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Article

Social Housing Net-Zero Energy Renovations With Energy Performance Contract: Incorporating Occupants' Behaviour

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Abstract
This article examines how the behaviour of occupants is assessed in a project with ambitious targets for energy use reductions and within the framework of an approach based on an energy performance contract. Its starting point is the observation that there may be significant disparities between the consumption threshold required by the regulations or the labels and the actual building consumption in its post-delivery existence. While behaviour cannot be the only factor explaining this overconsumption, the promoters of high-performance renovation operations often marginalise their importance. The recent surge in requirements for energy consumption reductions in new or renovated buildings in Europe further exacerbates these problems. In light of these challenges, there is a strong demand for compulsory verification of post-delivery performances and for developing energy performance contracts. In this context, the behaviour of a building's occupants can no longer be considered as a simple adjustment variable. Through the analysis of Energiesprong, a net-zero energy renovation approach for the social housing developed in the Netherlands and in France, built around the principle of an energy performance contract over a long timeframe, the article highlights the injunctions to behavioural changes, the strategies, the negotiations, and the adjustments deployed by the project leaders. It finally shows that there is still a long way to go before the occupant's behaviour in a high-energy performance renovation project is fully taken into account.

Keywords
Energiesprong; energy performance contract; France; net-zero energy renovation; occupant behaviour; social housing; the Netherlands

Issue
This article is part of the issue "Zero Energy Renovation: How to Get Users Involved?" edited by Tineke van der Schoor (Hanze University of Applied Sciences) and Fred Sanders (CPONH NGO).

1. Introduction

At a time when concerns associated with climate change and the depletion of various kinds of resources are increasingly acute, we are seeing an acceleration in the implementation of policies on the ecological transition in Europe. Reducing the consumption of carbon energy, especially in the buildings sector, is one of the primary goals (Rosenow et al., 2017). The main measures consist of fixing performance obligations and maximum permitted energy consumption thresholds relating to the field of application of thermal regulations. Generally, conformity with these objectives has to be demonstrated in the design phase through studies and simulations and is only very rarely verified from actual consumption data captured after delivery, when the building is already in use.

However, numerous reports and studies (Branco et al., 2004; Santin et al., 2009) have revealed that there may be significant disparities between the consumption threshold required by the regulations or the label and the actual consumption of the building in its post-delivery existence. These disparities can be explained by various factors occurring during the design, the construction, and the post-delivery phases. Among all factors, occupants' behaviour seems to play a significant role (Gram-Hanssen & Georg, 2018).

These disparities in consumption can be very problematic for the owners and/or the occupants of the buildings, who may find themselves facing higher energy bills than expected. The recent surge in requirements for energy consumption reductions in new or renovated buildings in Europe further exacerbates these problems. Very ambitious approaches that aim to achieve energy neutrality are emerging. Although not yet compulsory, post-delivery verification of actual consumption is increasingly included as part of high-quality labelling and certification procedures. In the light of these challenges, we are seeing strong demand on the part of building owners, supported by the regulatory authorities, for the development of a guarantee of real performances (Zou et al., 2018), such as energy performance contracts (EPCs). These aim to provide contractual security and guarantees regarding reductions in the energy consumption of a building or stock of buildings, consumption that is verified and measured over time (Shang et al., 2017).

In this context of compulsory verification of results and performance guarantees, the behaviour of a building's occupants becomes even more important. It seems essential to incorporate and understand it at a fine-grained level for a finished project to conform to expectations with regard to lower energy consumption (Jain et al., 2017; Lu et al., 2017). That, at least, is the argument of this article, which raises the following research questions: (a) How does a project with ambitious targets for reductions in energy use coupled with EPC assess occupant behaviour? and (b) what consequences and impacts do these types of projects have on the occupants?

In order to tackle these questions, we studied the EnergieSprong approach (Box 1), a procedure that proposes a very high-performance energy renovation standard, such as net-zero energy (NZE) aiming to refurbish a building or a cluster of buildings to achieve a zero balance between energy consumed and energy produced from renewable sources, and is built around the principle of a guarantee of neutral energy performance over a long timeframe (25–30 years). Studying how occupants' behaviour is accounted for in this kind of innovation system seems particularly useful to us because the efforts needed to make a building energy-neutral require profound alterations to inhabited space, alterations that also demand changes in behaviour.

In the last few years, the scientific literature has become interested in the Energiesprong approach. Studies have emerged, mainly from Dutch and English researchers. These studies are mainly concerned with understanding the economic model of Energiesprong in connection with national regulatory tools, by analysing the costs and the number of renovations carried out (Visscher, 2017), the role of intermediary actors (Brown et al., 2019; Sovacool et al., 2020), or the EPC (van Hal et al., 2018). The industrial aspect of the process is also fairly studied (Micelli & Mangialardo, 2017). Some studies focus on transfer to other countries and the feasibility of adapting the Energiesprong model (for the United States, see Egerter & Campbell, 2020). In France, a study illustrates the innovations and transformations for the professions and the actuator systems involved (Pellegrino, 2019). Fewer studies are interested in the role played by occupants' behaviour in Energiesprong or, broadly, in NZE renovations (van der Schoor, 2020; van Oorschot et al., 2016; Wekker, 2020).

As part of this research, we aim to shed light on this less covered aspect of the Energiesprong approach. We adopted a socio-technical perspective. The aim is to go beyond, on the one hand, techno-centric approaches, which reduce the behaviour of occupants to a few standardized socio-demographic variables, and, on the other hand, studies from economics and environmental psychology, which, by focusing on the individuals' orientations, can fail to examine the influence of context on energy-related behaviours (Bourgeois et al., 2017). From this socio-technical perspective, we decided not to directly investigate occupants' behaviour, examine technical systems in the renovated houses, or undertake a measurement campaign to quantify energy consumption. Instead, we apprehended Energiesprong NZE renovation projects with energy performance contracting procedures as a process anchored in space and time, involving numerous stakeholders, including the establishment of protocols and forms of contract and a massive recourse to technical equipment, systems, and technologies, and we investigated how occupants' behaviour is assessed in the different stages of a project. In order to

Box 1. Short presentation of Energiesprong.

Energiesprong was born in 2010, in the Netherlands, and aims at scaling up NZE (*nul op de meter* in Dutch) renovations, developing the industrialization of buildings' processes (Figure 1), starting from the social housing sector. The implementation of a set of innovations (contractual, organisational, regulatory, technical, and financial) initially focused on the renovation of social housing and has enabled the social landlords to launch a renovation plan over an extended period and on a large scale, which has had the effect of halving the price of a home renovation (Oostra, 2017). Beyond the Netherlands, the approach is now being applied in the United Kingdom, France, Italy, the United States, and Germany, among others. In France, although still at an experimental stage, it appears to be gaining ground. A charter supporting Energiesprong was signed in 2017, involving 111 partners, including 14 social housing landlords, with a commitment to undertake 3,600 renovations before 2022. At the time of writing (January 2022), 6,316 renovations, in progress or completed, are listed on the Energiesprong website.

Figure 1. A prefabricated facade for a renovated house in Wattrelos.

do that, we have mobilized a large body of literature. In this corpus, three areas of study seem particularly relevant for our study: The first one explores domestic energy behaviour (Frederiks et al., 2015; Lutzenhiser & Gossard, 2000; Steemers & Yun, 2009) and, specifically, in relation to the use of new technologies and the materiality of the domestic space (Shove, 2003; Stephenson et al., 2010); the second one focuses on high-performance energy renovation projects (Gianfrate et al., 2017; Gupta & Gregg, 2016); and the last one is dedicated to the comprehension of the "energy performance gap" (Gram-Hanssen & Georg, 2018; McElroy & Rosenow, 2019; Topouzi et al., 2019; Zou et al., 2018) and of the procedures designed to deal with it, such as the EPCs (Jain et al., 2017; Lu et al., 2017; Zhang & Yuan, 2019). The analysis of literature on EPC reveals a paucity of studies, putting this contracting form in perspective with the behaviour of the occupants by illustrating the impacts that it can have on the latter, which is the perspective adopted by our study.

In Section 2, we describe the methodology and the case studies. Section 3 presents the results of the research. In the first place, we describe how the stakeholders (building owner and members of the project consortium) in the Energiesprong approach in France and the Netherlands tried to incorporate the behaviours of building occupants in the different stages of the renovation project. Secondly, we focus on the performance gap and on the questions raised by the EPC. These findings will then be discussed and assessed in Section 4.

2. Methodology

As part of a larger project that encompasses multiple research pathways, we analysed Energiesprong NZE renovation in the Netherlands and in France in its principal field of application: social housing. The choice to study Energiesprong in the Netherlands depends on the fact that, since the Dutch experience predates that of the other countries, it provides finer-grained material and allows going further in the study of the post-delivery phase. In the context of this article, we will also rely on the study of two Energiesprong projects in France. Although too recent to allow for post-delivery feedback, these French projects will contribute further material to the analysis of pre-project and construction phases and by showing a different operational and economic model.

From the very beginning of the research the centrality of the EPC appeared, raising questions concerning the challenges and the consequences that it generates. This led us to dedicate part of the interview time to dealing with the EPC and, in particular, with the place given to occupants' behaviour in this procedure. The present analysis relies on 25 interviews carried out with social landlords, associations of social landlords, constructors and associations of constructors, technical engineering offices, intermediate contractors, and local public authorities (Table 1). Semi-structured interviews were carried out based on a protocol composed of two parts. The first one is common to all the interviews and focuses on the role and the interests of the person and the represented structure in the Energiesprong approach. The second part is specific to the type of actors interviewed. The topic of the EPC integrating occupants' behaviour was discussed with all the actors by adapting the exchanges to the role they cover in the procedure. Finally, some other questions were adapted to the field of study. As the Dutch projects are older, the interview focused more on feedback. In France, it is rather the adaptation of the model, in particular economic, which was questioned.

We specifically interviewed stakeholders who have been or are engaged in an Energiesprong energy renovation projects in two municipalities in the Netherlands (one project in Stadskanaal and three projects in Leeuwarden, that we were also able to visit in June 2021;

Table 1. Body of interviews used for this article.

	Case study localisation	Project data	Type of stakeholder	Position of the respondents	Date of interview
The Netherlands	Stadskanaal	2018–2020; 183 individual houses	Construction company	1. Customer and market project manager, 2. Energy and technology officer	12/05/2021
			Architecture office	Project manager	06/06/2021
			Social landlord	Housing portfolio manager	19/05/2021
			Local public authority	Energy and housing officer	01/06/2021
	Loppersum	2017–2019; 173 individual houses	Social landlord	Property manager	07/06/2021
	Leeuwarden	2017–2021; three projects, same landlord and constructor; 118 + 132 + 55 individual houses; 84 dwellings	Social landlord	Property manager	09/06/2021
			Local public authority	Sustainable development policy advisor	17/05/2021
			Construction company	Innovation manager	12/07/2021
			Energy supplier	Strategy and innovation consultant	30/06/2021
			Architecture office	Project manager	08/06/2021
	National level	—	Intermediate contractor	Sustainability, circular economy, and scale-up project manager	03/05/2021
			Researcher	Doctor of architecture and building environment	17/03/2021
			Researcher	Senior researcher at the built environment research center	16/03/2021
			Association of construction companies	Director of energy transition program	14/07/2021
France	Pays de la Loire	2021–2024; four projects, association of landlords; 2,000 individual houses	Social landlord association	Director	07/05/2021
			Technical engineering firm	Director of development	10/06/2021
			Association of construction companies	Director	07/05/2021
			Local public authority	Deputy director of energy and environmental transition	04/06/2021
	Wattrelos	2021–2022; 160 individual houses	Social landlord	Operational activity manager	28/04/2021
			Architecture office	Project manager	07/04/2021
			Construction company	Site manager	17/05/2021
			Technical engineering firm	Research department manager	27/04/2021
			Local public authority	Manager of town planning and building permits	06/05/2021
	National level	—	Intermediate contractor	Energy market and territories director	14/04/2021
			Energy supplier	1. Regional director, 2. Assistant delegate connection, 3. Large project and smart grid manager	04/06/2021

Note: Anonymity required by stakeholders.

we also wanted to study Loppersum project, but only the social landlord accepted to be interviewed) and some French municipalities (Wattrelos, visited in May 2021, and different municipalities in the Pays de la Loire region involved in one common large project).

The paucity of existing projects explains the choice of the French case studies. The very first pilot projects, in the towns of Hem and Longueau, have a limited scale (10 and 12 individual houses) and have been studied elsewhere (Pellegrino, 2019). The Wattrelos project (160 houses) is the first large-scale Energiesprong project in France, followed in chronological order by a similarly large project in Pays de la Loire. Other ongoing projects are too recent to supply materials for analysis. Regarding the choice of case studies in the Netherlands, we first made a table listing all the Energiesprong projects in the Netherlands, drawing on Projecten—Energielinq (https://stroomversnelling.nl). We analysed this corpus through several filters: the size of the operations, the landlords with the greatest number of projects, and the construction companies involved. After combining these criteria, we chose two contrasting case studies: the Stadskanaal project and the Leeuwarden project, the former involving prominent and very active actors in Energisprong and the latter, in contrast, involving actors with little experience in this type of project.

Beyond the interviews, additional materials included a large body of literature as well as numerous regulatory texts, documents based on communication around pilot projects, or else project specifications.

3. Results

3.1. Inform, Convince, and Constrain in a Standard: The Three Facets of Taking Occupants' Behaviour Into Account

In this part, we show that building owners, architects, and construction firms had not anticipated and, consequently, struggled to understand that the success of the NZE approach heavily depends on the occupants' motivation and ability to change their behaviours. In other words, the role of occupants' behaviour in this process has been underplayed.

3.1.1. The Pre-Project Phase: Making People Accept the Approach at All Costs

It would seem essential to the success of the Energiesprong renovation, the purpose of which is summed up in a set of specifications (Box 2) and in which the use of energy is fundamental, that the inhabitants of Energiesprong projects should understand and accept it.

In fact, the need to obtain prior approval for the renovation projects from 70% of tenants in the Netherlands and from 50% in France complicates the task for building owners (Figure 2). In addition, the consumption and performance data of the renovated building have to be monitored in order to check that the NZE target is met, which requires the prior consent of the residents for these data to be used (this data collection process has to comply with the General Data Protection Regulation). In this very tricky phase, the landlords organise discussion meetings with residents in order to demonstrate the day-to-day benefits of Energiesprong and to address their questions and concerns (Woonwaard & BAM, 2016). A mismatch between the expectations of landlords and of residents can be found. While the primary goal for the landlord and the project consortium is energy neutrality, in most cases the priority for tenants is improving comfort and aesthetics, explains one Dutch landlord: "'I've got a lovely kitchen. I've got a nice bathroom. My toilet looks good.' Nobody talks about: 'I have an energy bill of zero'" (Landlord 1, interview, 2021). As a number of landlords explain, the concept of energy neutrality is not very obvious or very exciting for residents, since the savings on energy bills are only visible after a year of residence in the renovated space.

Similarly, while the most significant changes in terms of technical systems—the main topic of discussion and

Box 2. Energiesprong specifications.

Energiesprong projects are required to meet a particular set of specifications:

- The temperature within the home must be 21°C and not exceed 25°C for more than 10% of the year.
- The interior air quality and ventilation that is comfortable for occupants must be maintained at fixed levels.
- Domestic hot water consumption must remain below a certain threshold.
- The energy requirement of the dwelling must be below 25 kWhPE/m²/year, with the implementation of a performance guarantee regarding a real overall energy balance capped at 60 kWh/m²/year.
- The renewable energy produced must be at least equal to the consumption requirements (energy neutrality).
- Monitoring of the consumption and energy performance of housing units is required in order to meet the NZE target.
- The NZE target must be guaranteed every year in accordance with a standard situation based on "normal conditions of occupation" defined during the design of the project.

Source: Energiesprong (2021).

Figure 2. Stadskanaal. On the right, we can see a resident is in his garden, satisfied with his new house. On the left and in other houses of the district the renovation project did not take place because the residents were opposed to it.

innovation for the project consortium—are the installation of photovoltaic panels, a heat pump, and an external plant room (Figure 3) to manage the operation of the building's energy system and mechanical ventilation system, the residents are more interested in very practical and much less structural questions, such as the electric hob that replaces their gas cooker. This is in fact the issue around which opposition tends to crystallise, as one French design office project manager told us: "Removing their gas, that's also something that is difficult to explain to people" (Member of technical engineering firm 1). Some landlords even end up covering the costs associated with ditching gas, which is a change that can also put people off the project, in particular the need to acquire a whole new set of appropriate saucepans and frying pans.

Figure 3. External plant room installed in the garden in Hem (France) and Stadskanaal (Netherlands).

These two examples show how, in the pre-project phase, building owners and residents perceive the renovation project in different ways. The NZE concept remains an abstract one for the occupants, who are more interested in improvements in appearance and comfort. It should also be stressed that in this pre-project phase, most of the landlords interviewed, especially in the Netherlands, chose not to spend too much time talking about the significant behavioural changes that the new technical objects and systems (photovoltaic panels, heat pump, ventilation system, etc.) will require. As we will see, this choice, made in order not to frighten tenants and to persuade them to go along with the project, will have serious repercussions after delivery when tenants begin to experience the impact of the changes caused by the renovation.

3.1.2. Construction: Renovation Timespan and Work on an Occupied Site

In the Energiesprong specifications, the renovation work is carried out while the site is occupied and must be completed as quickly as possible: two weeks per dwelling, including a maximum of one week inside the house itself in order to limit the inconvenience for tenants. While the two-week limit for the work is usually respected, which is a noteworthy improvement on traditional renovation processes, the tenants will, in fact, be inconvenienced over a much longer period, notably because of the need to upgrade or remake the utility networks (electricity, gas, and fibre; Figure 4). In addition, work will continue across the neighbourhood as a whole for several months, which prompted this remark by the project representative of a design office working with a French consortium: "To say that it's only 15 days of renovation work for the tenants is somewhat sugar-coating the pill" (Member of technical engineering firm 2). From the point of view of the occupants, this way of working has the advantage that they do not have to move out while the renovation is underway. In the Netherlands, a communal house may be set up in the neighbourhood where tenants can rest, have a shower, or cook on days when the water and electricity are cut off in their homes.

On the other hand, managing the work is particularly difficult because the scale of the project (several hundred houses renovated at the same time) means that there is a wide variety of family and social arrangements, to which the construction firms and subcontractors have to adapt. An energy and technology manager of a Dutch construction firm explains:

> When you renovate 10 houses, you get 10 kinds of people. We have old people who need care. We got young people [who] go to school and need to study at home or do homework. We got people who are on holiday and don't want to give us the keys of the house. (Manager of construction firm 1)

While some companies apply the learning by doing and treat this complexity as an opportunity to develop the business and their skills in working on an occupied site, others fail to cope with the challenge. As a result, the quality of the work and the relationship with tenants are compromised, and the landlord and contractors tend to blame each other for the failure (interview with the project representative of a Dutch construction firm). In addition, our interviews reveal the lack of foresight, on the part of both the landlords and the occupants themselves, about the upheaval produced by the speed of the spatial changes during the work: "At certain point when

Figure 4. Public space affected by energy network upgrade in Wattrelos.

you're sitting in your living room you didn't have a window behind you anymore. At the front, you could walk straight out from your living room" (Landlord 1). A French landlord and constructor share the same feedback. It is at this point that the tenants become aware of the scale of the changes caused by the renovation to the space where they are living.

3.1.3. After Delivery: A Normative Approach to Changing the Behaviour of Residents

After delivery, the occupants should have the capacity to use the technical and digital devices to track their consumption and manage the equipment independently. The Energiesprong specifications stress that this personal monitoring should be "simple to use and accessible to everyone" (Energiesprong, 2021, p. 6). They also specify that the residents should be assisted so that they can use their new equipment to an optimum level.

When they move fully back into their homes (Figure 5), the tenants are invited to a further meeting where the aim is to explain the operation and use of the new systems. Long-term support may be arranged by the building owner or by the maintenance contractor in the consortium, with the aim of explaining to the occupants the right behaviour to adopt in the renovated house. Energy ambassadors can also be established, as happens in the Netherlands: These are people who have already experienced an NZE renovation and want to share their experience and help other households in the neighbourhood to get to grips with the new technologies. However, this approach remains fairly rare in the post-delivery follow-up of residents.

Despite this support, tensions emerge a few months after the delivery, concentrated around two topics: the extent to which the behaviour adopted by residents is consistent with the recommendations set out in the specifications; and the degree to which the occupants appropriate the renovated spaces, in particular the technical equipment and systems. The operation of these systems needs to be understood and practised. For example, the dwellings are very well insulated and use mechanical ventilation, which means that windows should be opened as little as possible. The support and information provided by the landlords resemble coaching. The aim is to push the tenants into changing their behaviour, which they may not enjoy, particularly because of the fact (as we saw previously) that the subject is not introduced sufficiently early on. "That's something, especially in the beginning, that took quite some anger with people because they said: It's quite another way of getting used to it," explains one landlord. An analysis of the language employed by landlords or energy maintenance firms shows that they often use expressions that indicate a normative attitude: "People have to find another way for their drier" (Landlord 1), or "in a hyper-insulated house dwelling with dual-flow ventilation, he [the tenant] needs to understand that he can't behave in the same way as he did with his old house" (Member of energy maintenance firm 1), or else "they [the tenants] have to take care that they're not using too much water" (Landlord 1). It is therefore up to the tenants to adapt and to adopt the right behaviour in accordance with the specifications and following the indications and information provided by the building owner and the consortium. Among these indications, there is also the idea that the new technical system is self-managing and that the ventilation, heating, etc., are regulated automatically. So, the tenants should intervene as little as possible in order not to disrupt the system, which they are expected to trust: "Before, they

Figure 5. Wattrelos. Once the renovation is complete, residents can reappropriate their homes.

[the tenants] had radiators in the living room. When it's cold, you turn up the radiator a little more. Now, they have to trust the system" (Landlord 2).

However, feedback from the building owners shows that these adaptations remain partial. First, the tenants find it hard or are unwilling to abandon their old habits (for example, they continue to open the windows rather than adapting to mechanical ventilation). Second, they may not understand the operation or the purpose of these objects and systems, as one Dutch landlord explains: "People don't know how to use it [the heat pump]. We explained it many, many times, provided people with a lot of explanation about usage, but still, people are not used to it" (Landlord 3; Figure 6). Or else they use the systems incorrectly, for example ignoring a malfunction warning signal which they do not know how to interpret or pressing buttons thinking that they are switching a device on, when in fact they are switching it off, etc.: "People just don't understand the whole concept of all these things being connected" (Landlord 3). What is lost is the very essence of this type of renovation project, the fact that everything is interconnected and that a mistake or wrong behaviour can compromise the energy balance of the whole system. Getting to grips with the new technologies is even more problematic for older people or people who do not speak the language of the country.

Feedback also shows that a partial understanding and a distorted interpretation of the project objectives can actually prompt tenants to adapt their behaviour but in the opposite direction to what the building owner wants. Households remember the slogan "E = 0" but do not link it with the notion of "good behaviour," so they adopt very energy-intensive habits in the belief that their energy bills will still be zero. We heard an example of this rebound effect from the representative of an architect firm in the Netherlands: "You can shower in 4–5 minutes. But if you think: 'I'm living in a very energy-efficient house, oh, I can also shower 10 minutes, it's fine.' Also in other projects, we see this kind of problems" (Architect 1).

While the aim of the Energiesprong approach is to reduce energy consumption and improve housing quality, the scale of the renovation work is so large and the changes so profound that they do not immediately get strong support from tenants. After several sessions to explain the benefits of this kind of renovation, the operation of the technical systems, and the consumption recommendations of the EPC, the project becomes a reality but not everything seems to be resolved. A gap remains: the issue of behavioural habits that are unsuited to a high energy performance building.

3.2. Whose Fault Is It? Mechanisms of Responsibility Sharing in the Event of Overconsumption

As we have seen, for the renovation project to achieve the results that the system is expected to produce and that the building owner and the consortium wants, the ways in which residents use the building and its amenities need to change significantly. In this section, we will raise the question of what happens if this behavioural adjustment does not take place. Who bears the risk associated with the EPC and who bears the cost of any overconsumption caused by misuse of the building? We will see that it is down to tenants to pay for any energy consumption that exceeds level "E = 0," but that arrangements are proposed to manage tricky or potentially conflictual situations.

Figure 6. Heat pumps and meters in Wattrelos.

3.2.1. Overconsumption Caused by Occupant Behaviour

Immediately after the delivery of the renovated buildings, monitoring of their energy performances begins. The tenants receive a letter with the login details needed to track their energy consumption figures online. Monitoring of the performance targets set in the preparation phase of the project is based on the measurement of several indicators:

- The building's total energy consumption (with a breakdown for heating and specific energy use);
- Domestic hot water consumption;
- Renewable energy production;
- Living space temperature;
- Recommended temperature of the heating thermostat.

When the building owner and the tenants obtain the first consumption data, one of two possibilities may arise. In the first, there is a sharp reduction in the energy bill, to the point that it comes close to, reaches, or even exceeds energy neutrality. In this case, tenants will obviously be very satisfied since the financial saving may be significant. In fact, the issue of reductions in energy consumption, although seen in terms of saving money rather than saving energy, becomes central and, as a result, attracts unconditional commitment to the project even from households that had expressed doubts or dissatisfaction in the previous stages, as was explained to us by an expert (who previously worked for a landlord) responsible for supporting landlords in their projects.

The second possibility is that energy consumption remains high. Our study was not intended to measure actual consumption after delivery, and it was not possible to collect quantitative data on this subject through the actors interviewed and for our case studies. Nevertheless, the interviews made it possible to qualitatively highlight the existence of significant performance gaps. A quantitative assessment of these gaps concerning other NZE renovations within the framework of Energiesprong shows differences both in real energy costs compared to the project plan and in households' energy bills compared between them (up to 950 euros per year per household; Borsboom et al., 2015).

This may be caused by the behaviour of the tenants (adopting the "wrong" behaviour or failure to adopt the "right" behaviour, rebound effects, omissions, and mistakes in the managing the technical systems, etc.). A landlord in the Netherlands gives a very striking example:

> I think last week, we even had a lady that said like, 'Oh, I have a really huge electricity bill.' No, it's the whole year she did not use the solar system at all because she switched it off….We have this really, really a lot. (Landlord 3)

In the event of differences between actual consumption and stated performance targets, the measured indicators will be used to assess whether the underperformance is explained by a gap between the actual conditions of occupation of the dwelling and the "normal occupation conditions" defined in the design phase (Energiesprong, 2021). Tracking this will make it possible to assess whether or not the failure to meet the targets—and hence the overconsumption—is attributable to tenant behaviour. If it is not, it is up to the contractor—which provides the EPC in the project consortium—to do what needs to be done to identify the cause or causes of the excess consumption (faults, adjustment, or installation errors, etc.) and to fix them, otherwise he becomes liable to the penalties set out in the contract. If, on the other hand, the excess consumption is attributable to the behaviour of the occupants, it is they who are required to pay the corresponding cost to the energy supplier.

This situation may be problematic for tenants. They will find themselves having to pay for excess consumption, which may equally be the result of free choice (they decide to set the thermostat to 22° C and not 21° C) or of a misunderstanding of how the technical systems work, a wrong setting, etc. The result will be dissatisfaction, complaints, and conflicts between the tenants and the landlord: "Now they [the residents] are using the house and they miss the old kind of heating….There are a lot of complaints, but complaints we can't fix because that's the system we chose" (Landlord 2). In a field case in the Netherlands, the tenants complain to the municipality and ask for help even if it's not directly their responsibility: "That is the problem. People come back and they say, 'You promised me a zero bill, but now I have to pay extra' " (Municipality 1).

3.2.2. Comparison Between Two Economic Models

In the Netherlands, the economic model adopted and enshrined in the Energy Prestatie Vergoeding (EPV) Law in 2016 provides for tenants to pay a sum equivalent to what they spent before on rent and energy, although the latter sum is supposed to be zero after renovation. The whole of this sum is paid to the landlord (while the energy supplier only receives the subscription fee), who therefore receives—in addition to the rent—the sum of money (called the "energy plan") previously paid to the energy supplier and can use the additional money to finance future NZE renovations (Figure 7). This means that, if energy neutrality is not achieved, the household will ultimately have to pay more than before the renovation. The danger of this model is that it could make households even more vulnerable by potentially exposing them to a greater risk of energy poverty.

For their part, landlords are also subject to heavy pressure in relation to tenants, but also in relation to the EPV mechanism, as was explained by a researcher who had worked on this issue: "The house might use too much energy and then they [the landlords] run into

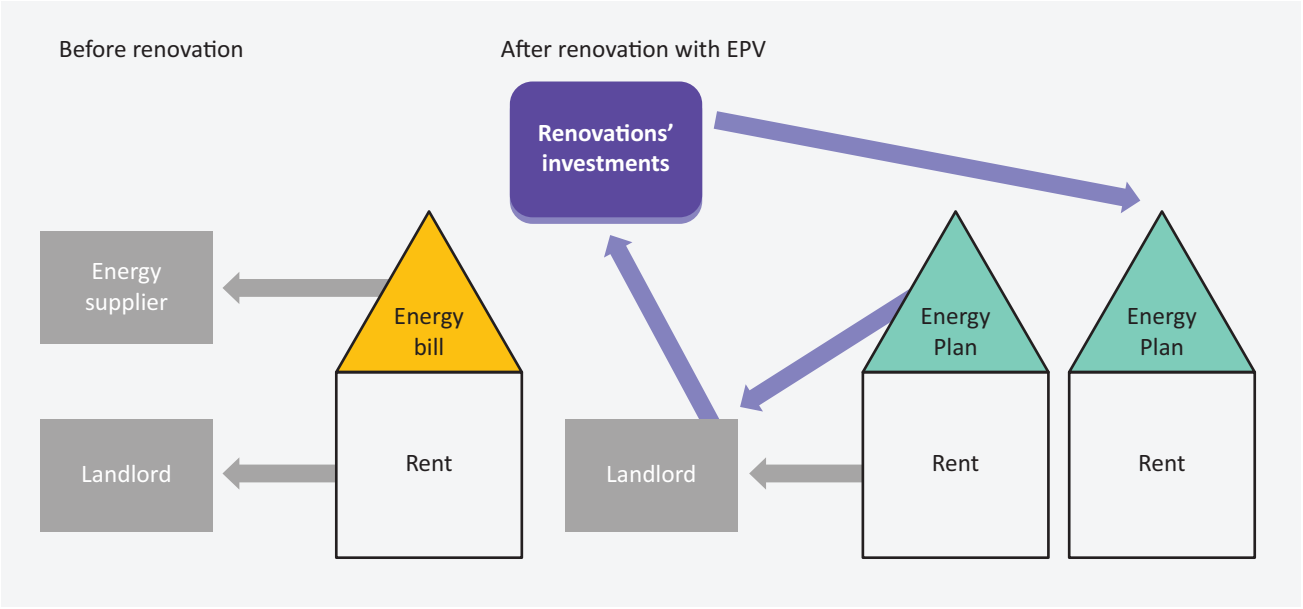

Figure 7. Economic model with EPV.

problems because it combines with the EPV. And it's a housing corporation so the people have low incomes and it's creating a problem of course" (Researcher 1). Indeed, if energy neutrality is not achieved, landlords lose their right to receive the money in the energy plan which is paid directly to them by tenants, unless they are able to show that the building had generated the agreed quantity of energy and that any shortfalls are attributable to the behaviour of the occupants.

In France, the economic model is different because landlords cannot manage the energy for their buildings and rent levels are heavily controlled. Tenants continue to pay their bills, usually significantly reduced, to the energy supplier. Landlords benefit by selling the energy produced by the photovoltaic panels and reinjected into the grid, can make modest rent increases in line with the legal parameters, and, in particular, can increase the maintenance charge through the tenant's energy efficiency contribution: They have the right to do this because they have carried out major energy efficiency improvements. However, by contrast with the Netherlands, the model here assumes that households spend less after renovation than before and that the reduction in the energy bill is much greater than the increase in the service charge and rent, as a French social landlord explained. In France, if there is any excess in consumption attributable to tenants' behaviour, energy bills should still remain lower than they were before the renovation work.

Whereas in France the process is still too recent for data on consumption and energy bills to be available yet, in the Netherlands, building owners have, on the one hand, had to negotiate more advantageous conditions for tenants and, on the other hand, to give a central place to the question of energy uses within the project. For example, one landlord offered the tenants of one of the sites where renovation work was underway the option of a guarantee that their expenditure on energy would never be greater than it was before the renovation:

> The next thing we did is we asked the people to give us their energy bill from the last three years….We made an agreement with them that if the house, the installation doesn't deliver the amount of energy we promised you, then the difference is from that moment on, you'll never pay more than your old energy bill. Everything else above that will be on us. (Landlord 1)

Building owners, but also the project consortia, are gradually realising the scale of the behavioural changes required of the occupants. In particular, they are becoming aware that they underestimated this factor, which has proved to be extremely important to the success of the project, as a landlord in the Netherlands acknowledges: "That also was something we didn't think over before: the complete change of environment for our people who rent our houses" (Landlord 2). This realisation has prompted some actors to question the way in which the specifications are constructed. The standardisation of behaviour assumed in them, as well as the average values calculated, cannot reflect the variety of the social situations within the renovated housing stock or the disparity of behaviours within a single building. A Dutch landlord gives an example:

> The boiler, that was a problem because we designed that thing in a household of 2.85 people. I never saw a household of that size, but we shall work with a family with three, four kids and they all want to shower before they went to work or school. When the mother

> wanted to do the dishes, she had no warm water because the installation was designed at the average of 2.85 people. (Landlord 1)

The need to take the sociodemographic characteristics of the tenants into account has acquired new importance in the eyes of building owners, but also for the intermediate contractors initially charged with developing the approach in the Netherlands (Platform 31):

> A few years ago, we started with the building type, so we made building topologies, but that turns out to be only a very small part of the puzzle because very different people with different social and economic opportunities can live in the same type of building. Of course, that's much more important, or at least equally important to the state of the building. (Platform 31, interview)

In the case of other actors, this realisation has not led to a rethink about the principles of the project, but reinforces the idea of a normative approach that requires a change in behaviour on the part of the tenants and more vigorous oversight of that behaviour, as evidenced by this extract from an interview with a sustainable development official in a municipal housing department: "We can tell people: 'Look, we promised you net zero but that is a technical thing. In real life, it can be higher. So, you have to adjust your lifestyle'" (Municipality 1). The support as currently provided thus seems insufficient, and some landlords recommend that it should be reinforced through the acquisition of new in-house project monitoring competencies.

4. Discussion and Conclusion

The results of our research show that the Energiesprong approach, like other projects of NZE renovation, opted for complexifying technical systems and equipment in order to attain the demanding ambitions of energy neutrality. This choice was made in a context of strong pressure to decrease the consumption volume of the existing building stock, requiring from social landlords a quantitatively and qualitatively high yearly renovation rate.

At the same time, this choice seems to neglect the results of a by now fairly rich scientific and grey literature showing that, for their part, occupants experience difficulties in adopting and adapting to such complex and integrated systems, which may compromise the whole enterprise and generate performance gaps (Gianfrate et al., 2017; Gupta & Gregg, 2016). As our research shows, in accordance with the literature, these performance gaps are characteristic of a number of projects involving the use of new technologies that deeply transform space and call for corresponding behavioural changes. Occupants may not want to change their behaviour, for example, because they prioritize comfort over the reduction of the energy bill (Pellegrino, 2013; Shove, 2003) or because they may simply not understand or be aware of how they should act (as shown also by Gram-Hanssen & Georg, 2018; McElroy & Rosenow, 2019; Topouzi et al., 2019; Zou et al., 2018). In other words, the way in which social landlords and building actors regard occupants' behaviours appears to be very prescriptive and based on the idea that occupants will eventually behave as expected by the EPC. But, as things turn out, occupants are far from behaving as *homo economicus* and do not act rationally and knowingly, maximizing their (selfish) utility and anticipating problems and solutions. As a result, as Geels et al. (2018, p. 24) suggest, "the dominant perspectives on reducing energy demand have a number of limitations and these limitations are reflected in the partial focus and frequent ineffectiveness of the current policy mix."

In this regard, the results of our research concur with and reinforce those of other studies, in particular on the factors that limit and foster the acceptance by residents of innovative renovation concepts (Gram-Hanssen, 2014; van Oorschot et al., 2016); on the need to include residents and give them support before and, in particular, after the renovation, in order to foster acceptance and trust (Sanders, 2020; van der Schoor, 2020); on the opinion of residents regarding the mechanisms of an NZE renovation and the subsequent level of satisfaction with it (van der Schoor, 2020); on the objections to renovations on the part of residents encountered by landlords (van Goor & Brink, 2020); and finally on the importance of taking behaviour into account in projects with an EPC (Jain et al., 2017; Lu et al., 2017).

In addition, this article explores the extent to which residents' behaviours are taken into account in an NZE renovation. It shows how, in all phases of the project, there is a mismatch between the way the project is perceived by the building owner and by the residents (as found by Wekker, 2020). In the pre-project phase, building owners are more interested in achieving a consensus in order to obtain the necessary agreement from tenants for the renovation work to go ahead. The emphasis is placed on improvements in comfort and aesthetic appearance, while the notion of energy neutrality is held in the background. There is very little or no prominence given to the need for residents to adjust their behaviour to the requirements of the new technical systems, and indeed building owners themselves underestimate the importance of this adjustment. Once the building is delivered, the behaviour of residents suddenly becomes a vital issue, because their failure to comply with the project specifications results in excess consumption and hence a failure of the NZE principle. Under the provisions of the EPV law, this failure has serious consequences for both residents and landlords.

What emerges from this research is also that strong performance and guarantee constraints have failed, at least in this approach, to radically change the way in which resident behaviour is considered and incorporated into the project, with the result that the disparities

between expected and actual consumption persist. This raises questions about the role of the EPC. On the one hand, it increasingly seems essential to the real success of an ambitious energy project, because it can be used to monitor the project at every stage and to identify the party or parties responsible (and therefore liable to penalties) for any failures and shortfalls from the targets. On the other hand, by setting a framework of essential targets, the guarantee excludes other objectives which, if not met, do not expose the building owner, the contractor, the design office, etc., to possible penalties. In other words, establishing explicit specifications for a set of behaviours that must be maintained in order to guarantee final consumption level signifies, at the same time, that any behaviour by residents that strays outside this framework is not covered by the contract and will make them liable for any impact on consumption.

This opens questions about the overall efficiency of the measure—the fact that an EPC of energy neutrality exists does not imply that actual consumption will be truly neutral, which was nevertheless the primary aim in view—as well as on the responsibility of the actors involved in the process: Who is bearing the risk of this contract?

Ultimately and paradoxically, the self-same technical solutions intended to ensure the success of the approach seem to contribute to its possible failure. This may lead to frustration, which affects building owners as well since, despite the EPC, as a result of the specific project choices, they find themselves facing excess consumption, additional costs, and complaints from residents. Our research findings also show that this frustration and these difficulties are real, but that, so far, they have only led to partial questioning of the fundamental principles of the approach. Some landlords wonder whether the imperatives of reducing energy consumption need to be pushed so far; others, as we have seen, wonder whether the specifications should be changed. More radically, some Dutch landlords are considering the advantages that might come from a more intrusive approach, which is to rehouse the former occupants and bring in new residents once the renovations are complete, who would find it easier to adopt the appropriate behaviour. This approach has already been tried in the Netherlands in operations where the decision is made to demolish and rebuild rather than to renovate and is often accompanied by a change of population.

In the end, there is still a long way to go before the occupant behaviour in a high energy performance renovation project is fully taken into account.

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Conflict of Interests

The authors declare no conflict of interests.

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