Energy regulations for houses in the Netherlands
Theory and practice

Visscher, Henk; Meijer, Frits

Publication date
2016

Document Version
Final published version

Published in
Proceedings of the RICS COBRA 2016

COBRA 2016

Toronto, Canada

20 - 22 September 2016

Supported by:

rics.org/cobra

RICS COBRA 2016

The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors

Held in Toronto, Canada in association with George Brown College

20 - 22 September 2016

ISBN: 978-1-78321-160-9

ISSN: 2398-8614

Royal Institution of Chartered Surveyors

Parliament Square

London

SW1P 3AD

United Kingdom

www.rics.org/cobra

ENERGY REGULATIONS FOR HOUSES IN THE NETHERLANDS: THEORY AND PRACTICE

Henk Visscher[1], Frits Meijer

[1] *Delft University of Technology, Faculty of Architecture and the Built Environment, OTB Research for the Built Environment, Julianalaan 134, 2628 BL Delft, the Netherlands*

ABSTRACT

A drastic reduction of use of fossil fuels in the built environment is urgent. The energy saving potential of the building stock is considered to be large and it is seen as the most cost efficient sector to contribute to CO2 reductions. According to the regulations and policies of the European Union in 2020 only nearly zero energy buildings will be build and by 2050 a the whole building stock should be energy neutral. The current practice shows that the energy saving goals can only 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 EU Member States to develop and strengthen energy performance regulations both for newly built buildings (controlled via building approval procedures) as for the existing building stock (via energy performance certificates or labels). This paper presents some insights in in the theory and the practice. Actual energy use deviates considerably from the required or modelled energy use. The performance of buildings and building services are not as expected and the behaviour of the occupants seems not well understood by the policymakers. This is concluded from on-going research. What could be alternative approaches for the current used governance approaches?

Keywords: Building regulations, energy performance regulations, energy performance certificates.

INTRODUCTION

Climate change mitigation is maybe 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. 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, the 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 and energy performance certificates for existing buildings. There are also policy programmes that support actions to reach the goals like building only 'Nearly Zero Energy Buildings (NZEB)' by 2020 and to realize a 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 more and more NZEB projects are being build. However, there is quite some evidence that the mainstream of building projects do not realize the expected energy performance in practice. What is perhaps even more

[1] h.j.visscher@tudelft.nl

important in this respect is that the focus predominantly should be on the existing building stock. About 75% of the buildings that will make up the housing stock in 2050 have already been built today. For this purpose it is important to get insight in weather the energy performance certificates give reliable information or not.
More and more researchers have found evidence of the so-called Performance Gap. This paper elaborates on this subject in the next section. Furthermore some insights in the results of energy performance regulations for newly built houses are presented. The next sections shows insights in the relation between the energy labels (EPC's) for existing dwellings and the actual energy use in dwellings. Finally the results are discussed and conclusions are drawn.

THE PERFORMANCE GAP

In the last few decades many European countries have introduced various energy saving requirements in their national building codes. Before the nineteen seventies there were no such regulations at all, but after the first oil crises in the mid-nineteen seventies the firsts demands on minimum U values for walls were introduced. In 1995 the Netherlands replaced the more prescriptive forms of regulations by energy performance requirements, which should give more freedom to find innovative solutions to reduce the total amount of energy use of the building. Since the introduction of the EPBD all EU member states are required to set up some form of energy performance regulations. Building regulations are meant to prescribe a minimum accepted quality level of a building according to societal needs. The characteristics of a building can influence the energy use only partially. The actual energy use is determined by the behaviour of the occupant. The design and materialisation of a building can give better conditions for comfortable temperatures and in 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, like for refrigerators, washing machines, computers and cooking appliances are not controlled by the regulations. In older buildings the energy used for space heating and cooling is dominant. In newer buildings with very high levels of insulation, the electricity use 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. Once the building is being used there is no control on the energy use. The 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 can lead to deviations with the actual energy use. This can be called the Performance Gap. The term Performance gap might suggest that the deviations are mainly due to different than expected performance of a building, but as described before it can have various reasons including the behaviour of the occupants.
In recent years more and more studies were carried out to compare the actual energy use with the expected or modelled energy use. The general pattern that follows from these studies is that in dwellings with a good (theoretical) energy performance according the actual energy use in general is higher than modelled and in the dwellings with a bad (theoretical) performance, the 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 so called rebound effect: if the conditions improve and the people have the idea that the building is more energy efficient,

they become less carefull in their energy use behaviour and for instance use higher temperature settings and wear thinner clothing. 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 seem to be highly under estimated. In a study on solid walls with on an average assumed U value of 2.1 W/m2K, in fact a value of 1.6 W/m2K were found (Rye e.a. 2011). In addition to this there is large impact by the behaviour of the occupants. Where the models assume an average heating of the whole building in the older building the occupants tend to heat only the spaced that they really use.

THE REALISATION OF REQUIRED ENERGY PERFORMANCES FOR NEW DWELLINGS IN PRACTICE

In 1995 energy performance regulations for space heating and cooling of newly built constructions were introduced in the Netherlands. The regulation consisted 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 (EPC, not to be confused with the Energy Performance Certificates for existing buidlings described in the next section). Every few years the level of this Energy Performance Coefficient was decreased, representing a lower energy use demand for the building related energy use. In 2021 this EPC will be on the level of nearly energy neutral according to the EPBD. Since the introduction of the energy performance regulations only a few studies were carried out to assess the effect of the regulations on the actual energy use in the houses in reality. The samples were of limited size as well. Two studies found no statistical correlation between the energy performance coefficient level and the actual energy use per dwelling or per square meter. Analysis of the WoON (2009) survey, that was carried out on behalf of the Dutch government in 2006 containing a representative sample of 5000 dwellings, also found no correlation between the different levels of the energy performance coefficient and the actual energy use per dwelling and per square meter (see Figure 1). 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 diary’s. 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 EPC. Due to the relatively small sample size, the differences between the actual heating energy of buildings with different EPC values were insignificant. Nonetheless the average consumption was consistently lower in buildings with lower EPC, but by far not as low as expected. In this sample the increasing level of the energy performance over the years appeard to have very little effect on the actual energy use. Guerra Santin found that building characteristics (including heating and ventilation installations) were responsible for 19% to 23% of the variation in energy used in the recently built building stock. Household characteristics and occupant behaviour seemed to be responsible for 3% to 15% of the total variance due to the rebound effect. On the basis of this study and other literature one can state that building characteristics, household characteristics and occupant behaviour altogether are responsible for at most 38% of the variation on energy consumption of dwellings built after 1995. Therefore at least 62% of the variation in energy use was unexplained by theoretical performance and behaviour and must be caused by other reasons.

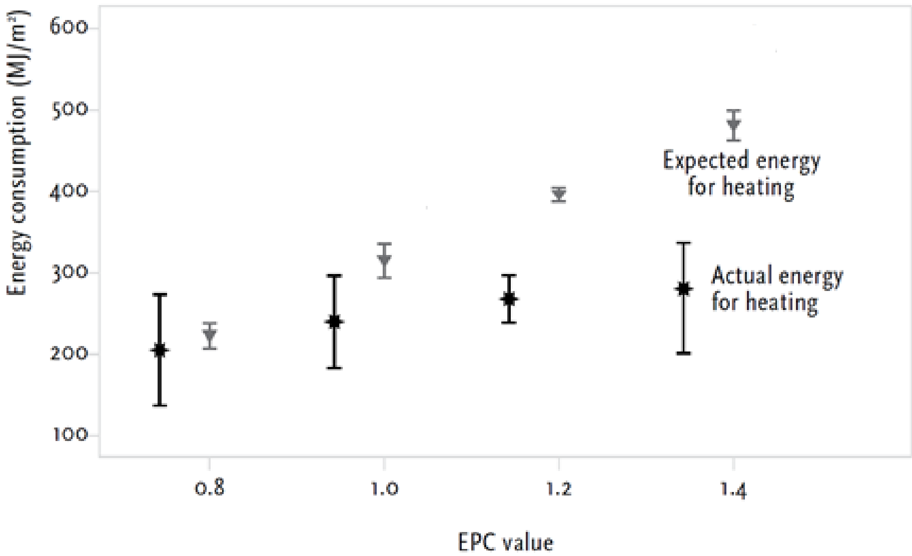

Figure 1 Mean and 95% confidence interval for the actual energy consumption (MJ/m2) and expected energy for heating (MJ/m2) per EPC value (Guerra Santin, 2009)

There are also indications that the gap is related to design and construction faults and that heating services operate in very different conditions than assumed beforehand. Nieman (2007) showed that in a sample of 154 dwellings, 25% did not meet the energy performance requirements in the design phase because of mistakes in the calculations. Nevertheless the building permit was issued. In 50% of the dwellings, the realization was not in accordance with the design. These results comply with other findings about inadequate performance of the building industry but also by a low level of quality monitoring by the construction parties and the poor performance of the building control authorities in the Netherlands and other countries (Meijer e.a. 2002, 2006, 2008, Heijden, e.a. 2007). Taking into account the above findings, one can have some doubts if further tightening of the energy performance regulations will lead to a better energy performance in practice. Perhaps there are other and more efficient solutions to decrease the energy consumption of newly built dwellings in practice. 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 putting in place an effective and efficient building control and enforcement process. Checking the actual performance in the completed building becomes more important. The Dutch building control system is currently being reviewed. A new law on quality assurance for buildings will be introduced shortly. The main change will be that the responsibility for plan approval and site inspections will change from municipal authorities to private parties. At the same time the emphasis in the new system is more on assuring that the building 'as built' complies with the regulations. For many decades the main focus of building control in the Netherlands has always been on the design. So, this change can be considered as step in the right direction. It is unclear yet how detailed such a compliance check on the completed building for the energy performance will be. For nearly energy neutral buildings it would have to include blower door test to check the air tightness and / or infrared scans to find thermal leakages. Never the less after the building is completed a new 'uncontrollable' situation starts for the actual energy use when the occupants start using the house.

ACTUAL ENERGY USE VERSUS CALCULATED ENERGY USE IN 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 EPC's). These EPC's give an indication of the energy that is required 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 the Netherlands however, the complete social housing stock is labelled with an EPC. The social sector in the Netherlands is still relatively large (35%) and well organised. For the social housing stock the EPC's are collected in a database called SHAERE. With this database the progress of the renovation practices can be monitored. Besides that the relation between the EPC's (with the calculated energy use) and the actual energy use can be studied. A few years ago the sector formulated ambitious programmes, but these have been scaled down because of several reasons. The economical crises in 2008 reduced the financial capacities of the housing associations.

The housing market also dramatically slowed down which also affected the funding for renovations because this largely depends on the sales of property. Also it proved to be difficult to get approval of tenants for

renovations that require an increase of the rents (70% of the tenants have to agree). It is hard to assure the saving of energy costs resulting of the improvement of the dwellings. All in all the progress of renovations and energy upgrading measures stay far behind expectations and the in 2008 formulated ambitions

The social housing sector agreed with the government and the National Tenants Union to a covenant about energy renovation goals. Most important goal is to reach an average label B in 2020 for the whole sector, which comprises 2.3 million dwellings (35% of the total stock). Research with the SHAERE data base shows the progress in renovation. Figure 2 demonstrates the label steps over the years 2010 to 2013. It can be noted that most of the renovations have led to small improvements. If the current figures are extrapolated to 2020, we can see that the goals of an average label B will not be reached. The label indexes relate the calculation of the Energy Index, which is for label B 1,25.

The actual domestic energy use is, besides the physical characteristics of a dwelling, largely influenced by the use and behaviour of the tenants. Some preliminary figures demonstrate the difficulty in 'forcing' reduced energy use by improvements of dwellings. The dwellings with the worst EPC (G) in practise use far less energy as expected, while the most energy efficient dwellings (A) use much more. This is probably due to a combination of the rebound effect and an increase in comfort level of the dwellings and underperformance of the buildings and installations. Figure 5 shows the actual and theoretical gas consumption per dwelling per EPC. These findings for the Dutch housing stock were first generated in a research project by Majcen (2013a, 2013b).

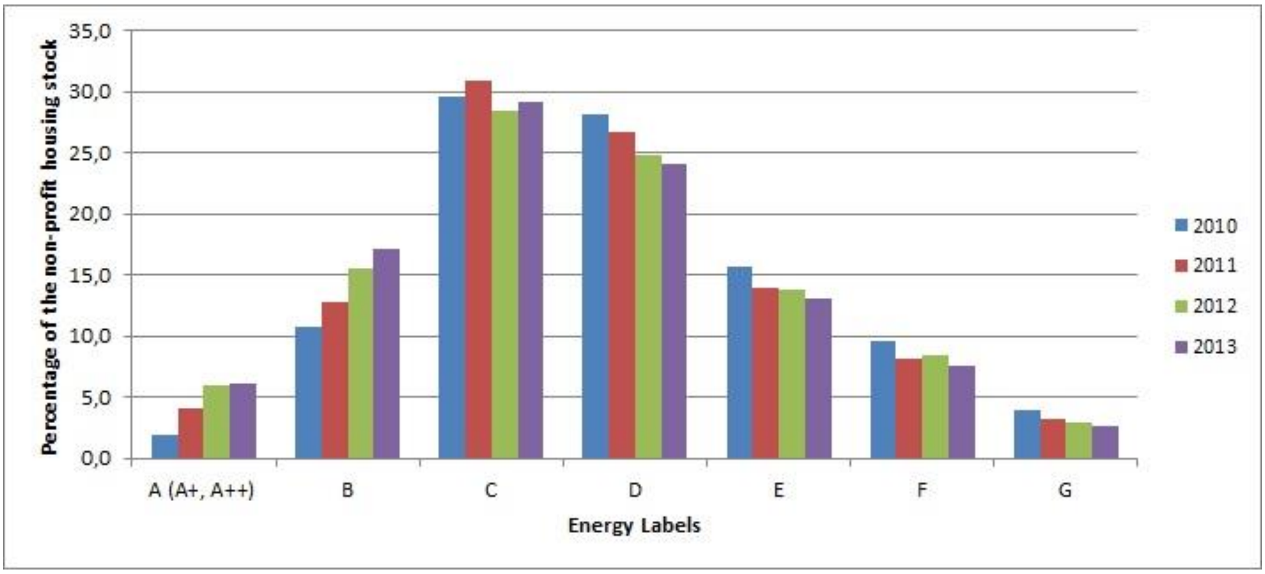

Figure 2: Distribution of the energy labels of the non-profit rented housing sector in SHAERE database (Filippidou, F, e.a., 2014)

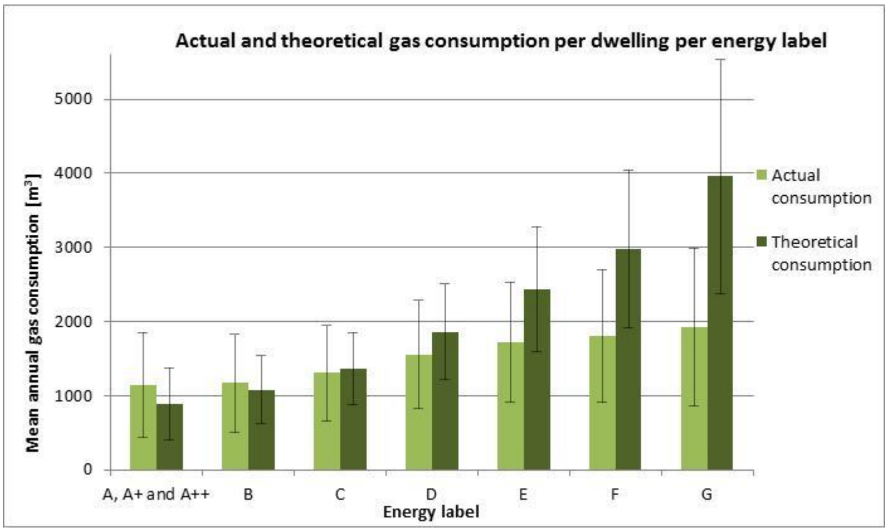

Figure 3 Actual and theoretical gas consumption in Dutch dwellings (Majcen et al., 2013a)

This research was based on the Dutch energy labels issued between 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 EPC's. This data was, on the basis of the addresses of the households, linked to actual energy use data, provided by the CBS (Statistics Netherlands), which collected this data from the energy companies. The combined data file was then cleaned up by deleting incomplete or obvious incorrect EPC's. 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 in a next step it was analysed per

square metre of floor area of dwelling (figure 5). Almost no difference can be seen between these, 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 square metres of floor area, 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 lower 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, in contrast to the rest of the categories for which the theoretical calculation largely overestimated the actual annual gas consumption.
It appears from this research 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. The actual heating energy consumption is on average lower than theoretical consumption levels for most buildings (in this study for dwelling with labels C to G) as was observed previously by Guerra Santin e.a. (2009), Branco e.a. (2004) Tigchelaar e.a. (2011), Cayre e.a. (2011) and Hens e.a. (2010). Guerra Santin already pointed out that at a lower EPC value, the difference between the expected and actual consumption will be smaller. This study has proved this, and showed that even in very energy-efficient buildings actual gas consumption can exceed the predicted levels.

DISCUSSION AND CONCLUSION

Developments in building regulations and control

In the Netherlands as well as in many other countries, the building regulations are a recurring subject in the debate of governmental reviews. On the one hand regulations should be minimized to reduce the administrative burden on citizens and businesses. On the other hand, new quality themes emerge that require regulatory intervention. Energy reduction and climate change are such themes. The European Union and its Member States have implemented regulations and enforcement schemes that should ensure very energy efficient new buildings and have introduced instruments to improve the energy performance of the existing building stock. Although the general deregulation trend in Europe has led to less governmental intervention in the building sector, in the field of energy efficiency the number of regulations have increased and became more stringent. The desire for deregulation has led to a greater emphasis on the responsibility of building owners and actual quality control has been transferred from the municipalities to private parties. At the same time the emphasis of the quality control moves from the design to the as built situation. The increasing importance of assuring energy performance in this development of the regulations seems not to get the attention it would deserve. The high potential and expected energy savings in buildings increases the need for accurate quality control.
The past few years OTB – Research for the Built Environment, Delft University of Technology, has been involved in studying alternative visions on building regulatory systems in international comparative projects (eg. in ECORYS e.a. 2015). What can be noticed in most countries are discussions (or sometimes even concrete developments) where the balance slowly shifts from:

- Command and control regulations towards more economic incentive based policies.
- Public control and enforcement towards a more dominant role of private parties/building professionals (together with the materialisation of far more robust and reliable certification and accreditation schemes).
- A strong focus on control of the design to monitoring of the building process and testing of the quality of the final building and post occupancy monitoring.

For a successful transition towards energy neutral construction stricter demands must be set on the knowledge and skills of the building professionals (designers, engineers, installers, constructors, etc.). They will have to use new techniques and improve the quality and accuracy of the work. This means that they not only will have to improve their operating procedures but also have to implement performance guarantees. Maybe the competent persons scheme in England could be an interesting example for this. Owners and users will require quality guarantees from the designers, installers and constructors. Certification and accreditation of parties, processes and products will become more important for building processes in general. For the realization of high energy performance standards, a reliable quality assurance system will be very important. In most countries that have some experiences with passive houses some form of performance guarantee and associated quality assurance scheme exists.

Misfits of current regulatory approaches

In the analyses we have seen that with the current approach of the general regulatory tools the actual energy reduction in houses is only influenced partly. Firstly it only adresses the energy use that is partly related to the physical condition of the building. Fair enough, building regulations want to influence the building not the users. A large share of the domestic energy use (the appliances) is in this way not controlled at all. Besides that the part that could be influenced by the regulations, still needs improvement. The control should be focussed on the quality of the as built situation. For nearly zero energy buildings it would require airtightness tests and infrared scans. At the same time there should be much attention for the adequate functioning and the capacity of ventilation systems. Regulations should guarantee a basic minimum level, but for many quality aspects the design quality in practice should be and is on a higher level. In the Netherlands we can see that in most building plans the requirements for ventilation capacity in the building regulations are used as the design level. This appears to be very risky. Any mistake during the construction process will lead to a reduction of the minimum required performance, and when the building is being used natural pollution of the system will further reduce the performance. A poor performing ventilation system will lead to more opening of windows and thus negatively influence the energy use.

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 leads to wrong assumptions of payback times of the investments.

Strict regulations for new houses and when renovating the old ones do increase the physical performance of the building, but have a limited influence on the actual energy use.

Energy Performance Guarantees

An innovative approach for deep energy renovations to nearly zero in the Netherlands is called the Net Zero Energy Renovation concept (Rovers, 2014). Houses from the nineteen sixties and nineteen seventies with a poor energy performance get a new highly insulated skin, heat pump heating and PV panels. The renovation process is highly industrialised and the renovation time is limited to a few days. Currently it is mostly done with houses from housing associations. A new law allows the housing associations to increase the rents with an assumption of costs of the average energy bill. After the renovation the tenants only pay a higher rent but no energy bill at all, as long as their actual energy use is limited. This only works if the theoretical estimations of the actual energy use were right from the start on. The approach is also developped for owner-occupants which are given a energy performance guarantee by the construction company. This is a kind of Energy Performance Contract. Also in this case the owner occupant pays for the renovation and gets a guarantee for a zero energy bill. The first evaluations are appearing now (Energiesprong, 2016), but they are only based on just a few cases. It appears that a part of the occupants are satisfied, but for occupants the concepts are based on too low temperatures (20^{o}C), sometimes too short times for showering and also a quite energy sober life style. If these occupants exceed the allowed level of energy use, they will have to pay for it. According to the presented insights in actual energy use we can understand that there will be much variation among users. The near zero concept of houses will reduce the variation, but still there will remain some variation and really zero can't be guaranteed.

REFERENCES

BPIE (Buildings Performance Institute Europe) (2011), *Europe's buildings under the microscope*

Branco, G., Lachal, B., Gallinelli, P., Weber, W. (2004) Predicted versus observed heat consumption of a low energy multifamily complex in Switzerland based on long-term experimental data, *Energy and Buildings*, Volume 36 (6) 543-555.

Cayre, E., B. Allibe, M. H. Laurent, D. Osso (2011), There are people in this house! How the results of purely technical analysis of residential energy consumption are misleading for energy policies, *Proceedings of the European Council for an Energy Efficient Economy (eceee) Summer School*, 6–11 June 2011, Belambra Presqu'île de Giens, France.

Cohen, R., Bordass, B., (2015), Mandating transparency about building energy performance in use, *Building Research and Information*, 43 (4) 534-552.

DECC (Department of Energy and Climate Change), Brook Lyndhurst, (2012) *Domestic Energy Use study: to understand why comparable households use different amounts of energy*.

ECORYS, Delft University of Technology (2015), *Simplification and mutual recognition in the construction sector under the Services Directive*, European Commission

Energiesprong (2016). *Eerste ervaringen met prestatiegarantie voor nul op de meter woningen* (First experiences with performance guearantees for zero on the meter dwellings).

Filippidou, F, Nieboer, N, Visscher, H, (2014), The Pace of Energy improvement in the Dutch non-profit housing stock, in *Proceedings of SB 14, World Sustainable Building Conference*, Barcelona.

Filippidou, F, Nieboer, N, Visscher, H, (2015), Energy efficiency measures implemented in the Dutch non-profit housing sector, *ECEEE conference, France*

Guerra Santin O., Itard L. and Visscher H.J. 2009, The Effect of Occupancy and Building Characteristics on Energy Use for Space and Water Heating in Dutch Residential Stock, *Energy and Buildings*, 41, 1223-1232.
Guerra Santin O. and Itard L. 2010, Occupant behaviour in residential buildings in the Netherlands: Determinants and effects on energy consumption for heating, *Building Research & Information,* 38 (3), 318-338.
Hamilton, I.G., Summerfield, A.J., Lowe, R., Ruyssevelt, P., Ewell, C.C., Oreszczyn, T. 2013, Energy epidemiology: a new approach to end-use energy demand research, *Building Research and Information* Vol. 41 (4), 482-497.
Heijden, J. van der, Meijer, F, Vischer, H., (2007), Problems in enforcing Dutch building regulations, *Structural Survey,* 25 (3-4), 319-329.
Hens, H., Parijs, W. and Deurinck, M. (2010), Energy consumption for heating and rebound effects, *Energy and Buildings*, 42 (1), 105-110.
Meijer, F.M., Visscher, H.J. and Sheridan, L., 2002, *Building Regulations in Europe, part I: A Comparison of systems of building control in eight European countries*, Housing and Urban Policy Studies 23, Delft, Delft University Press.
Meijer, F.M. and Visscher, H.J., 2006, 'Deregulation and privatisation of European building-control systems', *Environment and Planning B: Planning and Design*, Volume 33 (4), pp. 491-501.
Meijer F.M. and Visscher H.J., 2008, 'Building regulations from an European perspective', in *Proceedings of COBRA 2008* - The construction and building research conference of the Royal Institution of Chartered Surveyors, RICS, London.
Majcen, D., Itard, I. and Visscher, H.J. 2013a, Theoretical vs. actual energy consumption of labelled dwellings in the Netherlands: Discrepancies and policy implications, *Energy Policy* 54, 125 – 136.
Majcen, D., Itard, L., Visscher, H.J. 2013b, Actual and theoretical gas consumption in Dutch dwellings: What causes the differences? *Energy Policy*, 61, 460-471.
Majcen, D., Itard, L., Visscher, H.J. 2015, Statistical model of the heating prediction gap in Dutch dwellings: Relative importance of building, household and behavioural characteristics, *Energy and Buildings*, 105, 43-59.
Nieman 2007, *Final report Housing quality indoor environment in new built dwellings*, Vrom inspectie Regio Oost, Arnhem.
Rovers, R., (2014), New energy retrofit concept: 'renovation trains' for mass housing, *Building Research and Information*, 42 (6) 757-767.
Stevenson, F, Leaman, A., (2010a) Evaluating housing performance in relation to human behavior: new challenges, *Building Research and Information* 38 (5), 437-441.
Stevenson, F, Leaman, A., (2010b) Developing occupancy feedback from a prototype to improve housing production, *Building Research and Information* 38 (5), 549-563.
Tigchelaar, C., Daniëls, B., Maenkveld, M., (2011) Obligations in the existing housing stock: Who pays the bill?, *Proceedings of the European Council for an Energy Efficient Economy, Eceee Summer School*, 6–11 June 2011, France.
WoON Energie, 2009, Woononderzoek Nederland, module energie, VROM.