Energy labels in Dutch dwellings – their actual energy consumption and implications for reduction targets

Daša Majcen
Research Institute OTB
Delft University of Technology
Jaffalaan 9
Delft
The Netherlands
d.majcen@tudelft.nl

Laure Itard
Research Institute OTB
Delft University of Technology
Jaffalaan 9
Delft
The Netherlands
l.c.m.itard@tudelft.nl

Henk Visscher
Research Institute OTB
Delft University of Technology
Jaffalaan 9
Delft
The Netherlands
h.j.visscher@tudelft.nl

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Abstract
In Europe the Energy Performance of Building Directive (EPBD) prescribes a compulsory energy labelling of existing dwellings. In the Netherlands a national labelling scheme is applied since 2008. The label is based on a theoretical calculation of the gas and electricity consumptions accounting for the physical characteristics of the dwelling, its heating, ventilation and cooling systems and standard use characteristics. In addition to the label, occupants are provided since 2010 with the theoretical gas and electricity consumptions. This paper reports on a large scale study comparing labels and theoretical energy usage with data on actual energy usage. A database of about 200,000 labels was coupled with data from Statistics Netherlands on actual gas and electricity consumptions provided by energy companies. Discrepancies between the actual and theoretical energy usage were analysed. The study showed that the less efficient energy labels consume much less energy than predicted by the label, but on the other hand, dwellings with labels A and B consume more than predicted. The energy saving targets are examined to demonstrate that most energy reduction goals may not be achievable if actual energy consumption is taken as the basis for future consumption calculations instead of theoretical consumptions.

Introduction
In Europe the Energy Performance of Building Directive (EPBD) prescribes a compulsory energy labelling of existing dwellings. In the Netherlands a national labelling scheme is applied since 2008. The label is based on a theoretical calculation of the gas and electricity consumptions accounting for the physical thermal quality of the dwelling, its heating, ventilation and cooling systems and standard use characteristics. A single energy label certificate consists of the awarded label and, since 2010, also the theoretical gas and electricity consumptions in the dwelling. These theoretical consumptions will differ from the actual ones because they are based on the physical dwelling quality and not on the dwelling use. Therefore, large differences may be expected in energy consumption between similar dwellings depending on the number of occupants and their lifestyles.

The EPBD is a policy instrument developed to support higher energy efficiency in the housing stock. The labels are used at national and European level to set-up policy targets and to estimate possible energy and CO_2 savings. It is therefore of main importance that, at the level of the dwelling stock, the differences in theoretical energy use between different label categories are in agreement with the actual differences. But are they?

In paper by Guerra Santin and Itard (2012), the actual and expected energy consumption for 248 Dutch dwellings built after 1996 were compared. In energy-inefficient buildings with a high EPC, actual energy consumption for heating was almost half that expected, whereas in buildings with a low EPC (energy-efficient buildings), the actual and expected heating energy consumptions coincided much better. In another study conducted in the Netherlands (Tigchelaar et al., 2011), the theoretical consumption was also overestimated. In a study by Cayre et al. (2011), the actual and theoretical energy consumptions in 923 French dwellings were studied and similar conclusions were made – the French EPC model overestimates the theoretical energy consumption in the sample. When observing the actual consumption of two types of dwellings in Belgium, the actual consumption on average was approximately half of the calculated energy use (Hens et al., 2010). On the other hand, in 12 multi-family thermally retrofitted buildings in Austria (Haas et al., 2000), the actual energy consumption significantly exceeded the expected. Similar results were obtained by Branco et al. (2004) in Switzerland and by Marchio et al. (1991) in France. The phenomenon of underestimated theoretical consumption can partly be explained by the 'rebound effect', by which more efficient technologies (such as a low energy dwelling) cut energy bills but thereby encourage increased consumption. A typical example of rebound effect is temperature control – dwellings with a programmable thermostat consume more energy than households with a manual thermostat or manual valves on radiators (Guerra Santin, 2010).

It seems that the theoretical energy consumption tends to be overestimated when looking at average and less energy-efficient dwellings and underestimated when observing new or retrofitted buildings. However, the size of the samples in the studies mentioned is relatively small and the representativeness of the sample for the national dwelling stock is also not addressed at times. This paper reports on a large scale study comparing labels and theoretical energy usage with data on actual energy usage in the Dutch dwelling stock.

Research Methods and Data

The 'energy label database' of AgentschapNL, the agency of the Dutch Ministry of the Interior and Kingdom Relations that manages the official registration of the energy labels consists of all dwelling labels registered in 2010 (342,194 cases). This database contains for each dwelling the energy label, the theoretical gas and electricity consumptions, the floor area, construction year and type of heating equipment for space heating. The database had to be linked to the 'actual energy use' database from CBS (Statistics Netherlands), the organization that is responsible for official national statistics. First, the energy label database was cleaned up (there were labels without addresses, double labels and labels with incomplete data), after which 255,273 cases remained. The actual energy use database contains 283,821 cases. To guarantee privacy and anonymity the coupling between both databases was made by CBS. Because CBS had some doubts about the quality of their data for collective heating installations, those were left out of the final database as well as cases that were clearly unrealistic (like dwellings with a floor area of more than 1,000 m^2, dwellings with a primary energy use of more than 500,000 MJ and dwellings with gas heating equipment but no gas consumption). The final sample contains therefore 198,228 cases.

Unfortunately the energy label database does not contain data about the heating equipment for warm tap water or about the ventilation equipment or about the age of the equipment. The theoretical gas use in the energy label database excludes gas used for cooking. In the actual energy database gas consumption is included. At the level of the dwelling stock this introduces a potential difference of approximately 3 %.

The actual energy use from the CBS is the energy use reported by energy companies for the year 2009. However, the energy companies are legally obliged to record the gas and electricity meters only once per three years, meaning that it cannot be guaranteed that the 'actual' energy use from the CBS database is really the actual energy use in 2009. It may therefore be that if dwellings were renovated recently, the 'actual' energy use reflects the energy use before renovation instead of the real actual energy use. This may concern the 359 dwellings that were renovated after 2006. The actual gas consumption for 2009 was corrected for degree days, accounting for the degree days as defined in the theoretical calculation.

The theoretical electricity consumption excludes the electricity used by household appliances because they do not relate to the building itself. All other end uses, such as electricity for hot tap water, auxiliary electricity (ventilation system, heat pumps etc.) and lighting are taken into account also in theoretical electricity consumption. However, in the actual energy use database, the electricity consumption includes all electricity consumed in the dwellings –therefore also the electricity for household appliances. In case of electrical heating (local electrical radiators or heat pumps) it is not possible to correct the consumption for degree days because of the aggregation of all electricity consumption in the dwelling. This may also introduce a small bias.

In our sample more than half the dwellings have a label C or D. Approximately 1 % have a label A, A+ or A++ en 4 % have a label G. Our sample is not completely representative for the total Dutch dwelling stock. There are relatively much more social houses in the sample (~80 %) than in the total dwelling stock (~33 %). This is because agreements were made between housing associations and government about labelling, while there is no enforcement of labelling for private owners or renters.

Results

GAS

The main results of the study can be found in Figures 1 and 2. Similarity with Figure 1 is evident. In Figure 1 the theoretical gas consumption in each label category is compared with the actual gas use of the dwelling. For the gas consumption per square meter of dwelling, see Figure 4. The main result is that the label predicts well the trend for the actual gas usage. The better the label, the lower the average gas consumption. The actual reduction in gas usage by each label step (e.g. from G to F or from C to B) is between 3 and 19 %. However, for the most energy efficient label categories (A, A+, A++ and B) the gas consumption is underestimated, as opposite to the poorer label categories (D to G), where it is strongly overestimated. The worse the label the higher the theoretical overestimation. In label category G the actual gas consumption is half the theoretical value.

The error band in Figures 1 and 2 gives the range of ±1 standard deviation of the gas consumption. The range is larger for the actual consumption than for the theoretical one because (among others) the actual occupancy characteristics (e.g. number of people in household en presence of people) vary more than assumed in the standard characteristics used for the calculations.

ELECTRICITY

As opposed to what we observed in the previous chapter on gas consumption, the theoretical electricity consumption is underestimated (Figure 3). In Figure 3 we can observe that both

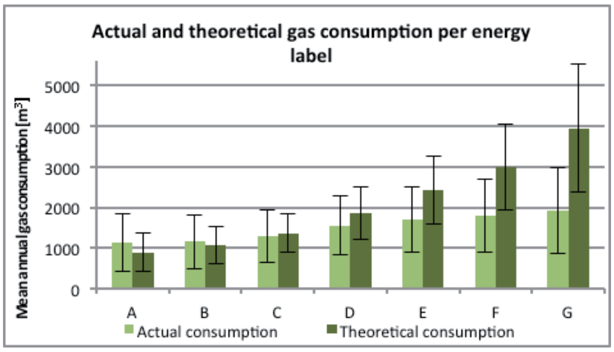

Figure 1. Actual and theoretical average gas consumption (m^3) in dwellings per label category with ±1 SD.

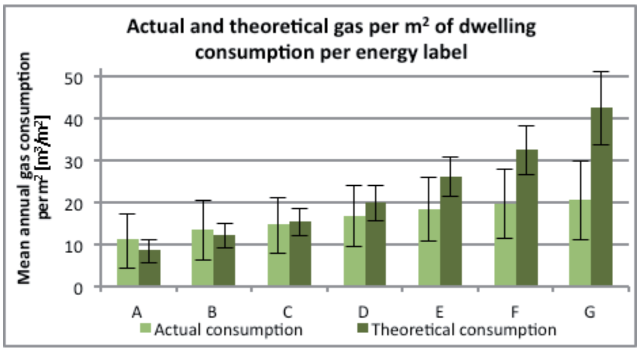

Figure 2. Actual and theoretical average gas consumption (m^3) per m^2 floor area per label with ±1 SD.

the actual and the theoretical electricity consumption do 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.

Unfortunately, it was not possible to remove the bias introduced by the fact that actual electricity consumption includes appliances, since such detailed data was not available.

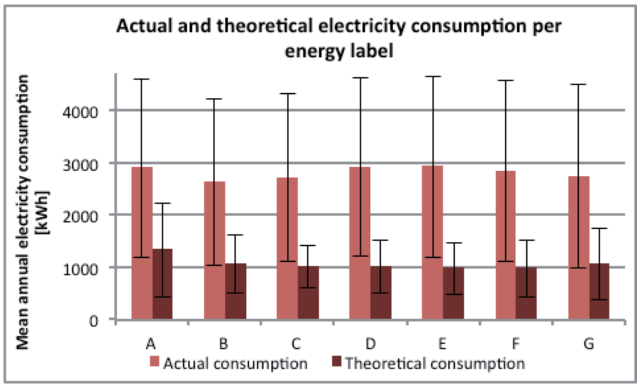

Figure 3. Electricity consumption in different label categories with ±1 SD.

TOTAL PRIMARY ENERGY AND CO_2 EMISSIONS PER LABEL CATEGORY

An interesting insight into the total primary energy consumption (Figure 4) can be gained if summing up the primary energy relating to gas and electricity consumption. 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 partly due to the fact that the household appliances are not a part of the label.

However, the span of theoretical consumption is much higher between label A and G than it is the case in actual consumption. 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 is 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.

Moreover, since European targets are not solely aiming on reducing the energy consumption but also on reducing the CO_2 emissions, 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 (0.0613 kg vs. 0.0508 kg 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 CO_2 emissions per unit energy than gas, therefore it plays a stronger role in this chart. 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 roughly only half of that, see Figure 5.

IMPLICATIONS FOR ENERGY REDUCTION TARGETS IN THE NETHERLANDS

In order to determine the range to which savings are actually achievable by improving the energy label of dwellings, three different scenarios were tested. The analysis of consumption in the three scenarios is particularly interesting because it predicts the potential savings not only on the basis of the theoretical values, but also on the basis of the actual consumption data from our sample. Calculations were conducted with the assumption that the whole Dutch dwelling stock was labelled and the average consumption values described in previous section apply.

We used several targets as a benchmark. The Dutch federation of housing associations (Aedes) committed itself in the 'Covenant Energy Savings Housing Associations Sector' to save 20 % on the consumption of natural gas in the existing social housing stock and to achieve a 24 PJ reduction in energy consumption until 2020 by improving these dwellings to a B label or at least by 2 label classes (Convenant Energiebesparing Corporatiesector, 2008). Under the 'More with Less' programme, the Dutch government and external stakeholders committed

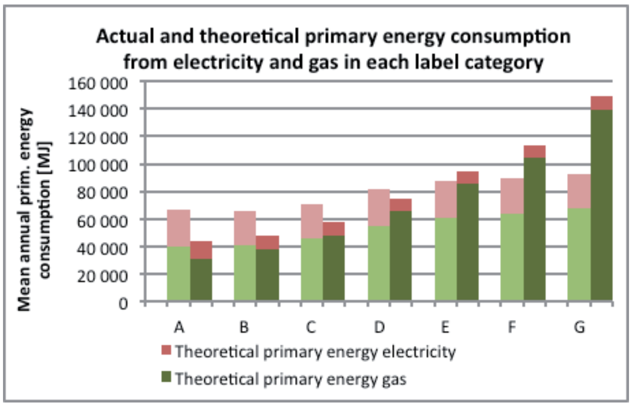

Figure 4. Primary energy consumption in different label categories.

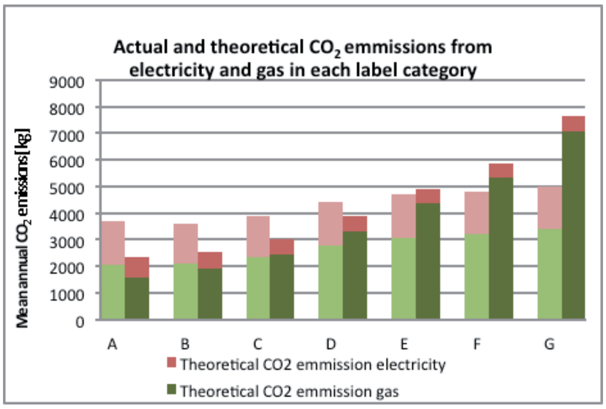

Figure 5. CO_2 emissions in different label categories.

Table 1. Energy and CO_2 savings in all three scenarios.

		scenario 1	scenario 2	scenario 3	scenario 1	scenario 2	scenario 3
		+ 2 labels or until label B	all dwellings label A	all dwellings label B	+ 2 labels or until label B	all dwellings label A	all dwellings label B
	Agreed savings	Actual consumption			Theoretical consumption		
Covenant Energy Savings Housing Associations Sector	-24 PJ in en. use	70PJ	85PJ	96PJ	72PJ	146PJ	117PJ
	-20% gas use by 2018	16%	24%	22%	34%	54%	44%
More with Less	-100 PJ by 2020	70 PJ	85 PJ	96 PJ	72 PJ	146 PJ	117 PJ
	-20/30% in en. use by 2020	12%	15%	17%	30%	43%	38%
SERPEC-CC	-19% in en. use by 2020	12%	15%	17%	30%	43%	38%
IDEAL EU project	-10% in en. use by 2020	12%	15%	17%	30%	43%	38%
Dutch government	-16% CO_2 reduction	6%	9%	12%	21%	24%	27%
EC Action Plan for Energy Efficiency	-27% in en. use by 2020	12%	15%	17%	30%	43%	38%

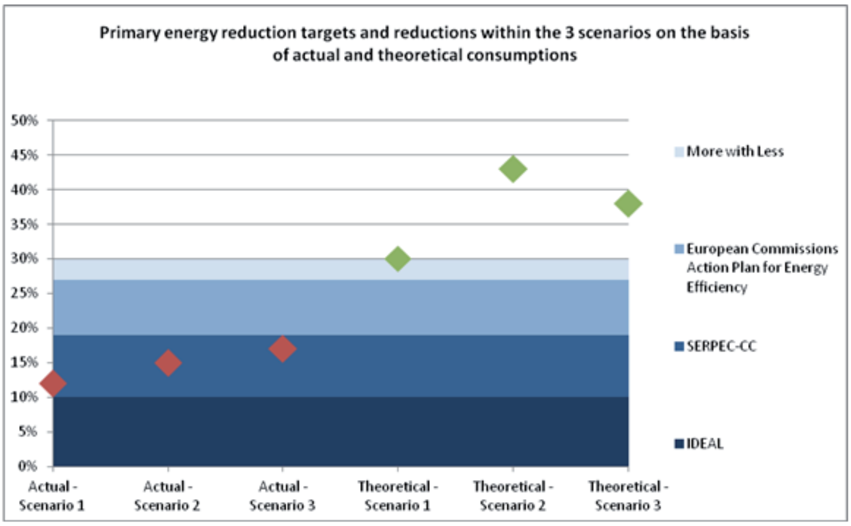

Figure 6. Primary energy reduction targets and reductions within the 3 scenarios on the basis of actual and theoretical consumptions.

to achieving a reduction of 20–30 % in the energy consumption (100 PJ) of buildings by 2020 (Meer met Minder, 2008). The SERPEC-CC EU project identified reduction potential in European Union within the built environment as 19 % below 2005 emissions by 2020 (SERPEC-CC, 2009). European project IDEAL established that cost-effective energy savings of 10 % could be achieved by 2020 (IDEAL, 2009). The EC's Action Plan for Energy Efficiency, published in 2006, defines the primary energy reduction potential of the residential buildings sector as 27 % (Action Plan for Energy Efficiency, 2006). As part of this, the Netherlands committed itself to reducing its total greenhouse gas emissions by 16 % by 2020 (Kabinetsappreciatie Europees energie- en klimaatpakket, 2008).

The first scenario equals the one proposed in the 'Covenant Energy Savings Housing Associations Sector', which aims to improve dwellings for at least by 2 label classes until the label B is achieved (so that dwellings with C labels are only improved by one label, dwellings labelled with B or A would not get improved, and all other dwellings are improved by 2 label classes) by the year 2018. The second scenario assumes improving all labelled dwellings to label A, while the third assumes refurbishment to label B (dwellings currently labelled with A or B do not get improved).

The differences in potential saving obtained through label calculation method or by using the actual energy consumption data are clear. According to the theoretical consumption, most of the targets would already be achievable with the implementation of the least stringent scenario – the only exception is the 100 PJ decrease in energy consumption as defined under the 'More with Less' Agreement. However, this target can be achieved in the other two more radical scenarios.

However, the picture is completely different when the average actual consumption in each label category is used. The only target achievable with the first scenario is the 24 PJ reduction in the energy consumption of social housing. The 20 % reduction in gas consumption throughout the whole dwelling stock, also proposed under the 'Covenant Energy Savings Housing Associations Sector', is also achievable with the implementation of scenario 2 or 3. All other targets regarding primary energy consumption reduction except the target of European project IDEAL, do not appear to be achievable (Table 1 and Figure 6), regardless of the refurbishment scenario chosen. Interestingly, according to primary energy savings and CO_2 emission reductions, it seems better to aim for scenario 3 than scenario 2, since this scenario offers higher actual reductions of primary energy consumption and CO_2 emissions (but not gas consumption). This is a consequence of the phenomenon evident from Figure 2, which predicts a higher actual consumption of electricity for label A then for label B. The primary energy in one kWh of electricity is so high that it outweighs the impact of primary energy derived from gas consumption (which is indeed lower in dwellings with an A label).

Conclusions and Recommendations

Our study has showed that in very energy-efficient buildings actual gas consumption can exceed the predicted levels (Figure 1). On the other hand, less energy-efficient dwellings are predicted to use more gas than they actually do: theoretical gas consumption seems to be around twice the actual levels. Unlike gas consumption, the discrepancies between theoretical and actual consumption for electricity are relatively constant for all the different categories (Figure 2) and a part of the difference is probably caused by electricity consumption by household appliances. However the electricity consumption is very important in the carbon footprint of households – it accounts for approximately two-thirds of all CO_2 emissions, which is why efforts should be made in the future to reduce not just the demand for heating from households, but also the demand for electricity.

The question remains of whether it makes sense to indicate the theoretical gas and electricity consumption on the label as has been done in the Netherlands since 2010. This may cause confusion instead of assisting the occupant, because it is not representative of actual values. A dwelling with a good label does not necessarily mean low energy usage. The label gives an approximate indication of the thermal quality of the dwelling but cannot predict the real energy consumption.

The theoretical energy consumption from the energy labelling method is systematically used by housing associations and diverse institutions, including governmental ones, to calculate the feasibility of renovation measures and their pay-back times. An important finding of this study is that the reduction in primary energy consumption, which is assumed to happen when improving a building from label G towards label A, turns out to be much lower in reality than expected. From our calculations based on actual energy consumption, it seems that the targets for energy and CO_2 reduction may be unrealistic. It was discovered that even if the whole Dutch housing stock were refurbished and upgraded to an A label (which would in itself be an unrealistically ambitious undertaking), the actual primary energy savings would not meet most of the current targets (Table 1). However, if the theoretical levels of consumption are used, most of the targets seem (misleadingly) achievable. The targets for gas consumption and reduction in CO_2 emissions turned out to be similarly problematic. In the future, the actual energy consumption of houses should be taken into account when formulating targets. This way, measures developed to meet the targets will have a better chance of success.

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