Effectiveness of energy performance certification for the existing housing stock

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Abstract:
The energy saving potential of the housing stock is considered to be large. Also this is considered to be the sector where energy efficiency measures can be pursued in the most cost effective way. In Europe the Energy Performance of Buildings Directive is a driving force for member states to develop and strengthen energy performance regulations for new buildings and set up a system of energy certificates for the existing stock and develop improvement policies based on these regulation tools. The goals are to build net zero energy buildings in 2020 and to reach a neutral energy situation in the whole stock by 2050. By now in the Netherlands a large share of the housing stock is labelled (Energy Performance Certificate). This paper is based on a research in which the indicated energy use according to the issued labels are compared to the actual energy use in the dwellings. The results point out that the influence of occupants on the actual energy use are large and potential savings might be (far) less in practice: in low labeled dwellings the energy use is less than expected, in the high labeled dwellings the energy use is somewhat higher than expected. What is the impact of these findings for the improvement policies of governments and housing associations?

Keywords:
Energy performance certification, energy use, housing, policy, building control

1 Introduction

Buildings are responsible for approximately 40% of EU's energy consumption. In order to achieve a significant reduction in energy consumption of the residential and utility sector through informing renters and buyers of the energy consumption of their dwelling, the European Performance of Buildings Directive was issued in 2002, setting an EU framework for energy performance certification (EPBD 2002/91/EC). The general requirements of the 2002 EPBD regarding residential buildings were to develop a system of energy certification for new and existing buildings, regular inspections of heating and air-conditioning systems and setting of minimum energy performance standards for new buildings and extensively renovated existing buildings with a useful floor area over 1000m2. Mandatory energy certification , which is the focus of this paper, is set for all properties constructed, sold or rented out.

All member states have implemented the directive by the end of 2009, some more efficiently than others (Andaloro, 2010). The two major deficiencies of the directive as was concluded in the EU project IMPLEMENT, are the looseness of the regulations in the directive, which leave extensive room for interpretation and the fact that no sanctions are given in the cases where the rules of the EPDB are ignored (for example no energy certificate when selling a house). Furthermore, the European Project IDEAL-EPBD was specifically aimed at investigating why energy performance certificates seem hardly to motivate dwelling owners to take measures to improve the energy performance of their dwelling, proposing several policy improvements to improve the impact. However, all these projects are dealing with EPBD implementation strategically, overlooking the accuracy and outcomes of the calculation methods implemented. This undoubtedly varies throughout the EU, since the methodology of the energy performance certificates (EPC) has not been defined by the directive and is in hands of individual member states. They have developed very different approaches and methodologies. However, in 2004 the EC appointed the CEN (mandate M/343) to develop a series of standards. These include the following: EN 15217 (energy performance of buildings—ways of expressing energy performance of buildings and for energy certification); EN15603 (energy efficiency of buildings—overall energy use and definition of energy rating); EN ISO 13790 (energy performance of buildings - calculating energy used for heating and cooling). Still, the methodologies are not fully following the standards in all member states (Andaloro, 2010), including the Netherlands.

Despite having developed all the standards and despite the flood of information regarding the implementation of the directive itself, there are only a few studies examining the calculation method, and comparing the calculated energy consumption, which represents the basis for the label, with what the dwellings actually consume. It is clear that the theoretical values are merely an estimation of the actual consumption, since they are based on standard values and do not take occupant behaviour into account. However, the labels also provide homeowners/tenants with information on possible energy saving measures, and the pay back times of the measures are directly related to the theoretical consumption. Most energy reduction policies are based on the theoretical energy reduction potential. Consequently, future energy reduction targets are formulated. If the label is to become an efficient advocate for reducing household energy consumption in line with the set targets, the theoretical decrease in energy consumption when improving a dwelling’s energy label should be close to the actual decrease of energy consumption. This paper aims to quantify, how the certification of buildings relates to actual energy consumption and how this fits the imposed targets for household energy consumption reduction, on the example of the Netherlands.

2 Existing studies on actual energy consumption

According to Perez (2008), the lack of a complete database of energy performance certificates on a national and EU level, hinders the evaluation of the energy saving policies. Poor availability and accessibility of energy label databases for researchers is probably the main reason for this topic to remain largely under researched. The limited available literature that relates the label of the dwellings to their actual performance are mostly based on small samples, with the intention of quantifying the impact of occupancy as an explanation for differences. The following studies have been identified: Guerra Santin (2012) compared the actual and expected energy consumptions for 313 Dutch dwellings, built after 1996. The dwellings were categorised according to their EPC value (the Dutch energy performance coefficient for new buildings existed already prior to implementation of EPBD directive and has been periodically strengthened from 1996 on). The EPC (NEN 5128) calculation method is roughly similar to the energy index calculation method, which is nowadays used as the basis for the energy label. In energy inefficient buildings with a high EPC, actual heating energy consumption was almost twice lower than expected, whereas in buildings with a low EPC (energy efficient) both heating energy consumptions coincided much better. Due to the relatively small sample size the differences between the actual heating energy of buildings with different EPC values were insignificant, although the average consumption was consistently lower in buildings with lower EPC.

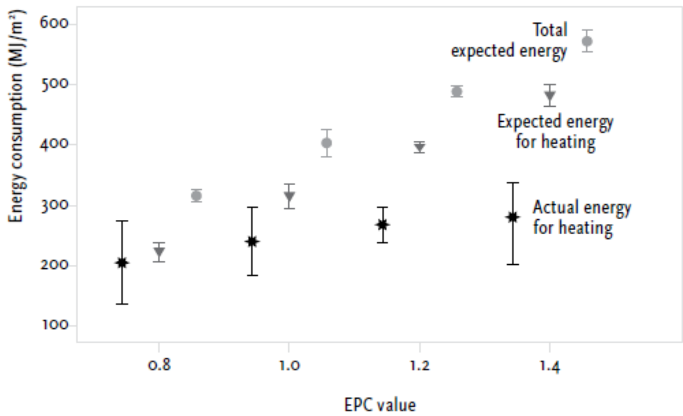

Figure 1: Mean and 95% confidence interval for the actual energy consumption (MJ/m2), total expected energy (MJ/m2) and expected energy for heating (MJ/m2) per EPC value (Source: Guerra Santin, 2012)

In another research conducted in The Netherlands by Tigchelaar (2011), a so-called heating factor was calculated (actual heat demand is divided by theoretical). The average heat factor in a sample of 4700 representative dwellings was found to be below one, meaning that the theoretical consumption is overestimated. Cayre et al. (2011) studied actual and theoretical energy consumption in 923 French dwellings and reached similar conclusions – the French EPC model overestimates the theoretical energy consumption in the sample, representative for the French dwelling stock. Similar was discovered by Hens (2010), observing actual consumption of two types of dwellings in Belgium (from 80s and 90s) – the consumption on average was only half of the calculated energy use. On the other hand, in 12 multi-family thermally retrofitted buildings in Austria, Haas (2000) has found evidence of actual energy consumption significantly exceeding the expected. Similar results were obtained by Branco (2004) in a multi-family complex in Switzerland and in a similar sample in France (Marchio, 1989). Based on these results, it seems that the theoretical energy consumption tends to be overestimated when looking at the average dwellings and less energy efficient dwellings and underestimated when observing new or retrofitted buildings. Usually this phenomenon can be partly explained by the so-called rebound effect (Berkhout, 2000). The idea is that more efficient technologies (such as a low energy dwelling) make energy services cheaper and thereby encourage to an increased consumption within the same service. A typical example of rebound effect was found to be the type of temperature control (Guerra Santin, 2010) - dwellings with thermostats actually turned out to consume more energy than dwellings without thermostat.

Sorrell (2009), provides an overview of methods for calculating rebound effect and a summary of available studies. He concludes accordingly, in OECD countries, that the mean value of the long-run direct rebound effect is likely to be less than 30%. This means that up to 30% of the efficiency gained through technical improvements of building and appliances are turned into increased consumption (higher comfort) following from direct change in user behaviour.

However, the size of the samples in these studies is relatively small, which sometimes leads to problems when assessing statistical significance of the results. Moreover, the representativeness of the sample is not addressed in the studies where the main goal is to investigate the sample and not the national dwelling stock. Therefore, even though there are some studies comparing the national theoretical energy consumption, which is the basis for energy label, it is very hard to predict what the energy label means globally within a member state. Even in countries where energy label databases do exist, there are only a few analyses of energy performance certificates available. The EPC in The Netherlands is based on the 'Decree on Energy Performance of Buildings' (BEG) and the 'Regulation on Energy Performance of Buildings' (REG) from December 2006. Despite the fact that the EPC fully came into force in 2008, however, the household energy data in The Netherlands does not show any relevant decrease in gas or consumption over the past 3 years (De Nederlandse Energiebranche, year) on a household level (taking temperature correction into account). The electricity and gas consumptions for the whole Dutch dwelling stock have also not decreased in the mentioned period (De Nederlandse Energiebranche, year).

3 Household energy efficiency and energy label in The Netherlands

3.1 The state of household energy efficiency in The Netherlands

The energy efficiency of the Dutch housing stock has improved by 28% (Odyssee ECN, 2009) in the period 1990 – 2008. The main reason for this significant improvement is believed to be the introduction of high efficiency condensing boilers. Moreover, the energy performance regulations for new dwellings have been strengthened, which has significantly increased the efficiency of newly constructed dwellings, resulting in halving their energy consumption in 2008 with respect to 1990. However, Guerra Santin (2010) argues that the trend of decreasing energy consumption in new dwellings has failed to continue after the year 1998, despite strengthening the EPC. Nevertheless, the improvements in energy efficiency can be noticed through the average household gas consumption in the same period (Odyssee ECN, 2009). Despite these promising achievement, the Dutch dwelling stock has grown steadily in the same period, approximately 1% each year. This two phenomena's together cause the total household gas consumption to stagnate rather than to decrease, despite the improved efficiency (Error! Reference source not found.). Even though the measures implemented in that period in the Netherlands place it in the lead of the European residential sectors (Odyssee ECN, 2009), there is no consistent evidence for reduction in gas consumption (the consumption in 2008 was only 5% lower than in 1990) and moreover electricity and oil consumption have in the same period grown for 32 and 39% respectively, which means that the total energy consumed by household has also grown for 5%.

Yucel (2011) claims that new construction can only achieve a limited reduction of energy consumption within the sector, since it contributes about 1% annually with a small fraction of demolishment of about 0,2%. According to Yucel, the new construction causes a very marginal energy consumption reduction by 2020, assuming the expected periodic strengthening and demolition and new construction rates. Renovation of the existing stock together with increased turnover is seen as the solution in for significant reduction of energy consumption. The Energy label strives to promote renovation and the turnover of more efficient buildings. Regarding renovation of labelled dwellings, a research conducted in Denmark (Kjærbye, 2008) showed that there was no significant energy reduction within 4 years after owners purchased the house (and received the label), with the exception of label A in first two years after purchase. Unfortunately, no similar study was found for the Dutch case at the time of writing this paper. On the other hand, the increased turnover of more energy efficient buildings has been observed in the Netherlands by Kok and Brounen (2010). The data acquired in this study enables an insight into real potentials for future energy savings, which the energy label scheme can lead to and thereby assess whether it will help in achieving the set objectives or energy and CO2 reductions.

3.2 Method of calculating the Dutch energy label for dwellings

The first goal of labels is to provide occupants and home owners with information on the thermal quality of their dwellings. The Dutch energy label calculation is described in ISSO 82.3. To increase to practical significance of the label, the expected (theoretical) energy usage of the dwelling is also mentioned on the Dutch labels issued from January 2010, expressed in kWh electricity, m3 gas and/or GJ heat.

An energy label ranges from A++ to G (Table 1). The categories are determined based on the Energy Index, which is calculated on basis of total primary energy consumption demand (Q_{total}). Q_{total} sums up the primary energy consumed for heating, hot water, pumps/ventilators and lighting, subtracting for the energy gains from PV cells and/or cogeneration (Equation 1).

$$Q_{total} = Q_{space\,heating} + Q_{water\,heating} + Q_{aux.energy} + Q_{lighting} - Q_{pv} - Q_{cogeneration}$$

Equation 1: Calculation of total energy consumption (Q_{total})

The energy index directly correlates with total energy consumption, but is corrected for the floor area of the dwelling and the corresponding heat transmission areas (Equation 2) in order to not disadvantage larger dwellings and dwellings with a greater proportions of envelope adjoining the unheated spaces (different dwelling types) at constant insulation properties and efficiencies of the heating/ventilation/lighting system. A shape correction is applied also when considering infiltration losses within space heating demand – the air permeability coefficient depends on building shape factor. Such correction for compactness is common also in other European countries, although it has been previously argued that not correcting would better promote energy efficient architectural design (PREDAC WP4 report, 2003).

$$EI = \frac{Q_{total}}{155 \cdot A_{floor} + 106 \cdot A_{loss} + 9560}$$

Equation 2: Calculation of energy index (EI)

The total primary energy demand can also be expressed as described in equation 3. Since primary energy is an energy form found in nature, that has not been subjected to any conversion or transformation process, appropriate heating values need to be taken into account when calculating it. The assumed heating value for gas is 35,17MJ/m^3 and the energy content of 1kWh electricity is 3,6 MJ. The efficiency of the electricity network is considered to be 0,39.

$$Q_{total}[MJ] = Q_{gas}[m^3] \cdot 35{,}17 \left[\frac{MJ}{m^3}\right] + Q_{electricity}[kWh] \cdot 3{,}6 \left[\frac{MJ}{kWh}\right] : 0{,}39$$

Equation 3: Calculation of total primary energy

Carbon dioxide emissions depend on the fuel used. For 1MJ of energy coming from gas, 0,0506kg CO_2 is emitted into environment and for 1MJ of electricity, 0,0613kg CO_2 (this is taking into account the network efficiency).

ENERGY INDEX								
A++	**A+**	**A**	**B**	**C**	**D**	**E**	**F**	**G**
< 0,50	0,51- 0,70	0,71-1,05	1,06-1,30	1,31-1,60	1,61-2,00	2,01-2,40	2,41-2,90	> 2,9

Table 1: Dutch Energy labels and the corresponding energy index values

The Energy Index and consequently the energy label are based on average occupancy, average outdoor climate and does not depend on the variation in behaviour of the occupants. The energy index reflects the thermal quality of the building. The ventilation, internal heat production, energy use for lighting and heat losses during water circulation all depend directly on useful floor area, which are defined as areas that are a part of the heated zone, including the rarely heated areas such as halls, toilets, washing rooms and storages. The attic is also included if it is heated and the roof insulated. The cellar and garage or other big storage areas are not included, since they are normally outside of the thermal envelope. The ventilation is calculated using a ventilation coefficient, which depends on the ventilation type. The infiltration losses are relative to the type of dwelling, since for each type of dwelling, characteristic lengths of frames, joints etc. are assumed (ISSO 82.3). The efficiencies are set also for all kinds of heating and hot water installation systems. Heat gains from the sun are taken into account during the heating season at rate of 855MJ/m^2 on a south vertical surface, accounting for frames and dirt on the glass. Possible gains if energy through PV cells or micro co-generation plants are accounted for.

4 Research methods and data

4.1 Energy label database

This research used all Dutch energy labels issued from beginning of January until December of 2010, counting over 340.000 cases with 43 variables (regarding building location and technical characteristics, properties of label itself etc.). This data set was provided by AgentschapNL – a public organisation appointed by the Dutch Ministry of the Interior and Kingdom Relations.

This data file was, on the basis of the address of the households, coupled to actual energy use data, which was provided by the CBS (Statistics Netherlands). CBS collets this data form the energy companies. The files of the two data sets were linked by the CBS to ensure anonymity. A clean-up of the combined data file (deletion of doubled addresses based on the label registration date, deletion of missing addresses based on missing value) was executed, leaving 247.174 cases. Because the CBS reported doubts about the quality of the data obtained for the actual energy of collective installations, it was decided to leave households with collective installation systems out of the analysis. Dwellings which have multiple installation systems were eliminated as well, since these are very specific cases. Cases where electricity consumption was 0 were removed as well, and missing values for gas consumption were defined. At this point, the gas values which were defined as missing were investigated. It turned out that most of them belong to dwellings with installations systems, which in fact do use gas. Such cases were deleted, and only the ones which use electricity as power source were kept in the database. The gas use was then redefined to 0 for these cases. Upon checking the theoretical energy use and areas of the house, outliers have been detected. The cases with the floor area of more than 1000m^2 and primary energy use of more than 500.000 MJ were discarded. Finally, the actual gas consumption values for 2009 were corrected towards the number of degree days used in the theoretical calculation. Ultimately, the sample contained 198.228 cases.

In this study, the variables energy index transformed into energy label, theoretical electricity consumption, theoretical gas consumption and actual electricity and gas consumption were used. Other variables, such as household floor area, dwelling type, construction and renovation year were examined to get an impression of the representativeness of the sample, but were not used in analysis.

4.2 Theoretical vs. actual energy consumption

The theoretical calculation method takes into account only energy for certain end uses and attempts not to take into account the end uses which are depend largely on occupant behaviour. On the other hand, as the name indicates, the actual gas and electricity consumption are derived from the dwellings energy bill and reflect the consumption for all possible purposes. An overview of differences can be seen in table 2. An important difference in electricity consumption are the household appliances which are not taken into account in theoretical calculation, but do appear on the electricity bill (and therefore in the database used). Appliances do constitute for 32,4% of household electricity consumption. The difference in gas consumption in gas used for cooking, which is only reflected in the actual value.

	Theoretical	Actual	% consumption of electricity/gas respectivelly
Electricity	· Hot tap water	· Hot tap water&heating	14,7%
	· Heating/Cooling	· Heating/Cooling	17,6%
	· Auxiliary energy (pump/ electronics/ventilation in heating installation, ventilation system)	· Auxiliary energy (pump/ electronics/ventilation in heating installation, ventilation system)	unknown, very small
	· (Negative) PV/WKK production	· (Negative) PV/WKK production	unknown, very small
	· Lighting	· Lighting	14,7%
		· Household appliances	32,4%
Gas	· Heating	· Heating	72,7%
	· Hot tap water	· Hot tap water	23,3%
		· Cooking	3,9%

Table 2: Comparison of end uses of gas and electricity in actual and theoretical consumption together with their contribution within the Dutch dwelling stock (source milieucentraal.nl)

4.3 Representativeness of the sample

The total Dutch dwelling stock accounted for 7,104 million dwellings in 2009 (CBS Statline). The researched sample therefore represents slightly less than 0,3% of the total dwelling stock. Since there were only a few cases in categories A++ and A+ the A labels were all aggregated into one category. The distribution of labels was then more normal and the results statistically more significant. As one can observe from Figure 3, more than half of the dwellings in the energy label database belong to the categories C and D. As for the rest of the dwellings are concerned, only 1% belongs to either one of the three most efficient categories (A, A+ or A++) and around 4% to G, which is the label of the most energy intensive dwellings. In the total Dutch dwelling stock, there is a slightly lower percentage of dwellings labelled with B and C (Figure 3).

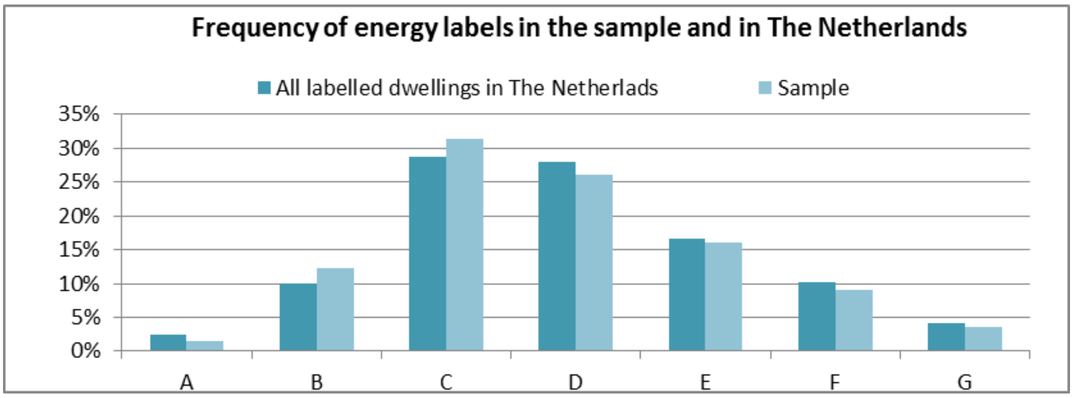

Figure 2: Shares of energy labels in the studied sample and in the Dutch dwelling stock (source Majcen and Itard, 2012)

Almost half of the dwellings were constructed in the 70s and 80s, until the year 1995. If this is compared to the whole Dutch dwelling stock, one can see that the distribution in the whole dwelling stock is slightly more even – more very new dwellings and more very old (Figure 3).

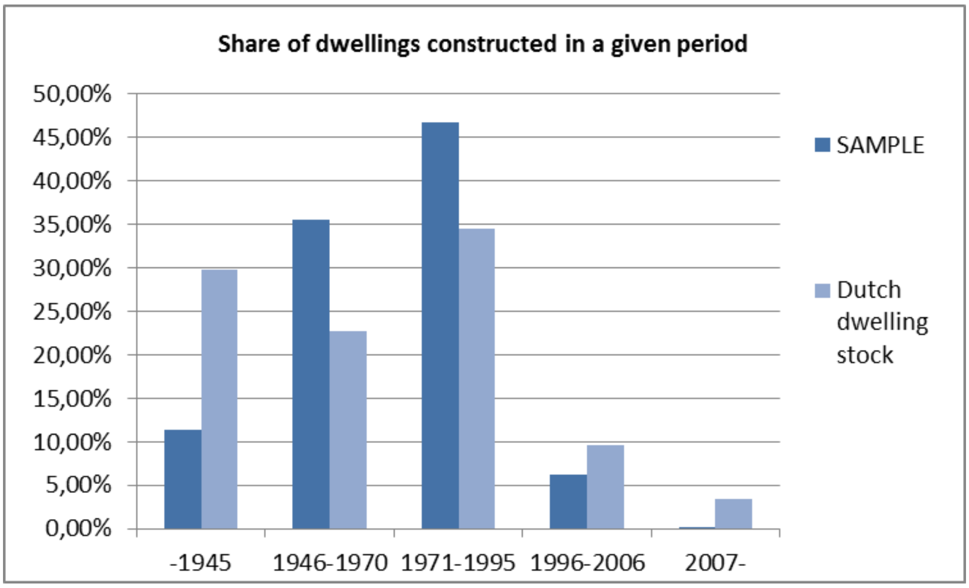

Figure 2: Number of dwellings per period of construction/renovation (source Majcen and Itard, 2012)

62% of Dutch dwellings are row houses. 11% of all dwellings are detached (single family) houses and the there is an equal share of apartments. This differs from the distribution in our sample of dwellings, which was aggregated to the same four categories in the Figure 5. The distribution of dwelling types according to the CBS in year 2009 is also plotted in Figure 5, and also differs slightly (the total stock is considered here to be 6,993 million dwellings). Discrepancy is the largest in the category of flats, which accounted for almost 36% of the sample, but represent only slightly more than 25% of the housing stock in 2008 according to the Energiecijfers database. There is less than average number of detached dwellings in the sample. On the other hand, there are more flats. This is also reflected in average size of a dwelling, which is more than 10m^2 smaller in the sample than is the Dutch average (Meijer & Itard, 2008).

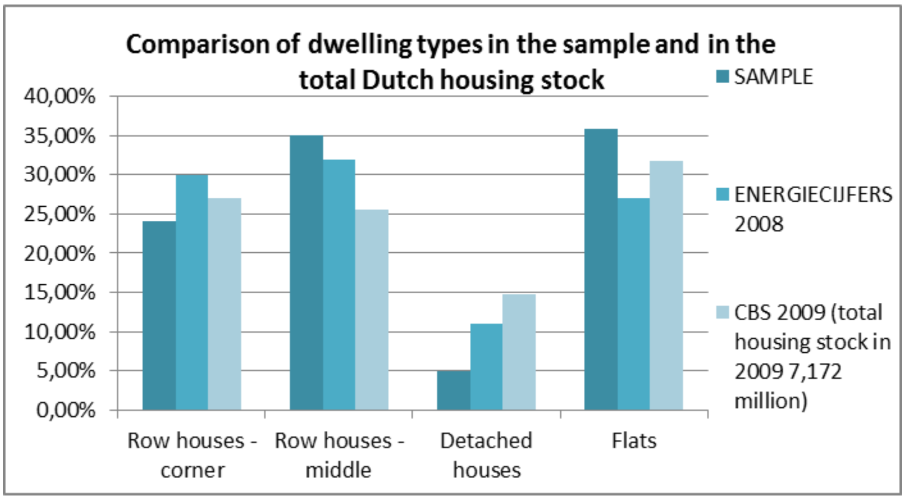

Figure 3: Representativeness of dwelling types in the sample and in the whole Dutch housing stock (source Majcen and Itard, 2012)

In terms of ownership structure, the sample differs significantly from the Dutch average (Energiecijfers database). Only slightly over 20% of the labelled dwellings are private owner occupant, while in the total dwelling stock the share is more than half (55%). Only 1% of dwellings in the sample is owner rental properties, whereas in the Netherlands, there are 12% of such dwellings. The third category is social housing, and is much better represented in the sample than in the total Dutch dwelling stock (79% vs. 33%), see Figure 6. This is caused for a large part by the lack of enforcement of this compulsory label for owner occupants.

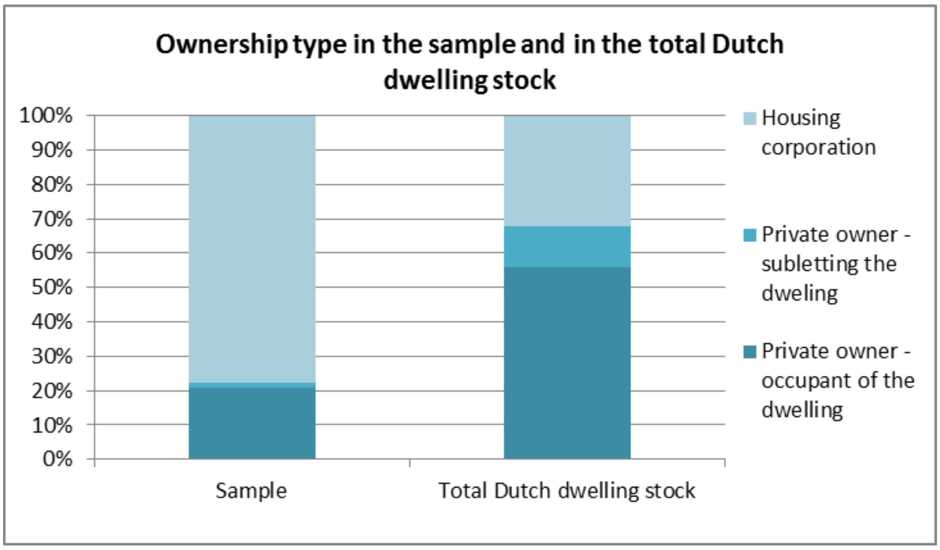

Figure 4: Ownership type distribution in the sample and in the total Dutch dwelling stock (source Majcen and Itard, 2012)

5 Results

5.1 Actual vs. theoretical energy consumption

First of all, a comparison was made between the actual and theoretical energy consumption per m^2 of dwelling in the abovementioned sample. The values appeared to be very well comparable, as can be seen from Figure 7. However, since it is known, that the theoretical consumption does not take into account end uses such as by household appliances (Table 2), which account for about 22% of total household energy consumption and gas for cooking, which contributes 1,3% it should intuitively be smaller. Because of gas and electricity as the two main energy sources in Dutch households are used for distinctive purposes, they are also examined separately in this study.

Within the analysed sample, the theoretical value for gas consumption is much higher than the actual, and the theoretical electricity consumption is significantly lower than the actual consumption of the same dwellings (Figure 7). In the case of electricity consumption, the fact that electricity from appliances is not taken into account, could to some extent cause the large underestimation of theoretical value, but judging from the values in Table 2 (appliances' contribution to electricity consumption is on average 32,4%, if the overestimation in our sample is due to appliances, they would contribute

64%) this is not the only cause. This might indicate that either the estimation for electricity consumption of household appliances is inaccurate, or the electricity consumption for hot tap water and heating are higher than predicted. As opposed to electricity, gas consumption is over predicted. Since the end uses of gas are the same with the exception of cooking, the differences in consumptions reflect either a deviation from assumed user behaviour or divergence from assumptions used to estimate space heating demand (air infiltration, U-values, floor area, transmission areas etc.) different than assumed in the theoretical calculation. This study does not aim to quantify where the discrepancies come from, but rather, the consequences of the inconsistencies for future household energy consumption.

In the total Dutch housing stock (Figure 7), 3480 kWh (32123 MJ) of electricity was consumed in a dwelling on average, according to Energie Nederland 2010. This is around 700 kWh (6224 MJ) more than the average in the studied sample. Similar goes for gas, around 1617 m^3 (56870 MJ) was the average consumption in 2010 according to Energie Nederland, whereas the consumption in our sample was app 1500 m^3 (52264 MJ). This discrepancy is likely to be caused by the larger average size of the dwellings in the whole Dutch dwelling stock.

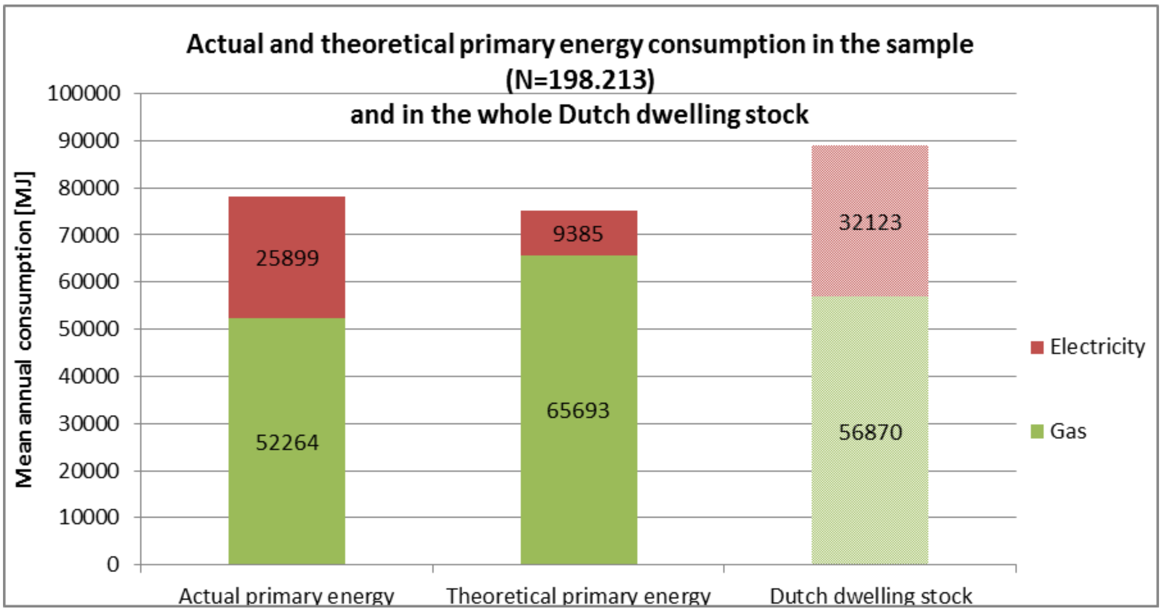

Figure 5: Actual and theoretical primary energy consumption in the sample and in the Dutch dwelling stock (source Majcen and Itard, 2012)

5.2 Energy consumption vs. energy label

5.2.1 Gas

To get an insight in how the energy label relates to the discrepancies described in the previous section, we examined gas and electricity consumption in the various label categories. The plots in this paper are presented with +/- 1 standard deviation. Because of the extremely large size of the sample it is not relevant to plot the 95% confidence interval, which is always very small, meaning that the location of the mean value is known almost without any uncertainty and all the differences were statistically significant on a 95% interval.

Figure 8 represents the actual and theoretical gas use per dwelling and Figure 9 the consumption per square meter of floor area of dwelling. What changes in the latter is the consumption of dwellings with label A, since those were found to be considerably larger than all other dwellings (Figure 10). From these figures it is clear that, although the increase of actual gas consumption corresponds to the increase in label, there is a clear difference between the mean theoretical and mean actual gas consumption of each label. For the most energy efficient categories: A, A+ and A++ as well as for category B Figure 8 and Figure 9 show underestimated theoretical gas consumption as opposed to the rest of the categories where the theoretical gas consumption is largely overestimated. The theoretical and actual values are only for label C quit similar. It is worth noting that in label category G, the actual gas consumption is only half of the theoretical consumption. The theoretical gas use predicts a much higher span between an energy efficient dwelling (A) and an energy intensive dwelling (G) than we observe in the actual gas use. If the two consumptions are thought of as a linear function, they greatly differ in their slope.

When standardizing the consumption per dwelling to the consumption per m^2 of dwelling, a better match between actual and theoretical gas consumption was expected since the dwellings could have different mean sizes in different categories. However, Figure 9 shows that this is not the case. The difference therefore does not arise because of different sizes of dwellings. It is noticeable that the standard deviation of theoretical consumption decreases in the Figure 9, meaning that the spreading in square meters floor area is responsible for a large part of the spreading in theoretical gas consumption at dwelling level.

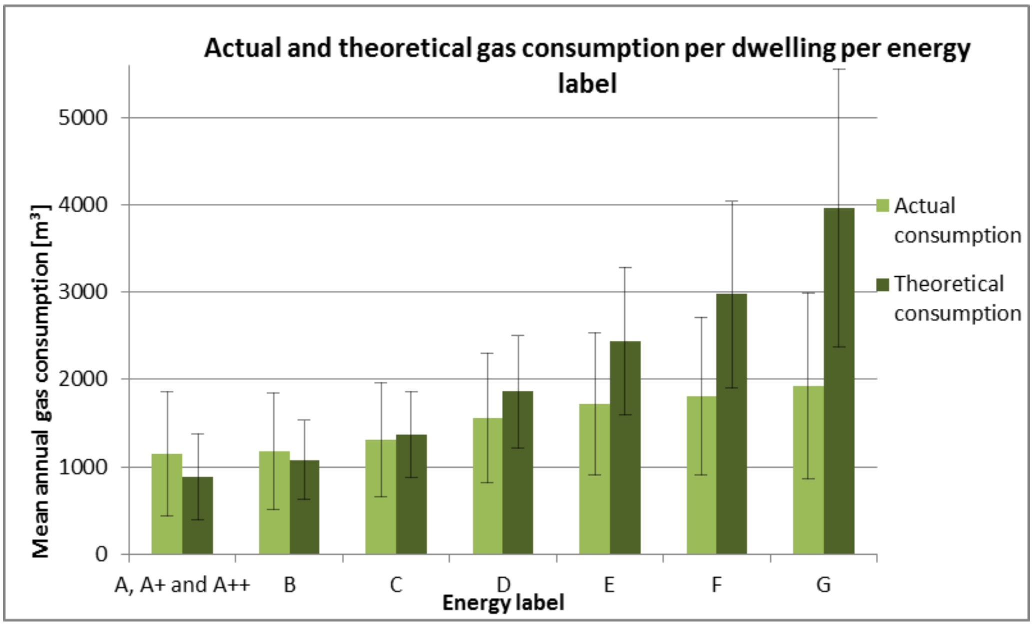

Figure 6: Actual and theoretical gas consumption per dwelling per label
(source Majcen and Itard, 2012)

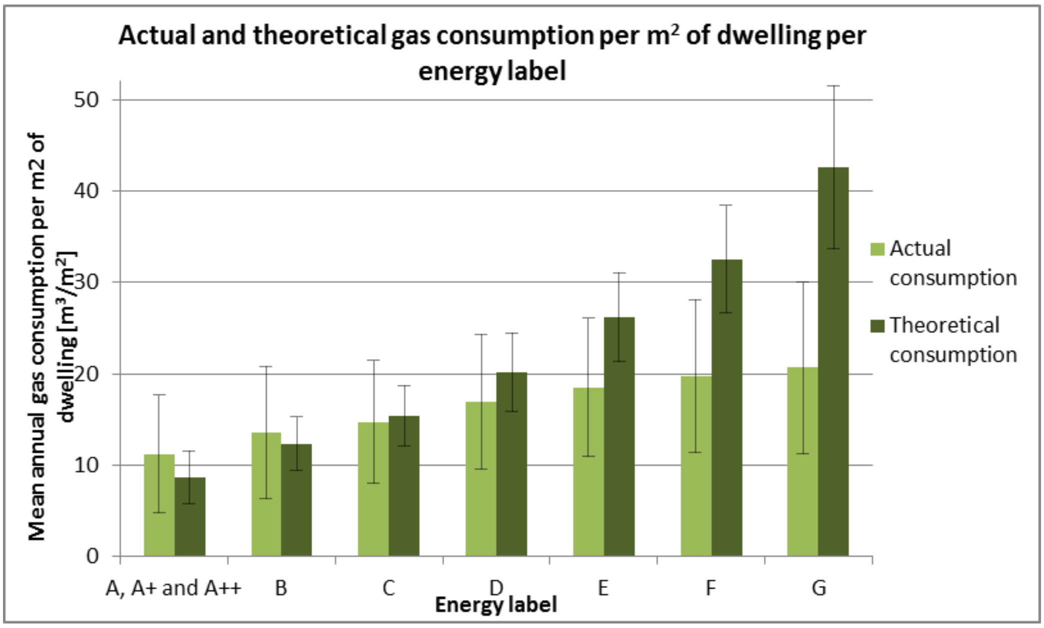

Figure 7: Actual and theoretical gas consumption per m2 of floor area per label (source Majcen and Itard, 2012)

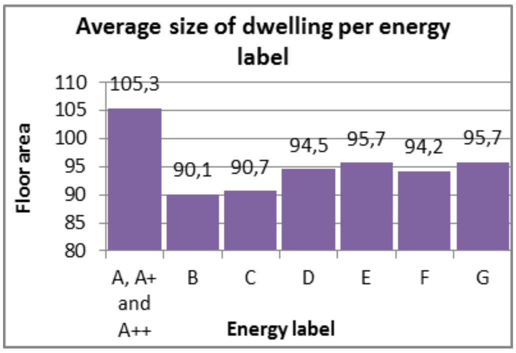

Figure 8: Average dwelling size (m2 floor area) in different label categories (source Majcen and Itard, 2012)

5.2.2 *Electricity*

As opposed to what we observed in the previous chapter on gas consumption, the theoretical electricity consumption is underestimated (Figure 7). In Figure 11 we can observe that both the actual and the theoretical electricity consumption does not depend much on the label. There is a very slight trend towards higher consumption in labels A, D and E which might be attributable to the electricity that is used for space and water heating in certain households or/and the larger floor areas.

Figure 12, where the electricity consumption is given per m^2 floor area, shows that the higher consumption in label A relates to larger floor areas, which seems not to be the case in labels D en E. The curve shows a slightly convex shape for the actual electricity consumption and a concave shape for the theoretical one, but finally the label will not appear to be very significant for the difference in electricity consumption. However, the differences between labels are very small compared to what was observed in gas consumption.

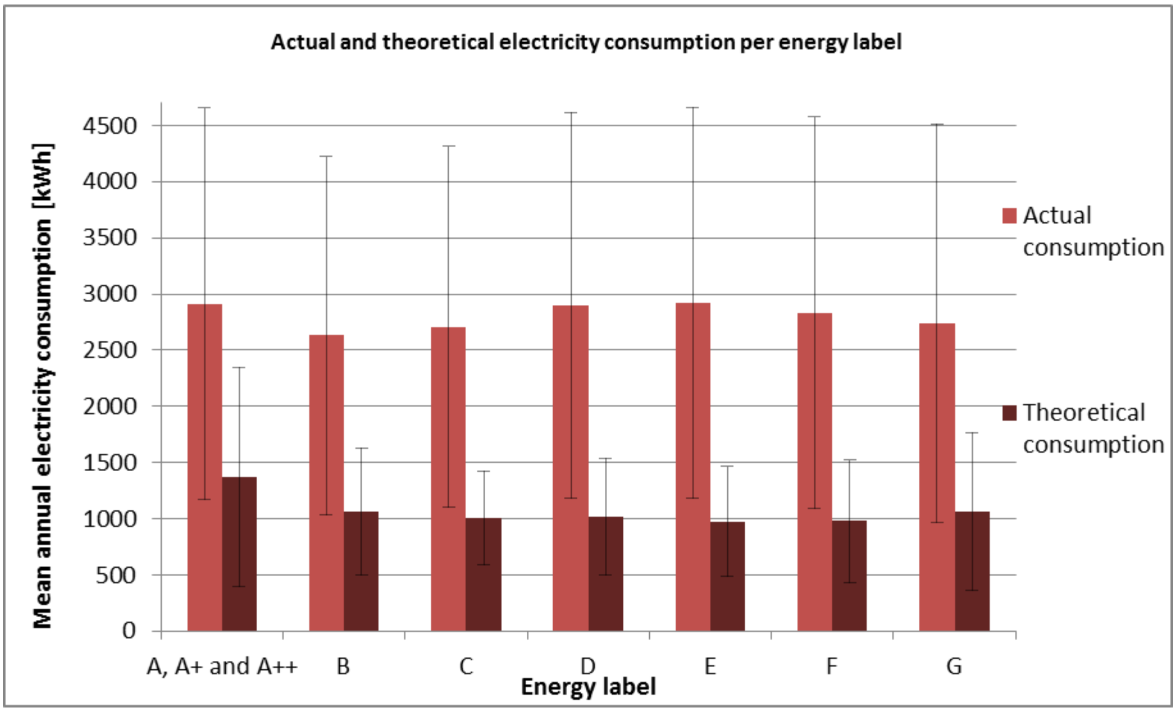

Figure 9: Electricity consumption in different label categories
(source Majcen and Itard, 2012)

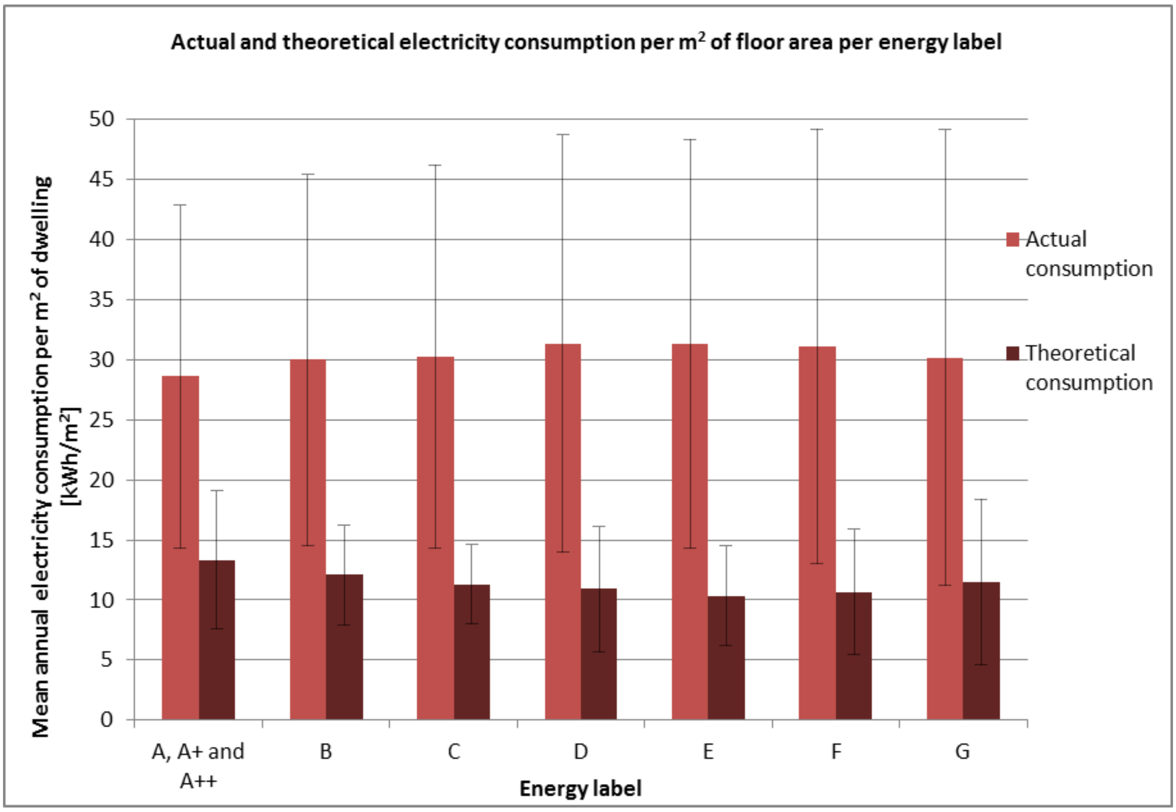

Figure 10: Electricity consumption per m2 dwelling in different label categories

(source Majcen and Itard, 2012)

5.3 Total primary energy and CO_2 emissions per label category

An interesting insight into the total primary energy consumption (Figure 13), can be gained if summing up the gas and electricity consumption according to equation 3. From this figure, the occupants in dwellings labelled with A – D label can expect to consume more than it is pointed out in the label. This will be partly a consequence of higher gas consumption and party due to the fact that the household appliances are not a part of the label.

However, what is worrying here is the fact that the span of theoretical consumption is much higher between label A and G than it is the case in reality (looking at actual values). This might have a very strong influence on the pay back times and on the achievable savings. The labels E to G seem to be consuming a very similar amount of actual primary energy, even though the technical characteristics are much better in E than in G. The label thus might reflect the technical characteristics of a dwelling, but if the actual primary energy consumption seems to be almost identical in each of the three categories, it might not be worth it to improve the technical specifications of houses labelled with G. From this figure it is clear that the savings which are expected to arise when improving the technical characteristics of a house, do not occur in practice. The theoretical primary energy consumption of label A is 70,2% lower than the consumption of label G, but the actual primary energy consumption of label A is only 27,8% lower than label G.

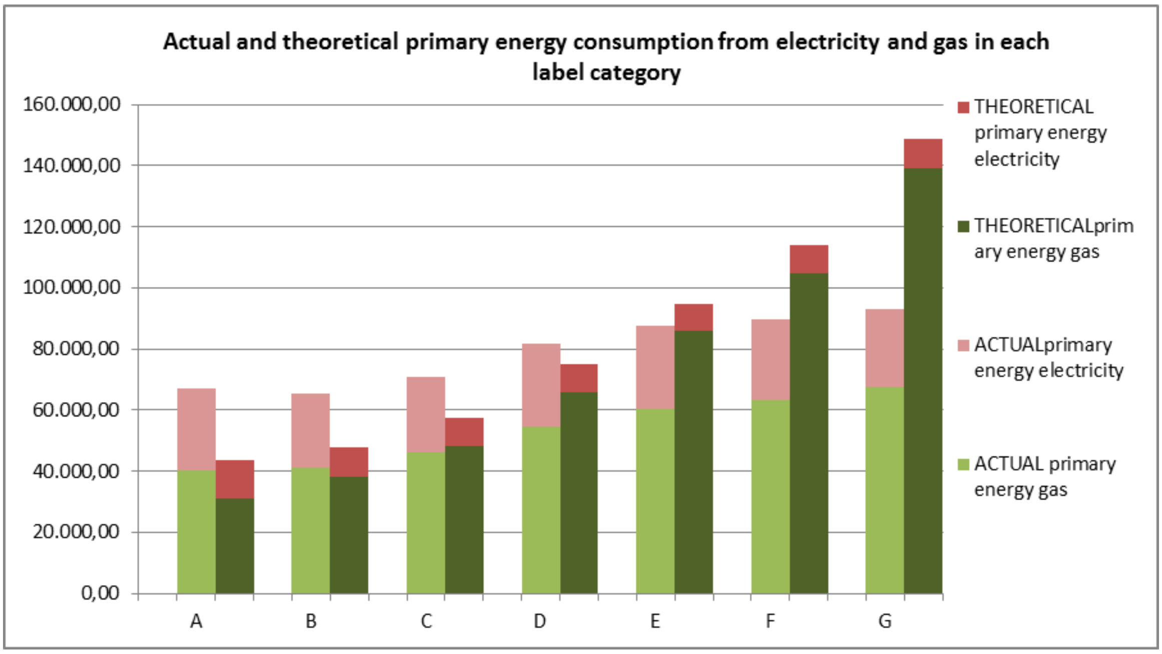

Figure 11: Primary energy consumption in different label categories
(source Majcen and Itard, 2012)

Moreover, since European targets are not solely aiming on reducing the energy consumption but also on reducing the CO_2 emissions, therefore it is illustrative to see what the energy label means in relation to CO_2 emissions. Since one megajoule of electricity produced in The Netherlands causes a larger CO_2 emission than a megajoule of gas (0,613kg vs. 0,508kg of CO_2 per MJ energy at household), a chart was produced, examining the emissions related to each label category. Electricity is responsible for more CO2 emissions per unit energy than gas, therefore it plays a stronger role in this chart. Theoretical CO_2 emissions are lower than actual in all labels except label G, because the household appliances are not taken into account in theoretical emissions. Interestingly, there is no significant decrease in CO_2 emissions among labels G, F and E and the label A is responsible for more CO_2 than the label B. The CO_2 emissions when improving a label from G to A, decrease for 55,4%, whereas in reality, looking at actual consumption, this decrease is only 13,1%.

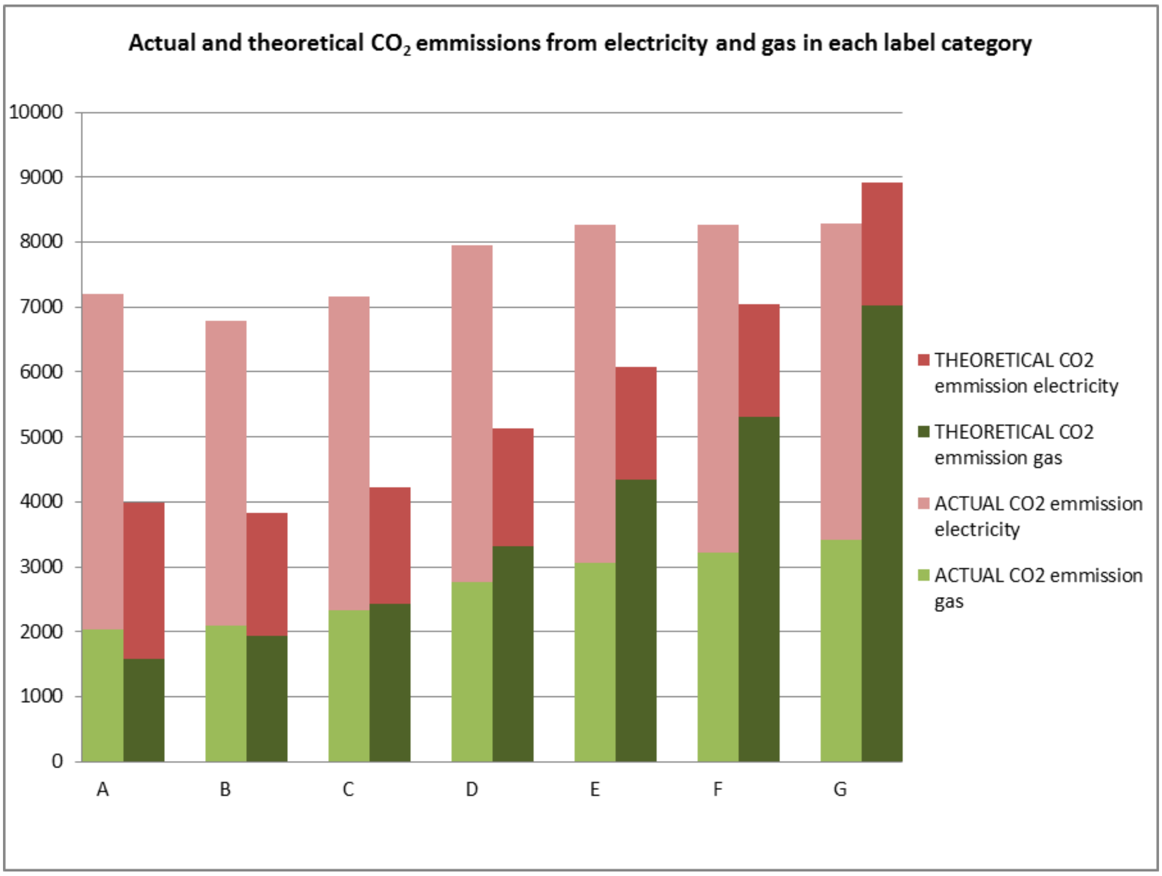

Figure 12: CO2 emmissions in different label categories (source Majcen and Itard, 2012)

6 Conclusion

This study was based on a large sample of households. Figure 3 showed the representativeness of the sample regarding the frequency of label categories, which was an important finding, since this study aimed to compare actual and theoretical energy consumption within a label and extrapolate the predictions which are made within the energy label calculation to the whole Dutch dwelling stock (section 4.4). Other aspects of the sample, such as type of dwellings or ownership type showed poorer representativeness, but this does not influence the results of this study, it might however, be useful information for further research and helpful to explain why there is a large discrepancy between actual and theoretical energy consumption.

Considering the fact that most of the gas consumption in The Netherlands is used for space and water heating, it can be concluded also from this study that the actual heating energy consumption is on average lower than the theoretical for most dwellings (in our study for dwelling with labels C to G) as was observed previously by Guerra Santin (2012), Tigschelaar (2011), Cayre (2011) and Hens (2010). Guerra Santin already pointed out that at a lower EPC value (for new dwellings), the difference between expected and actual will be smaller. Our study has proved this, and showed that in very energy efficient dwellings actual gas consumption can even exceed the theoretical use (Figure 8). On the other hand, low efficient dwellings are characterised by over prediction of gas consumption, the theoretical gas consumption seems to be around twice the actual. On the contrary to gas consumption, the discrepancies between theoretical and actual in electricity consumptions in different label categories are relatively constant (Figure 11) and most of the difference is likely to arise from consumption of household appliances. The fact that labelled dwellings differ in gas consumption, but not much when it comes to electricity consumption proves, that the energy label can (on a large scale) only be efficient in reducing gas consumption, at least as long as this is the main source of heating energy. However, in in Figure 14 one can see the importance of electricity in the carbon footprint of households – it is responsible for approximately 2/3 of all CO_2 emissions, which is why efforts should be made in the future for reducing not just the household heating demand, but also the electricity demand.

An important finding of this study is, that the primary energy consumption reduction, which is assumed to happen when improving a building from label G towards label A, turns out to be much lower when looking at actual primary energy consumptions of dwellings. This could lead to a miscalculation of payback times of the measures for improving the energy efficiency of the dwelling and the targets that have been set for primary energy as well as CO_2 reduction might not be realistic looking at actual energy consumptions. It was found out that even by refurbishing the whole Dutch dwelling stock to a label A (which is an unrealistic assumption), the actual primary energy savings cannot yield most of the current targets. However, if the theoretical consumptions are considered, most of the targets are achievable. The targets for gas consumption and reduction in CO_2 emissions turned out to be similarly problematic.

7 Implication of the findings

The energy performance certification of existing dwellings is considered to be an essential element of the European energy efficiency policies. This research has shown that a policies that are only based on improving the energy efficiency of dwellings and the heating and cooling services most likely will not lead to the energy and CO2 reduction goals as formulated. This is mostly due to the fact that in very bad performing dwellings the energy use is not as high as expected due to a lower comfort level (behaviour) and in very high classified dwellings not as low as expected due to lacking performances of the buildings and services (building control) and the rebound effect (behaviour).

Before renovation of bad dwellings the actual energy consumption and use of the dwelling should be investigated before one can say something about the potential savings. Maybe not all the provided comfort in renovated dwellings is desired or actually consumed. Whit an adjusted heating behaviour more saving could be achieved. To reduce the CO2 emissions the use of PV panels for the provision of domestic electricity use seems very effective.

8 References

Berkhout, P. H. G., J. C. Muskens, J. W. Velthuijsen, Defining the rebound effect, Energy Policy, Volume 28, Issues 6–7, June 2000, Pages 425-432

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, Issue 6, June 2004, Pages 543-555

Brounen D., N. Kok (2010), On the economics of energy labels in the housing market, Journal of Environmental Economics and Management, Volume 62, Issue 2, September 2011, Pages 166–179

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.

CBS (Statistics Netherlands) database, accessed on 9th April 2012, http://statline.cbs.nl/statweb/

Country specific factors – Report of Findings in WP3 (Deliverable 3.1), IDEAL EPBD European Project on Consumer response to energy labels in buildings, May 2009

Decision No. 406/2009/EC of the European Parliament and of the Council, 23 April 2009

Europe's buildings under the microscope, country-by-country review of the energy performance of Europe's buildings, Building Performance Institute Europe (BPIE), 2011, accessed on 9th April 2012 on http://www.buildup.eu/publications/19446

Energiecijfers database, accessed on 9th April 2012, http://senternovem.databank.nl/

Energy Efficiency Policies and Measures in The Netherlands Monitoring of Energy Efficiency in EU 27,

Norway and Croatia, ODYSSEE-MURE, ECN, 2009, accessed 16th March 2012 on http://www.odyssee-indicators.org/publications/PDF/netherlands_nr.pdf

Energie NED, De Nederlandse Energiebranche website with data resources: www.energiened.nl , accessed 28th March 2012

Energy Performance Certificates across Europe: From design to implementation, Building Performance Institute Europe (BPIE), December 2010

Energy performance of buildings directive (EPBD) 2002/91/EC

Evaluation of the impact of national EPBD implementation in MS, ASIEPI EU project, December 2009

Guerra Santin, O., L. Itard (2012), The effect of energy performance regulations on energy consumption Olivia Guerra-Santin and Laure Itard, Journal of Energy Efficiency, 8 February 2012

Guerra Santin, O. (2010), Actual energy consumption in dwellings; The effect of energy performance regulations and occupant behaviour, PhD thesis

Gönenç Y., E. Pruyt (2011), Energy Transition in The Dutch Dwelling Stock: Exploring the Extent of Inertia Against Change, Proceedings of International System Dynamics Conference 2011, July 24 – 28 2011, Washington DC, USA

Guide for a buildings energy label: Promoting bioclimatic and solar construction and renovation, PREDAC WP4 Report, 2003, accessed on 9th April 2012, http://www.cler.org/info/IMG/pdf/WP4_guide.pdf

Haas R., P. Biermayr (2000), The rebound effect for space heating Empirical evidence from Austria, Energy Policy, Volume 28, Number 6, June 2000 , pp. 403-410.

Hens, H., W. Parijs, M. Deurinck (2010), Energy consumption for heating and rebound effects, Energy and Buildings, Volume 42, Issue 1, January 2010, Pages 105-110

Implemeting the Energy Performance of Buildings Directive (EPBD) – Featuring country reports 2010, EPBD Concerted Action, April 2011

IMPLEMENT, Campaigning for the Future: Different approaches, unexpected results, Presentation of the experiences and outcomes of the project IMPLEMENT, March, 2010

Kjærbye, V. (2008). Does energy labelling on residential housing cause energy savings? Copenhagen: AKF, Danish Institute of Governmental Research

Marchio, D., A. Rabl (1991), Energy –efficient gas heated houing in France: Predicted and observed performance, Energy and Buildings, Volume 17, Pages 131 – 139.

NEN 5128 norm (2001)

Perez, L., J. Ortiz, R. Gonzales, L.R. Maestre (2009), A review of benchmarking, rating and labelling concepts within the framework of building energy certification schemes, Energy and Buildings, Volume 48, Pages 272-278

Sectoral Emission Reduction Potentials and Economic Costs for Climate Change (SERPEC-CC), Summary report, B. Wesselink, Y. Deng, October 2009, accessed on 9th April 2012

Sorrell, S., J. Dimitropoulos, M. Sommerville, Empirical estimates of the direct rebound effect: A review, Energy Policy, Volume 37, Issue 4, April 2009, Pages 1356-1371

Tigchelaar, C., Daniëls, B., Maenkveld, M., 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,Belambra Presqu'île de Giens, France.