EFFECTS OF THE DUTCH ENERGY PERFORMANCE REGULATIONS ON ENERGY SAVINGS IN DWELLINGS

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Abstract

In the Netherlands the energy consumption of new buildings is subject to performance based legislation, based on the Energy Performance Coefficient (EPC). The norm has been compulsory for almost 15 years, but only three surveys, one of them by the authors, were conducted to assess its effectiveness to reduce the actual energy use. The research described in this paper is based on the statistical analysis of several national databases and on the statistical processing of samples of dwellings representative for dwellings build after 1995. Although the consecutive strengthening's had no significant effect, the introduction of the energy performance regulation itself had an effect on the actual energy use. A correlation was also found between the actual energy use and the expected energy use calculated according to the energy performance regulation. This expected energy use for heating represents only one component of the EPC calculations and its effect seems to be counteracted by the other factors used to calculate the EPC-level. In addition we found that the characteristics of the building and heating equipment together with household characteristics and occupant behaviour explain only up to 42% of the variation in energy use. This could indicate that most dwellings are not realized as they are designed on paper and that it could be more efficient to ensure a correct realization of the calculated performances than to tighten the EPC level further.

1. Introdution

In the Netherlands the energy consumption of new buildings is subject to performance based legislation. The energy performance is based on the Energy Performance Coefficient (EPC). The lower the EPC, the more energy efficient the building should be. Ever since its introduction in 1995, the EPC-value has become stricter. At that time, the compulsory EPC-level was 1.4. Since then it has been lowered regularly down to a value of 0.8. It is likely that the level will be lowered again in the near future. In the framework of the Energy

Performance of Buildings Directive, 30 European EN-norms are being developed to establish the methods on which the energy performance is calculated. In the Netherlands, the norm has been compulsory for almost 15 years now and the evaluation of its effects on the actual energy used in dwellings should be useful to determine the efficiency of this type of regulation. In the present paper the effect of the Dutch EPC regulation on the energy use for heating in dwellings built after 1995 is assessed. In the chapter ‘methods and data’, the theoretical relationship between EPC and energy use for heating is briefly presented, as well as the main sources of literature and databases. The samples used for the analysis are described. The results of the statistical analysis on EPC, actual energy consumption and determinants of energy consumption are then presented. Finally, in the chapter conclusions and recommendations these results are discussed.

2. Methods en Data

2.1 Theoretical relationship between the EPC and the actual energy used for heating

The linker part of Figure 1 shows the relationship between the EPC and the different energy consumption items. The EPC-value accounts for space heating, space cooling, tap water heating, and electricity needed for mechanical ventilation en lighting. Energy use for cooking and electricity consumption for white and brown goods is excluded, because they are not related to the building itself. The right part of Figure 1 shows what is measured in practice for a) a dwelling with both electricity and gas connections (the most common supply in the Netherlands), b) a dwelling with both heat (district heating) and electricity connections and c) an all electric dwellings. It is evident in all cases that there is no direct match between the measured consumption and the components of the EPC. Monitoring the EPC is therefore not an easy task because it cannot be achieved by conventional monitoring (monitoring of the energy used at the meter box, getting the data either from the occupants either from energy companies).

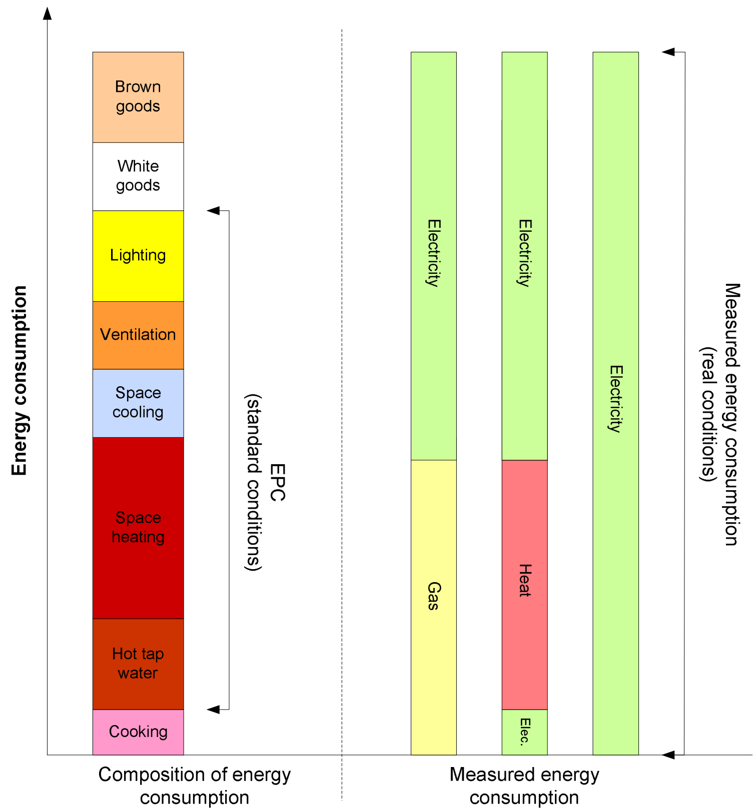

Figure 1: Build-up of the EPC and relationship with measured energy consumption.

Another difference between the EPC and the actual energy use is that the EPC calculate the primary energy consumption, which takes into account the efficiency of the energy distribution and conversion outside the dwelling. Measurements at the meter box of the dwellings don't. However, this is not problematic because the same conversion factors as in the EPC can be applied to make comparison possible.

The calculations on which the EPC-value is based are made for standard conditions, established in de norm NEN 5128 (2004). In these standard conditions, fixed values are used for temperature settings, internal heat gains, ventilation flow rates, heating demand for hot tap water and lighting. These values are assumed to be representative for an average Dutch household. Data from monitoring are dependent on actual conditions and preferences. However, in a statistical study based on a representative sample, the differences should be evened out.

To obtain the EPC-value, the total primary energy use for hot tap water, space heating, space cooling, ventilation and lighting is corrected by a neutralization factor that must correct for the size of the dwelling. A policy precondition to the implementation of the EPC was that a large dwelling with the same thermal quality as a small dwelling should not be penalized for its size, although it probably will consume more energy because of the larger heat losses area and the larger heating area.

2.2 Available data

There were only three surveys conducted during the past fifteen years to assess the effectiveness of the energy performance regulation against the actual energy used for heating. The first one in 2001, by Jeeninga, on a sample of 146 dwellings (Jeninga, 2001), the second one in 2004, by PRC (2004) and Uitzinger (2004), with a sample of 649 dwellings, and the last one in 2008, by the authors of the present paper, on a sample of 217 dwellings. The scarcity of data and the relatively small size of the samples may be related to the difficulties of monitoring as was explained in previous section. In the present paper we focus on the sample from 2008, the OTB sample, the results of which are compared to published results by Jeninga (2001), PRC (2004) en Uitzinger (2004).

In the OTB sample, two sources of data were used: a survey among households in two districts in the Netherlands, and Energy Performance calculation files from municipalities and architect firms. The obtained Energy Performance files were those from the dwellings where the survey was conducted, therefore allowing to match the responds from the household survey with data on building characteristics. The survey was carried out in autumn 2008 in two districts in the Netherlands built after the introduction of the EPC. The final sample size with usable energy data was 217 households. The energy reported by the respondents was from the last available energy bill, either in GJ or cubic meters for heat (district heating) and gas respectively. The data was corrected with heating degree days, based on the period 2006-2007 since the reported years varied from 2005 to 2008. The energy reported in cubic meters of gas included energy for space and water heating and cooking. The energy reported in GJ of heat included energy used for space and water heating, but not for cooking, since these households reported to use electricity for cooking. In addition, gas is reported as primary energy, and the generation of district heating is considered to have an efficiency of .95. Therefore, energy for cooking and the differences due to the efficiency of the systems might have a small effect on the reported energy use, as well as the fact that the heating degree days were applied to the total gas consumption and not only the gas consumption for space heating.

However, none of these samples may be assumed to be representative for the Dutch building stock build after 1995. There are many historical data about energy use in dwellings (BEK & BAK (1988-1994), HOME, EIB (2009), MONITweb (2009), KWR (2000) en WoON (2009). From these databases, the WoON survey is the only one accounting for a performance comparable to the EPC: the Energy Index (EI). Instead of being based on design data like in the EPC, the EI is based on inspections and the formula used for the calculation is comparable to the EPC formula. The WoON survey was carried out in 2005 by the Ministry of Housing in the Netherlands (www.vrom.nl). It consisted on two questionnaires applied to the occupants, and a dwelling inspection. The energy data included in the database refers to the real gas used during one year in the dwelling. The sample of buildings built after 1995contains 584 cases. Because the WoON survey is representative for the Dutch building stock, we used it in our study as a control for the results obtained from databases containing EPC values.

For the OTB and WoON samples, the correlations and differences between the variables and the actual energy consumption for space and hot tap water heating were determined using statistical analysis with SPSS (www.spss.com).

3. Results

3.1 Relationship between actual energy use for heating and EPC

In the OTB sample the dwellings were characterized according to EPC categories 'no EPC', '1.4≥ EPC>1.2', '1.2≥ EPC>1.0', '1.0≥ EPC>0.8' and 'EPC≤ 0.8'. These categories were chosen because the maximum allowed EPC value was set at 1.4 in 1996, and tightened to 1.2 in 1998, 1.0 in 2000 and 0.8 in 2006. No statistical significant differences were found between the actual energy consumption of houses with different EPC categories (for detailed statistics, see Guerra Santin (2009)). There is only a statistical difference between dwellings in the category 'no EPC' en dwellings with an EPC, meaning that the introduction of the EPC regulation had an effect on the actual energy use, but not the further tightening of the EPC-values. There were also no significant differences when the actual energy use per square meter was used instead of the actual energy use of the whole dwelling. Figure 2 shows the mean energy used per type of dwelling and per EPC category in the OTB sample. With the exception of corner houses, for which the decrease is significant, no differences in energy use were found for different EPC categories in flats, maisonettes, terraced, double and detached dwellings.

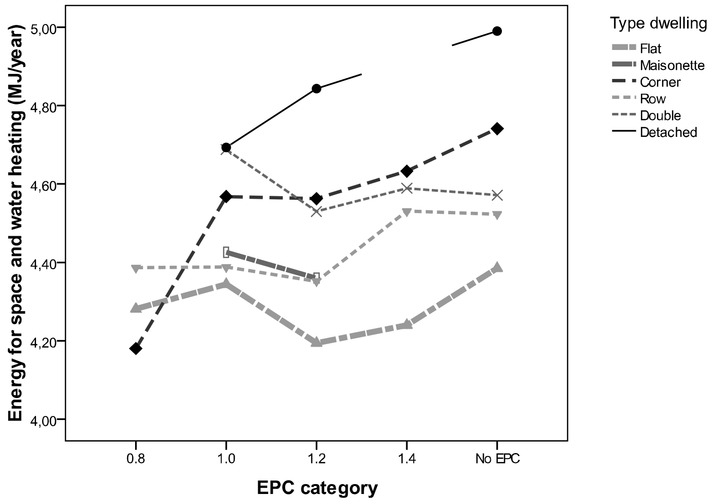

Figure 2: Energy used (mean LOG) per dwelling type and EPC level. For reasons of clarity, the 95% confidence interval is not plotted.

Similarly, analysis of the WoON database (for dwellings built after 1995) also shows the absence of correlation between the actual energy use and the Energy Index. Furthermore, an analysis of the gas consumption of dwellings built during different construction periods seems to indicate as well that there was no significant reduction of the energy used for heating in buildings built in the periods 1996-1997, 1998-1999 and 2000-2006 (see Figure 3). More data about the statistics can be found in Guerra Santin (2009).

The conclusions of the study by Jeeninga (2001) was that , although the average equivalent gas consumption seemed to decrease with the EPC, the 95% confidence intervals in each EPC categories were overlapping in such a way that it could only be concluded that

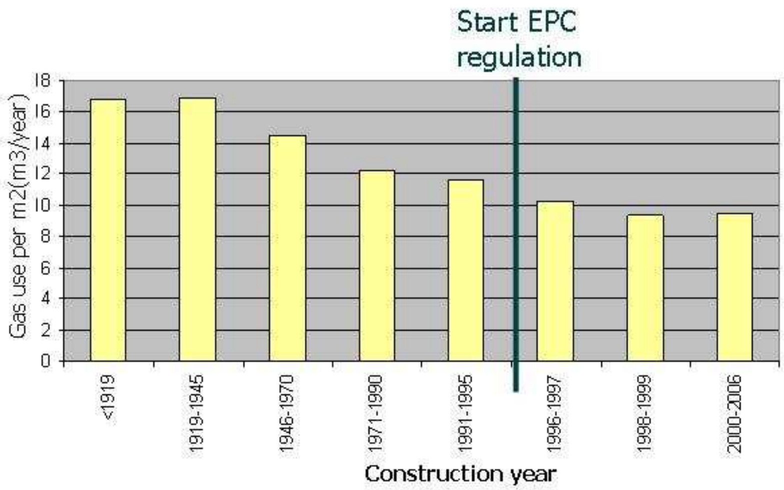

Figure 3: Average gas use per m2 dwelling in 2004 [10]

there was no significant difference in the energy consumption in the different EPC categories, except between the categories 0.75 en higher than 1.2. At the time the survey was conducted, an EPC of 0.75 was far below the maximum allowed level, therefore it could be that the projects with an EPC of 0.75 were experimental projects, carefully designed and realized.

The PRC & Uitzinger sample (2004) was by far the largest one and did seem to show strong significant differences between EPC categories. Although the statistical analysis could not be checked and there were concerns about the validity of the results (Itard, (2009)), it couldn't be excluded that the effect of EPC tightening is better observed in a larger sample. However, in a later analysis of the sample (Uitzinger, 2004) and in accordance to our results and those by Jeeninga (2001), no correlation was found between equivalent gas consumption and EPC. Additionally, the dispersion of the data (95% confidence interval) appeared to be less at low EPC-levels, indicating that the EPC regulation may have resulted in a more constant building quality.

3.2 Relationship between actual and theoretical energy used for heating (NEN5128)

The EPC is based on the theoretical calculation of the energy posts described in Figure 1 (Nen 5128, 2004), and therefore on the theoretical calculation of the energy use for space heating ($Q_{prim,verw}$) and tap water heating ($Q_{prim,tap}$).

In the OTB survey a correlation was found between the actual and the theoretical energy consumption, although the real energy consumption is mostly lower than the theoretical one.

Similar results were obtained by Jeeninga (2001) en Uitzinger (2004), showing that $Q_{prim,verw}$ is a fair predictor for the actual energy use for space heating.

Therefore we can state that although the EPC itself is not related to the actual energy use, some of its constituents ($Q_{prim,verw}$) are. This indicates that the formula used to calculate the EPC, summing up space cooling, ventilation, lighting and auxiliary energy, and using neutralization coefficients introduces some kind of noise.

3.3 Main statistical determinants of energy consumption for heating

In a previous study using the KWR survey (2009), which is a the predecessor of the WoON survey and contains less detailed data on the building characteristics and occupant behaviour than the WoON, we already found (Guerra Santin, 2009b) that 42% of the variation in energy consumption could be attributed to building characteristics, the type of dwelling being by far the most important parameter, followed by the useful living area, the construction year, the insulation degree, the presence of a thermostat, the number of heated rooms and the hours of presence home. Comparable data were found in Sonderegger (1978) and Leidelmeijer (2005). It was found that 4.2% of the variation on energy consumption could be attributed to household characteristics and occupant behaviour. However, this study encompassed the whole Dutch building stock and not only the recent one. Because the recent dwelling stock may be assumed to be more homogenous, it can be expected that building characteristics will explain less variation and occupant behaviour more variation.

The study was therefore repeated with the WoON survey with the dwellings built after 1995. In a regression analysis, taking into account only the significant parameters, 23% of the variation in energy used could be explained by the building characteristics, the most important parameters being the heat transfer surfaces and the number of bedrooms. These data are in accordance with results by Veringer (2005). Only 3.2% of the variation in energy used could be attributed to occupant behaviour, which is probably caused by the fact that too little data on behaviour was gathered to be able to take into account all possible relevant parameters (Guerra Santin, 2010).

In the OTB survey detailed data on the dwelling characteristics were gathered through municipalities and architects, and a statistical regression model showed that the thermal properties of the dwellings could predict 19 % of the variation in energy used, heat transfer surfaces and number of bedrooms being again the most important parameters. The OTB survey (Guerra Santin, 2010) was also designed to allow for a better screening of possibly relevant households characteristics and occupant behaviour and showed indeed that these were responsible for 11.5% of the variance in energy used for heating.

Jeeninga (2001) en Uitzinger (2004) found similar results on the effects of building characteristics, although the regression model in Uitzinger (2004) claimed to predict 70% of the variation which is in contradiction with other literature sources. Considering household characteristics and occupant behaviour, comparable results were found in Vringer (2005), who found that households that are motivated to save energy uses 4% less energy than households that are not. In Germany Schuler (2000) found that occupant behaviour could explain 11.7% to 14.9% of the variance in energy use. Other studies found that the building characteristics, the household characteristics and the occupant behaviour altogether can explain 50 to 86% of the variation on energy consumption: Ledelmeijer (50%, (2005)), Sonderegger (86%, (1978)) Pachauri (61-66%, (2004)).

4. Conclusions and recommendations

After almost 15 years of EPC regulation in the Netherlands, only three statistical studies were conducted to assess the effect of the regulation on the actual energy use. The samples were of limited size. In two of these samples, no statistical correlation was found between EPC-level and actual energy use per dwelling or per square meter. In the analysis of the woON survey, representative for the Netherlands, no correlation was found between the EI and the actual energy use per dwelling and per square meter. Although the consecutive strengthening's of the EPC values had no significant effect, the introduction of the energy performance regulation itself was found to have an effect on the actual energy use for heating. In all samples there was a fair correlation between the actual energy use for space and tap water heating and the theoretical energy use. This theoretical energy use for heating represents only one component of the EPC calculations and its effect seems to be counteracted by the other factors used to calculate the EPC-level, like the energy use for lighting, ventilation and auxiliary energy, and the neutralization factors.

This raises the question whether the choice for the calculation method in NEN 5128, although it is based on the legitimate whish to take into account solely building related energy consumption, can be sustained: first, it lacks controllability because affordable and simple monitoring is impossible due to the poor match with energy data that can be obtained at the meter box. It is only controllable under the assumption that dwellings can be monitored on a smart and detailed way. Second, the addition of the energy used for auxiliary energy, lighting, and mechanical ventilation and the neutralization factors, seem to introduce a considerable decrease of the controllability of the calculation.

Having stated that the consecutive lowering of the maximum allowable EPC-value had no effects on the actual energy used, we should carry on research on how to improve the reliability of the method with regard to the actual energy consumption and research whether there are more efficient ways to reduce this energy consumption. We found in the previous chapter that building characteristics (including heating and ventilation equipment) were responsible for 19 to 23% of the variation in energy used in the recent building stock. Household characteristics and occupant behaviour seem to be responsible for 3 to 15% of the total variance. Neither our study nor the studies found in the literature allow to state that building characteristics, household characteristics and occupant behaviour altogether are responsible for more than 38% of the variation on energy consumption of dwellings built after 1995. Therefore at least 62% of the variation in energy use is unexplained yet.

There are indications from literature that the explanation for this unexplained part could be related to buildings being realized differently than written in official documents and to HVAC services running under very different conditions than assumed on paper. A report by Nieman (2007) showed that in a sample of 154 dwellings, 25% did not meet the EPC requirements: the EPC was incorrectly calculated; nevertheless the building permit was issued. In 50% of the dwellings, the realization was not in accordance with the data used to calculate the EPC. Gommans (2007) monitored for 17 years the energy performances of energy efficient buildings. 40% of solar boilers appeared to function poorly. Only 25% of the heat pumps reached the expected efficiency. This was essentially due to realization faults, lack of control and lack of continuous monitoring. Another study by Elkhuizen (2006) in office buildings showed that up to 28% energy could be saved by better monitoring.

Taking into account the fact that tightening the EPC did not lead to less energy use for heating and that 62% of the variation in energy use is still unexplained, it seems legitimate to be careful about a further tightening of the EPC and to search if there are more efficient means to really decrease the energy consumption of new built. This could be done by ensuring a correct realization and monitoring of the calculated performances, putting attention on the knowledge needed by contractors (Tambach, 2010) and on an effective building control process (see Visscher, 2003). Finally, research on larger samples should be initiated to further confirm the results presented in this paper.

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