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Visscher, Henk; Meijer, Frits

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Visscher, Henk
h.j.visscher@tudelft.nl
Delft University of Technology, Faculty of Architecture and the Built Environment, OTB Research for the Built Environment,
Frits Meijer
f.m.meijer@tudelft.nl
Delft University of Technology, Faculty of Architecture and the Built Environment, OTB Research for the Built Environment

Abstract

The goals of energy saving and CO2 reductions to create an energy neutral building stock seem only to be reached by strict and supportive governmental policies. In Europe the Energy Performance of Buildings Directive and the Energy Efficiency Directive are driving forces for Member States to develop and strengthen energy performance regulations both for new buildings (via building approval procedures) and the existing building stock (via energy performance certificates or labels). The effectiveness of these current governance instruments and their impact on actual CO2 reductions are found to be inadequate for ensuring actual energy performance is achieved. To realize the very ambitious energy saving goals a radical rethink of regulatory systems and instruments is necessary. Building performance and the behaviour of the occupants is not well understood by the policymakers. Alternative forms of governance are needed which have more impact on the actual outcomes. Supportive governance to stimulate near zero renovations in combination with performance guarantees is a promising approach. Furthermore engagement with occupant practices and behaviours is needed. To ensure accurate outcomes-based governance a better understanding of building performance and behaviours of occupants must be incorporated.

Keywords: Building control, building regulations, energy performance, governance, housing stock, occupants

1. Introduction

Climate change mitigation is the most important driver for the ambitions to reduce the use of fossil fuels. There are also other reasons for implementing energy efficiency policies in the EU and its Member States. These include the wish to diminish the dependency on fuel imports, the increasing costs and the fact that fuel resources are limited as well as the impacts on public health. The European building sector is responsible for about 40% of the total primary energy consumption. To reduce this share, the European Commission (EC) has introduced the Energy Performance of Buildings Directive (EPBD) (2010/31/EC) and more recently the Energy Efficiency Directive (EED – 2012/27/EU). These frameworks require Member States to develop energy performance regulations for new buildings, a system of energy performance certificates for all existing buildings and policy programmes that support actions to reach specific goals (e.g. building only 'Nearly Zero Energy Buildings (NZEB)' by 2020 and realizing an almost carbon neutral building stock by 2050). Formulating ambitions and sharpening regulations are relatively easy to do. Technical solutions are currently available to realise the NZEB standard in building projects and an increasing number of NZEB projects are being built. However, substantial evidence exists that mainstream of building projects do not realize the expected energy performance in practice - the building performance gap. What is perhaps even more important in this respect is that the focus predominantly should be on the existing building stock. About 75% of the buildings that will comprise the European housing stock in 2050 has already been built today. Therefore, it is important to get insight in whether the energy performance certificates (EPCs) give reliable information or not. Many researchers have found evidence of the performance gap. This paper elaborates on this subject in next section. This is followed by reference to results of research by Guerra Santin (2009, 2010) focusing on the situation in newly built houses. The fourth section presents the findings of Majcen (2013a, 2013b, 2015) who studied in detail the relation between the energy labels (Energy Performance Certificates) and the actual energy use in dwellings. The fifth section discusses these findings in order to answer the main question: What could be adequate policies and regulatory tools to control the actual energy use in houses? The conclusions are presented in the final section. This paper is adapted from Visscher et al 2016.

2. Performance gap

Building regulations can only partially influence the energy use in a building. The other significant influence is determined by the behaviour of the occupant. The design and materialisation of a building can give better conditions for comfortable temperatures and in multi-occupancy residential buildings the lighting in the communal areas and use of lifts, so these aspects are subject of the regulations. All other forms of energy use in dwellings, (e.g. plug loads - refrigerators, washing machines, computers and cooking appliances) are not controlled by building regulations but covered by other legislation. In general, for older buildings the energy demand for space heating and cooling is dominant. In newer buildings with a very high level of insulation, the energy demand for appliances becomes dominant. Regulations focus on the design and in the best cases there is even some control on the performance of a building at the end of the construction process. However, after the building is occupied there is little if any control over the energy use. The energy calculation methods that are used or referred to in regulations are based on models and parameters of the performance of construction types and materials used an on the expected or modelled heating behaviour of the occupants. It is clear that all these models and assumptions do not accurately portray the actual energy use. This can be called the performance gap. The performance gap occurs for several different reasons: the built artefact does not match the design (substitutions and poor built quality), the mechanical services are not commissioned correctly, the inhabitants do not understand how to operate the building, the inhabitants' behaviour and practices are not as expected. Over the past 20 years numerous studies have compared the actual energy use with the expected or modelled energy use (Branco, Lachal, Gallinelli and Weber 2004; Cayre, Allibe, Laurent and Osso 2009; Sorrell, Dimitropoulos and Sommerville, 2009; Gram-Hanssen, 2010). The general pattern that follows from these studies is that for dwellings with a good (theoretical) energy performance the actual energy use in general is higher than modelled. For the dwellings with a bad (theoretical) performance, the actual energy use is lower. There are various explanations for these findings. For the presumed good performance buildings it is a combination of under performance of the building due to design and construction faults and changed behaviour of the occupants. This is partly the rebound effect (Berkhout et al. 2000; Galvin, 2015): if the conditions improve and the inhabitants think that the building is more energy efficient, they become less careful in their energy use behaviour (e.g. they use higher temperature settings, wear thinner clothing and operate the heating for longer periods). For the 'bad' performing buildings there is also evidence that the quality of the building could be under estimated. The U-values of solid walls in England were under estimated. Solid walls had been assumed to have U-value of 2.1 W/m2K, however recent research has shown a value in the range of 1.6 W/m2K (Li et al., 2015). Rasooli et al. (2016) found similar results in a study in the Netherlands. In addition to this there is large impact by the behaviour of the occupants. The models assume an average heating of the whole building, however in poorly insulated buildings the occupants are frugal and use heat sparingly, they also tend to heat only the spaces that they actually use.

3. Energy performances of new dwellings in practice

In 1995 energy performance regulation for space heating and cooling of newly built constructions were introduced in the Netherlands. The regulation consists of a standard (norm) that prescribes the calculation method which is called the Energy Performance Norm. The standard results in a non-dimensional figure called the Energy Performance Coefficient. Every few years the level of this Energy Performance Coefficient was decreased, representing a lower energy use demand for building-related energy use. In 2021 this Energy Performance Coefficient will be on the level of nearly energy neutral according to the EPBD. Since the introduction of the energy performance regulation there has been little assessment of the regulation's effect on the actual energy use in the houses. Two studies found no statistical correlation between the Energy Performance Coefficient level and the actual energy use per dwelling or per m2. Guerra Santin (2009, 2010) compared the actual and expected energy consumptions for 313 Dutch dwellings, built after 1996. The method included an analysis of the original energy performance calculations that were submitted to the municipality as part of the building permit application, a detailed questionnaire and some day-to-day occupant diaries. These combined approaches generated very detailed and accurate data of the (intended) physical quality of the dwellings and installations, about the actual energy use (from the energy bills) and of the households and their behaviour. The dwellings were categorised according to their Energy Performance Coefficient. Due to the relatively small sample size, the differences between the actual heating energy of buildings with different Energy Performance Coefficient values were insignificant. Nonetheless the average consumption was consistently lower in buildings with lower Energy Performance Coefficient, but not nearly as low as expected. In this sample, it was found that the increased level of the energy performance had very little effect on the actual energy use. Guerra Santin found that building characteristics (including heating and ventilation installations) were responsible for 19% - 23% of the variation in energy used in the recently built building stock.

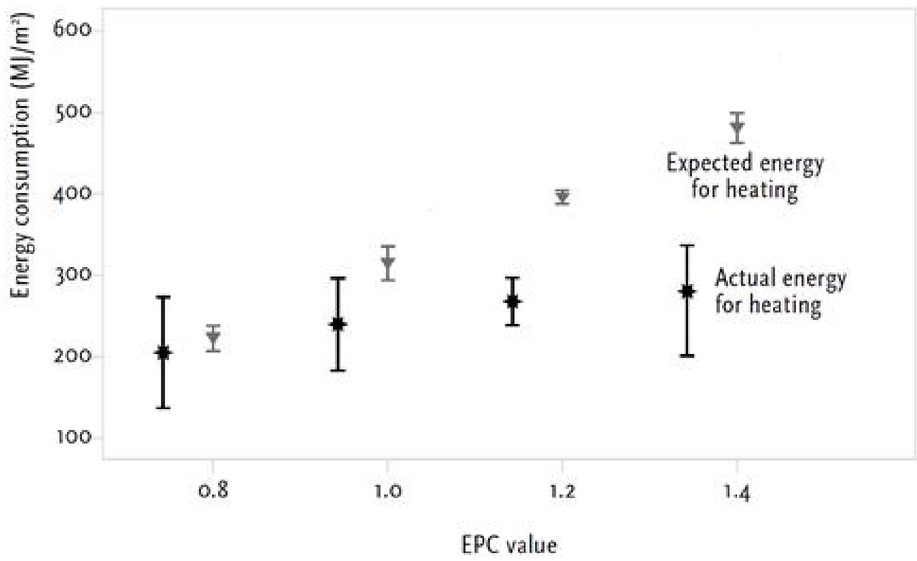

Figure 1 Mean and 95% confidence interval for the actual energy consumption (MJ/m2) and expected energy for heating (MJ/m2) per EPC value Source: Guerra Santin, 2009

Taking into account the above findings, it is doubtful whether further tightening of the energy performance regulations will lead to improvements in actual outcomes. Other and more efficient solutions exist to decrease the actual energy consumption of newly built dwellings. Important ingredients of the solution are: ensuring that appliances and installation are correctly installed, monitoring the calculated performances in practice; enlarging the know-how and skills of building professionals and creating an effective and efficient building control and enforcement process. Monitoring the actual performance in the completed building becomes more important.

4. Actual versus calculated energy use: existing dwellings

The largest energy saving potential is in the existing building stock. New dwellings add about one per cent per year to the housing stock in Europe. The most important policy tool required by the EPBD in the European Member States is the issuing of Energy Performance Certificates (or EPCs). These EPCs give a hypothecated indication of the required energy to provide a certain average temperature in the building and depend on physical characteristics of the building. The certificate has no mandatory implications in the sense that owners could be forced to improve their buildings to certain levels. Nonetheless it is a crucial instrument for benchmarking and formulating policy goals. Building owners in all EU Member States have to obtain an EPC for a building at the moment it is sold or rented out. This is not yet current practice everywhere, mostly due to lack of enforcement. This especially applies to the private housing stock. In a research project by Majcen (2013a, 2013b) the actual energy consumption was compared with the theoretical use according to the EPC's (see figure 2).

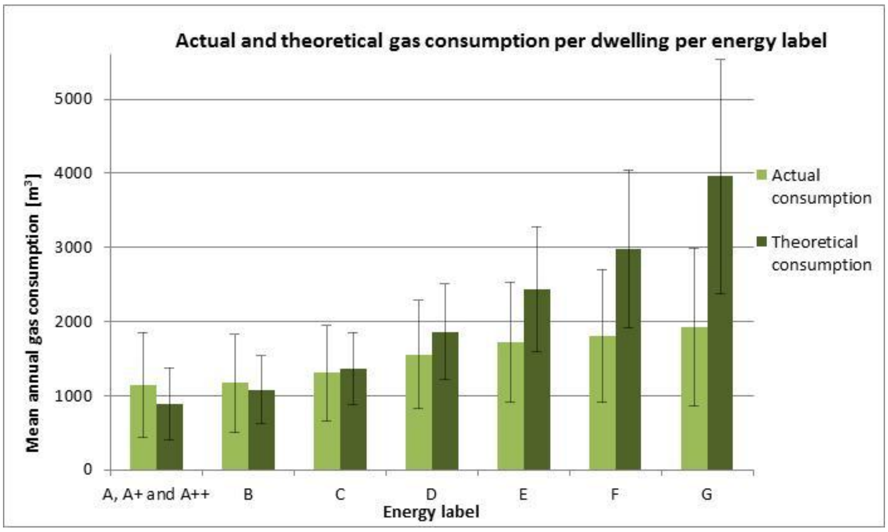

Figure 2 Actual and theoretical gas consumption in Dutch dwellings - per m2 dwelling area, Source: Majcen et al., 2013a

This research was based on the Dutch energy labels issued in 2010 - a total of over 340,000 cases with 43 variables (regarding building location and technical characteristics, the properties of the label itself etc.). This data set was derived from the publicly available database of the EPCs. This data was, on the basis of the addresses of the households, linked to actual energy use data. The energy data was provided by the CBS (Statistics Netherlands), which collected this data from the energy companies. The combined data file was then cleaned by deleting incomplete or obvious incorrect EPCs. This resulted in 193,856 usable cases. This still large sample proved to be representative for all housing types and energy label classes.

To understand how the energy label relates to the discrepancies, the gas and electricity consumption in various label categories were examined and analysed. The actual and theoretical gas use per dwelling was compared and then analysed per m2 of dwelling (figure 5). Little difference exists between the actual and theoretical energy use calculated per dwellings and per m2 , except the difference in actual gas use between label A and label B. At the level of individual dwellings, the actual consumption was identical, but at the level of m2 the dwellings in category A use less gas than dwellings in category B. This may relate directly to the fact that dwellings in label category A were found to be considerably larger than all other dwellings. From these figures it is clear that although better labels lead to higher actual gas consumption, there is a clear difference between the mean theoretical and mean actual gas consumption for each label. For the most energy-efficient categories (A, A+ and A++) and for category B, Figure 5 shows that the theoretical calculation underestimated the actual annual gas consumption. This is in contrast to the rest of the categories for which the theoretical calculation largely overestimated the actual annual gas consumption. This research indicates that the energy label has some predictive power for the actual gas consumption. However, according to the labels, dwellings in a better label category should use on average significantly less gas than dwellings with poorer labels, which is not the case.

5. Discussion: alternative policies and regulations to control energy use in dwellings

It is evident that current general regulatory instruments can only partly influence the actual energy use in houses. Regulations only address the energy use that is (partly) related to the physical condition of the building (as appliances and users are outside their scope). However, there needs to be a shift in focus to ascertain the 'as built' quality. For example, nearly zero energy buildings would require airtightness tests and infrared scans (to highlight any thermal bridging). The adequate functioning and the capacity of ventilation systems also needs testing. A differentiation is needed in regulations to account for in-use performance. This is because any mistake during the construction process will lead to a reduction of the minimum required performance and efficiency, thereby negatively influencing the energy demand. Analysing the actual energy use compared to the indications of the EPC’s gives a clear insight in the under prediction of the use in houses with good labels and large over predictions in the house with bad labels. This also leads to wrong assumptions of payback times of the investments. Strict regulations for new houses and retrofits will improve the physical performance of the building, but have a limited influence on the actual energy use. Given the limitations of current building regulations, what other forms of governance could be used to reduce the domestic energy use and CO2 emissions?

An innovative approach for deep energy renovations to nearly zero in the Netherlands is called the Net Zero Energy Renovation concept. Houses from the 1960s and 70s with a poor energy performance are retrofitted with a new highly insulated skin, air source heat pump heating and PV panels. The renovation process is highly industrialised and the renovation time is limited to two weeks or less. Currently these deep retrofits are mostly done to social housing (houses from housing associations). A change in governance has been influential. A new law allows the housing associations to increase the rent by the cost of the average energy bill. After the retrofit, the tenants only pay a higher rent but no energy bill at all, provided their actual energy use within a prescribed limit. This only works if the theoretical estimations of the actual energy demand are correct. Concurrent with this is the development of a new contractual obligation: an energy performance guarantee by the construction company. This is a kind of Energy Performance Contract where the owner occupant pays for the retrofit and gets a guarantee for a zero energy bill. In principle, the increase in rent should be offset by not having to pay an energy bill. The first evaluations are appearing now (Energiesprong, 2016), but they are only based on just a few cases. Some of the occupants are satisfied, but others are dissatisfied because the energy demand concept is below their expectation. It is based on lower indoor temperatures (20^{o}C), short times for showering and an energy sober life style. If these occupants exceed the allowed level of energy use, then they have to pay extra for it. There will be much variation among users but a reasonable baseline for normal energy demand may act as a positive influence on behaviours and practices. The near zero concept of houses will help to reduce the variation, but still there will remain some variation and really zero can't be guaranteed. This suggests that in addition to the physical aspects of creating a near zero building, there are also social aspects relating to energy demand that need to be addressed. However, the overall impact on energy and CO2 reductions from these buildings (and the underlying regime that created them) has been significant. Energy Performance Guarantees are basically a voluntary development by market parties. Until now, the underpinning governance has been supportive. The initiative was developed by an agency (Energiesprong which translates as 'Energy jump') and financially supported by the government. Recently the support programme has stopped and the expectation now is that the market should further develop it.

The policies for the existing stock are largely based on the EPC's. In the first place home owners and occupants are informed about the energy performance of a dwelling. This can influence buyers and should stimulate owners to renovate their homes. Often the incentive schemes use the concept of payback times. This is based on the argument why not invest (e.g. € 10,000) if this can be earned back in 10 years by a lower energy bill? The insights presented in this paper show that this hardly works for renovations on the skin of a building to reduce the heating demand. There is a slight reduction of energy use, but the comfort level increases (higher temperatures). To have a real impact on savings the retrofit should go to the level of near zero.

Another investment strategy is in on-site renewable energy generation. This is independent from the occupant behaviour. However, it is dependent on the energy price. The drastic reduction of the oil price in 2015 illustrates this. The feed-in tariffs for electricity are set by governments and are also unpredictable. In the Netherlands, homeowners can yearly feed in 3000 kW for the same price as the price they have to pay for electricity, which includes 75% taxes. This arrangement makes it very profitable to buy PV-panels. However the government is now considering a change to this regulation in 2020. This shows that taxes and incentives can be a very strong governance tool.

Murphy (2012, 2014) investigated how owner-occupiers respond to various kinds of incentives by the National and Local Dutch governments. Most of these incentives were connected to EPC's and advise on making houses more energy efficient. These forms of governance had only modest success. The willingness to invest in energy renovations is still limited, especially due to many uncertainties about the reliability of the contractors and the actual energy savings as found by Galvin (2014) in Germany.

Other forms of information about actual energy use seem more promising. Quarterly energy use reports of the energy companies give better insights and are related to previous year's corresponding quarter and to neighbours' energy patterns. Smart meters are nowadays installed on a large scale. In a few years most homes will have one. At the same time energy management displays are more and more used. Smart meters and these displays can be seen and used on smart phones. The insight will increase, but is this enough to stimulate energy saving behaviour including renovation investments? Studies (e.g. Darby, 2008) about the potential of giving accurate feedback to users about their behavior indicate that 5 to 10 % savings might be achieved.

6. Conclusion

To improve this situation for new buildings it has to be assured that constructions and installations are installed properly and in such way that they are not vulnerable for unpredictable or misuse by the occupants. This will set demands on both the construction industry and the control / enforcement process. The public building regulations and enforcement systems will continue to have an important role. The improvement of the existing building stock forms a big challenge. The potential energy savings are large, but the barriers to overcome are also high. Actual energy savings in renovated dwellings stay behind expectations due to rebound effects and lower than expected energy use in the old dwellings. Many owners believe that the benefits of the measures do not outweigh the costs. For all kind of governance policies and instruments, an accurate insight into the actual performances of buildings, actual energy use, behaviour and preferences of occupants will be essential. The unexplored territory for governance is how occupants' expectations, behaviours and social practices in using energy can be changed. Rational, economic incentives do not appear to be convincing or effective. Other levers, narratives and instruments are needed to monitor and encourage a frugal approach to energy demand and its management. To ensure the success of governance strategies and instruments, the support and engagement with occupants will have a vital role. This represents a new area for (national and municipal) governments and the construction supply side. For the latter, it will necessitate new forms of engagement with occupants to demonstrate optimised use and new social practices, as well as ensuring that energy performance guarantees deliver. The creation of positive feedback loops for inhabitants seems essential.

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