spread and every aspect of the project was discussed. Social media have been important for active communication. With an account on Facebook, YouTube, Twitter, LinkedIn, Google+ and Instagram, Prêt-à-Loger was present on all currently popular media.

Passive sources of information were used to inform the general public and press and as a source of information on the project for interested parties. The Prêt-à-Loger website presented all relevant background information; it included blogs, articles from the press, audio-visuals, pictures and live stream footage of the construction process.

The Home with a Skin made it to national television four times, reaching a crowd of millions, was published in newspapers throughout the country, hosted on websites with over 375



articles in 9 languages and interviews with team members aired on numerous radio stations in the Netherlands.

Audio-visuals have proven to be an informative method of communication for people that want background information in an accessible way. Numerous requests for the original material of Prêt-à-Loger footage were received, which indicates that these videos provide quality information and are worth watching.



Fig. 4: Prêt-à-Loger signage

Special importance was given to the design of Prêt-à-Loger's brand identity. The two colours used in the logo are blue and white - directly derived from the Dutch street-signage from the 1960s, the period in which (most) terraced houses were built. In an attempt to further contextualise the brand, with the colours, typeface, border and house-icon with inhabitants, the logo addresses the street, the skin, the house and the home in combination with the team-name *Prêt-à-Loger* and product *Home with a Skin* (Fig. 4).

7. Process

The reason to participate in the SDE2014 was to gain experience for the individual students in designing and building in practice as well as learning to work in a diverse team. Both designing and building were a cross-disciplinary process executed by students from fourteen different study backgrounds and sixteen different nationalities. Learning processes were mainly found in organising and managing a large team to work efficiently towards one goal and in the communication and cooperation between different professions. The pavilion itself together with the outcome of the competition is proof that the project in this regard is successful.

8. Results, discussion and recommendations

During the competition in Versailles the following prizes were won: 1st prize in sustainability, 1st prize in communication & social awareness, 2nd prize in energy efficiency and 2nd prize in construction management & safety. Overall, the team ended third with less than 3 points difference (out of a total of 1000) behind number 1.

In every design decision the house was imitated as realistically as possible. For example, exactly the same type of brick was chosen as outer wall finishing and the mass of soil was imitated using phase change materials. The exact orientation was copied, even though it is not optimally north-south orientated. This underlines the aspect that when dealing with an existing situation, orientation is part of the context. In few respects the original house in Honselersdijk was adapted to fit within the boundary conditions of the Solar Decathlon competition. The trade-off has been mainly regarding size, to fit within the Solar Envelope, and materialisation, to make it constructible within the time set. The most important aspect for representing the house in Honselersdijk is the quality and identity of a Dutch 'home.' This forms the main concept for the interior design: no hyper-modernistic unaffordable interior, but an existing home of a common Dutch family. To present the aspect of an 'existing home', a combination of second-hand furniture from Dutch families and austere new furniture were used (figure 5). Furthermore, elements that determine the identity of a home, such as pictures on the wall, shoes in the hallway, were implemented in the interior design.



Fig. 5: Interior of the Prêt-à-Loger house during visits at SDE2014: nothing fancy, all realistic

With the house being constructed in Delft several thousands of people have visited the house. Professionals, students as well as inhabitants have been given tours, presentations and workshops in the prototype house. All visitors have been enthusiastic about the project.



The house has had extensive monitoring to test its performance. Part of these tests were executed in Versailles as part of the competition during summer 2014. Other tests were executed in Delft in winter, as part of graduation research projects and in preparation of this article. Apart from this research into the technical performance of the house, feedback from visitors has also been documented. The prototype itself will continue to be used for research and education as well as creating awareness of sustainability and the possibilities of living quality among home-owners.

With over 375 known publications in journals, magazines, tv shows and websites it can be said that the Prêt-à-Loger project has had quite an impact on both the professional world and society. Smaller and bigger contractors are currently developing similar solutions, which emphasises the influence Prêt-à-Loger has had.

Taking into account these results, part of the Prêt-à-Loger student team decided to start investigating the possibilities of a start-up. The Prêt-à-Loger concept will be made into a marketable product.

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