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Using energy labels to monitor impacts of renovation works: lessons learnt from the evaluation of the subsidy scheme for energy savings in social housing of Amsterdam

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ABSTRACT

The municipality of Amsterdam stimulated, as part of its climate policy, the implementation of energy saving actions by housing corporations between 2011-2014. This was done by means of a subsidy scheme whereby housing corporations received funds per energy label step. With these label steps, 5.1 kiloton reduced CO_2-emissions/year were expected by the municipality. However, in an evaluation study by the Audit Office Amsterdam, the "actual" result was estimated to be only 1.65 kiloton reduced CO_2-emissions/year, based on an assessment using metered energy consumption of a sample of dwellings with similar energy labels. The causes for the difference between the theoretical savings and "actual" savings seem to be for an important part the energy behavior of occupants and in particular the heating and ventilation of the house. Households in energy-inefficient homes are more economical with the heating: they lower the temperature and heat relatively less rooms. Households in energy-efficient homes, on the other hand, are heating more rooms in the house and also seem to raise the temperature. These factors are responsible that the average energy use per label class lies closer together than expected by the energy labelling method. Therefore, the actual energy savings per label step are much lower, based on the control group. However, a before and after renovation comparison of metered energy use of a selection of 819 dwellings that took part in the scheme showed that significant gas savings were realized. The gas savings are dependent on the amount and types of energy saving measures taken. The gaps between theoretical savings and actual savings are much lower for some of the label steps with even for some label steps the same savings as expected theoretically. The Amsterdam case shows the limitations of using energy labels to estimate actual energy savings. And that using average values of metered energy use from a sample of dwellings other than the target group in the scheme has limitations as well.

Introduction

The municipality of Amsterdam stimulated, as part of its climate policy, the implementation of energy saving actions by housing corporations between 2011-2014. This was done by means of a subsidy scheme. The objective of the subsidy scheme was to improve housing energy labels and to reduce the energy use and CO_2-emissions of rental houses of housing corporations in the social housing sector of Amsterdam. The dwelling stock of the Amsterdam housing corporations includes 160,000 dwellings.

The housing corporations were offered a subsidy of €2,050 for each label step under condition of at least 2 label steps improvement per dwelling. So, the subsidy was higher for higher improvements in terms of label steps: from €4,100 per dwelling in case of two label steps, up to €12,300 for the largest label step (G to A).

The subsidy scheme was paid out of a local fund that was partly financed through payments by housing corporations to the city of Amsterdam to lease the ground where the houses stand on. The budget was 33.1 million euros for the period 2011-2014, enough for 16,500 label steps.

To calculate the expected effect of the labeling steps on energy use and CO_2 emissions, the municipality of Amsterdam used the following key figures[1]: gas saving per labeling step: 180 m^3/year; CO_2 emissions per m^3 of gas: 1.78 kg/m^3. These indicators are included in the Monitor Build the City II, (May 2013) (Audit Office Amsterdam, 2014). With these label steps, 5.1 kiloton reduced CO_2-emissions/year were expected by 2014 by the municipality of Amsterdam, based on 180 m^3 yearly gas reduction per label step.

This paper first briefly presents the results of the subsidy scheme. Then the evaluation method for the energy savings impacts is discussed, comparing estimates available from different sources, analysing the gaps and discussing related uncertainties. The sources used are: 1) the estimate made by the municipality of Amsterdam based on the theoretical energy use per label class (see paragraph above), 2) The estimate made by Audit Office Amsterdam based on metered energy use data from a sample of control dwellings with similar labels (OTB, 2014a) and 3) The analysis made by Filippidou et al. (2016) based on a before and after renovation comparison of the metered energy use of a sample of dwellings that took part in the subsidy scheme. These analyses were made in the frame of the EPATEE project (for more details about this project, see Broc et al., 2018).

Results of the subsidy scheme

Amsterdam subsidized 5,131 renovations of houses for 16,017 label steps with a budget of 33.5 million euros budget between 1 July 2011 and 31 December 2013. So, the target of 16,500 label steps was almost reached at the end of 2013. The budget for the subsidy scheme was increased from 33.1 to 45 million euros: the original budget of 33.1 million euros was increased by interest income from the local fund to 37 million euros and 8.6 million euros were provided as additional budget in 2014.

In 2016 an evaluation was made about the individual energy saving actions that were subsidized by the scheme (Filippidou et al., 2016; OTB, 2016). In the period 2011-2014 the Amsterdam housing corporations received subsidy for the energy savings in 9,009 houses (5.6% of their stock). Information was available from the national energy labelling registration only for 4,475 from these 9,009 houses. The individual saving actions that were undertaken include:

- in 2,118 houses (47%) a condensing boiler was installed
- in 1,573 houses (35%) glazing (windows) was replaced by more energy efficient ones
- in 1.184 houses (26%) a mechanical ventilation system was installed

[1] Each label step was expected to save 180 m^3 of gas. The assumption of a linear relationship between gas saving and label steps is simplified; it is based on the difference in theoretical gas use per label class (the dark bars in Figure 1). The expected savings were not calculated as the difference in theoretical gas use between label classes by using a sample of control dwellings. This “more detailed” method would also result in an overestimation as it is also based on theoretical gas use per label class instead of metered energy use data.

- 854 houses (19%) got wall insulation
- 413 houses (9%) got roof insulation
- in 296 houses (7%) floor insulation was installed
- 207 houses (5%) got solar PV
- 137 houses (3%) were connected to the district heating network

With these label steps, 5.1 kiloton reduced CO_2-emissions/year were expected by the municipality of Amsterdam. However, the Audit Office estimated only 1.65 kiloton reduced CO_2-emissions/year in their evaluation, based on an assessment using metered energy consumption of a sample of dwellings with similar energy labels (see next section). The estimated "actual" result in terms of CO_2 emission reduction was about a third of what was expected.

The gross cost of CO_2 reduction for the public budget of the subsidy scheme was evaluated by the Audit Office (Audit Office Amsterdam, 2014). The subsidy budget of 33.1 million euros is divided by the CO_2 reduction. For the CO_2-reduction the yearly reduction of 1.65 ktCO_2 is multiplied by an average lifetime of the energy saving actions of 20 years. This results in €1,000 per ton CO_2 reduction. This is much higher than the expected €320 per ton CO_2 when introducing the subsidy scheme because of the lower energy savings than expected. It should be noted that this indicator cannot be interpreted as the cost-effectiveness of the scheme since it does not consider other benefits from these actions such as lowering energy bills and providing a higher comfort for the tenants (see also section: Other indicators monitored and/or evaluated).

Several evaluative studies have been conducted to study the real saving effects of the scheme (OTB, 2014a; Filippidou et al., 2016; OTB, 2016). The method used for the evaluation by the Audit Office is explained in the next section. The method used by Filippidou et al. (2016) is explained in section: Evaluation using a before and after renovation comparison.

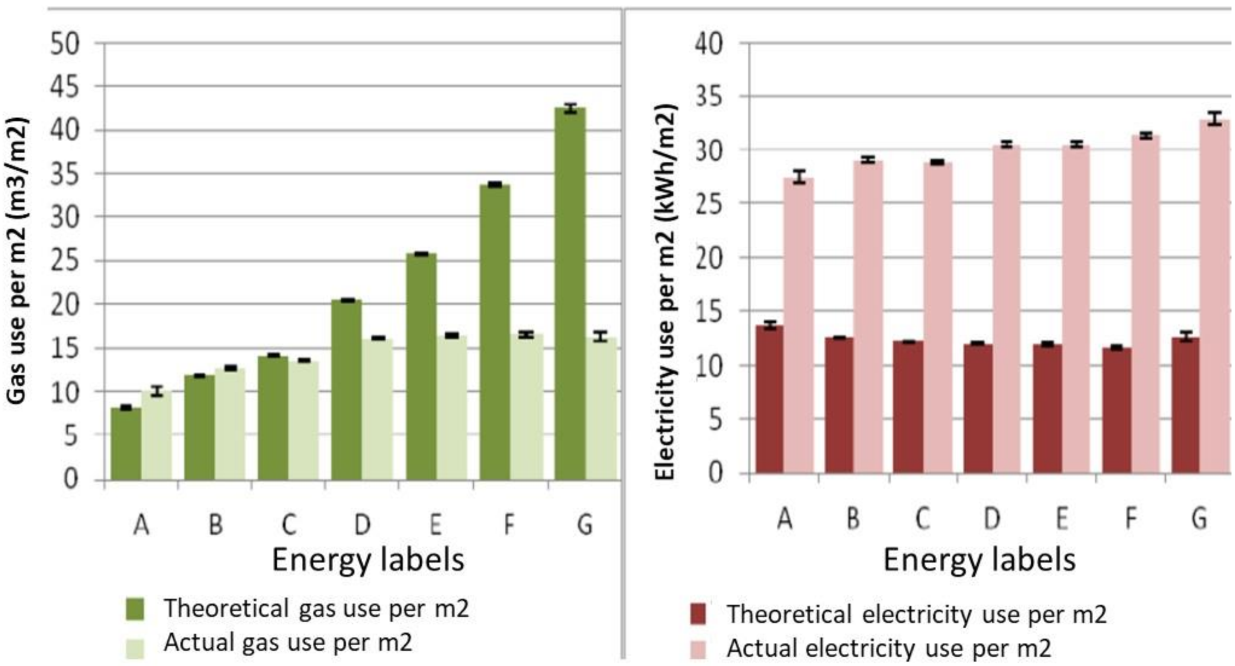
Difference between Theoretical and Actual energy use

In the evaluation study of the Audit Office (Audit Office Amsterdam, 2014), the energy savings of the subsidy scheme were calculated with the differences in average energy use per label class, based on metered energy use collected on a sample of "control" dwellings.

A comparison of the energy use of the rental houses before and after renovation (implementing the action) was not possible, because energy data before and after implementing the action were not available (at that moment). That's why the evaluator from the Audit office of Amsterdam choose for an analysis of the energy savings resulting from label steps to estimate "actual" energy savings as the difference of metered energy use for dwellings with similar energy labels as the labels reported for the dwellings where actions were implemented.

Data from the national energy labeling registration from the Netherlands Enterprise Agency (RVO) were linked to a database with metered energy use from CBS, the national statistics agency. From the differences in average energy use for different energy labels the "actual" energy savings per label step were estimated. It should be noted that the difference in average energy use per label class may reflect the differences in energy efficiency of the building envelope and heating systems, but also the differences in the energy behaviors of the occupants (see section: Uncertainties in the method used by the Audit Office). This analysis was done for more than 37,000 rental houses in social housing sector in Amsterdam. These are houses that did not benefit from the Amsterdam subsidy scheme. This analysis was focused on houses that had an energy label registration between 2010 and 2012 and that were not renovated in this period to make sure that the energy label of the house gives an actual representation of the energy efficiency of the house and is not outdated by renovation.

The figure below, taken from the Dutch evaluation report, presents the gas use (left figure) and the electricity use (right figure) per square meter for houses with energy labels A to G. The dark bars in the bar chart represent the theoretical energy use of the energy label based on engineering calculations, the light bars represent the metered energy use based on energy bills and metered data of the houses in the respective energy label category. The metered electricity use in this figure provides the whole metered electricity use, including appliances, while the theoretical electricity use only considers building-related energy use for example lighting, ventilation and cooling, so they are not entirely comparable. Because of this, no further analysis on the difference between theoretical and actual electricity savings was done. The estimated CO_2 emission reductions were based on gas savings only.



Source: OTB, 2014a (figure 10)

Figure 1. Actual (light) and theoretical (dark) gas use (left) and electricity (right) use per m² per label class.

Note: the average size of the rental houses in Amsterdam is 65 square meters.

One of the main conclusions from this study (OTB, 2014a) is that the real gas use of houses with an energy label D, E, F or G is much lower than the theoretical gas use. The differences between the real gas use of different labels are also much smaller than the theoretical differences between labels. This explains why the “actual” energy saving per label step as estimated by the Audit Office are much lower than expected in the Amsterdam subsidy scheme (with even for some label steps, no savings at all). The difference between theoretical and “actual” gas use is much smaller for labels A to C (theoretical use slightly underestimated), than for labels D to G (theoretical use overestimated, especially for the least efficient labels).

The overestimation of energy consumption in inefficient dwellings has been named Prebound effect (see also Sunikka-Blank and Galvin, 2012): cases where, before implementing an energy efficiency action, end-users tend to consume less energy than estimated by engineering models (in this case the energy labelling method).

Explaining the differences further

The causes for the difference between the theoretical savings and “actual” savings seem to be for an important part the energy behavior of occupants and in particular in the heating and ventilation of the house (Audit Office Amsterdam, 2014). A study by the Energy research of the Netherlands on the difference between theoretical and actual gas use in households comes to the same conclusion (Rietkerk et al., 2015). Households in energy-inefficient homes are more “economical” with the heating: they lower the temperature and heat relatively less rooms (and/or heat for shorter periods) (Audit Office Amsterdam, 2014; Rietkerk et al., 2015). This might especially be the case for low-income households such as those in this case study, as they cannot afford high energy bills. Households in energy-efficient homes, on the other hand, are heating more rooms in the house and also seem to raise the temperature (Audit Office Amsterdam, 2014; Rietkerk et al., 2015). In the study by Rietkerk et al. is was concluded that lower income homes behave more energy efficient, but energy poverty is not the decisive factor to explain differences in behavior, so the relationship is not that straightforward (Rietkerk et al., 2015). There are also indications that residents of energy-efficient homes more often open windows and doors to ventilate the home than residents of less efficient homes. These indications are based on the survey by the Research and Statistics Office (O+S) of the municipality Amsterdam among occupants of social dwellings (Audit Office Amsterdam, 2014). This ventilation behavior, however, does not demonstrably lead to higher gas use.

It appears that the assumptions that have been made in the label assessment system for homes are not always correct (OTB, 2014a, OTB, 2014b). For example, in the current system it seems the case that the energy use in older homes or homes with older heating installations is overrated. It also seems that the average temperature is estimated too high in the house and too large a proportion of rooms that are heated (Audit Office Amsterdam, 2014; Rietkerk et al., 2015). Research by OTB indicates that the temperature and amount of rooms heated probably play an important role in explaining the differences (OTB, 2014b).

Still, it cannot be ruled out that part of the disappointing effect will be caused by the fact that energy labels are sometimes insufficiently reliable. Despite improvements from 2010, it still occurs homes get a wrong energy label.

Uncertainties in the method used by the Audit Office

The Audit Office used average values of metered energy consumption per energy label class from OTB (OTB, 2014a) to make estimates of the energy savings for the actions reported for the scheme. These estimates also include uncertainties, but other types of uncertainties as the savings based on the theoretical energy use. Uncertainties in the approach are, for example:

- That it is questionable if the method ensures that the differences between average values per energy label class are equivalent to a before/after renovation works comparison. Other aspects (geometry, orientation, semi-detached vs. detached houses, etc.) would not have to play a role here.
- The assumption that the heating behaviors are the same for occupants that have always been in a C dwelling compared to occupants of dwellings that were renovated from E to C label (for example).

These uncertainties are difficult to assess. Therefore, results must be interpreted as an approximation.

Data quality issues

During the roll-out of the subsidy scheme, the municipality of Amsterdam only controlled the energy label of the houses after renovation. The evaluator did compare the subsidized label steps with the energy labelling registration database also for the situation prior to the renovation. This is very difficult because address data of houses are not written in a uniform way. The evaluator found a lot of missing data and mistakes and concluded that there were not enough controls and checks in the execution of the subsidy scheme. The energy labelling registration database includes often incorrect or inaccurate information about the situation in practice, so the reliability of registered energy labels is weak.

In the evaluation of the scheme by Filippidou et al. (2016), the richer SHAERE database was used in combination with the RVO data to determine in which dwellings measures were taken, but there were still issues related to data quality. For example, many dwelling reports in SHAERE indicated that no improvement occurred. Interviews with housing corporations, however, provided indications that the measures were indeed taken. This means that the renovation was not registered in SHAERE. This raises some questions about the reliability of databases like SHAERE (Filippidou et al., 2016).

Other uncertainties

The evaluation report in 2016 (OTB, 2016) provides data not only about the subsidized energy saving actions that reduce the gas use like insulation or condensing boilers, but also actions such as connection of houses to a district heating network or installation of solar PV. The estimated gas savings per label step, however, don’t consider these actions.

Experience Feedback from Stakeholders

ECN interviewed Mr. Jurriaan Kooij, senior policy evaluator, from the Audit office of Amsterdam, who was the project leader of the evaluation. Two main points are summarized below.

There was no business-as-usual scenario (baseline) developed, which raises the question: “What would have happened without a subsidy scheme?” It is not unlikely that measures would have been taken in absence of a subsidy scheme because of regular maintenance (for instance replacing a boiler at the end of its lifetime). If most measures would have been taken without a subsidy scheme the “additional” effect of the subsidy scheme is low. Thus, to monitor the “real” effectiveness of the policy instruments a baseline is required.

As a suggestion to improve monitoring it was recommended to make rules that parties that receive subsidies are obliged to make information available and accessible for evaluation. This way it can be made sure that the design of the policy is evaluative, goals are clearly formulated, data to measure the effects should be available, etc.

Evaluation using a before and after renovation comparison

In a study by Filippidou et al. (2016), the Amsterdam case was analyzed once again but this time based on metered energy use data of the dwellings that took part in the scheme, using a before and after renovation comparison. For the dwellings that have undergone renovation, longitudinal data from

2009 to 2013 was used to examine actual and predicted gas consumption before and after the measures were taken.

Data from the RVO label database and SHAERE database were coupled to the actual energy consumption data, which is collected by Statistics Netherlands from energy companies. The companies report the billing data, which are calculated based on annual meter readings annually. SHAERE is much richer than the RVO label database. It includes information on the dwellings' geometry, envelope and installations characteristics and the predicted heating energy consumption. The data is available before and after the renovations of the dwellings (until 2013). After the RVO data was matched to SHAERE, 7307 dwellings formed the final sample. After a filtering process, which is explained in the study of Filippidou et al. (2016), the final sample comprised 819 dwellings. So, the sample size was decreased considerably.

In Figure 2 the energy savings are presented categorized by the energy label steps. The first letter in the name of the category indicates the energy label pre-renovation and the second letter the label post-renovation. For example, category CA includes dwellings that have been renovated from label C to label A. The labels were taken from SHAERE but originate from the official RVO dataset. The change in gas consumption is shown for both the actual gas consumption and for the predicted gas consumption in all three figures. Note also that there are counterintuitive results in the predicted gas savings in the EA and EC categories: there has been an increase in the predicted gas consumption. This can be explained due to data quality issues. Large discrepancies between the labels registered in SHAERE and in RVO were observed. For a substantial number of the dwellings in category EA, the new label A is not registered in SHAERE. The pre-renovation label E remained in SHAERE along with the corresponding predicted energy consumption. The same seems to happen with the dwellings of category EC. So, the new labels were not registered in SHAERE.

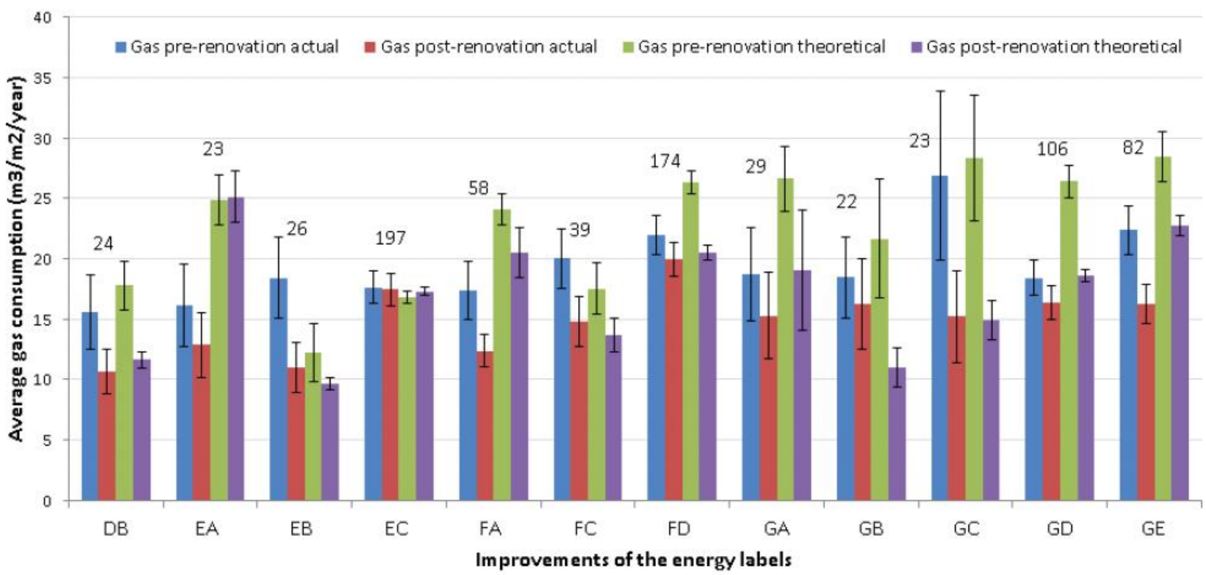


Figure 2: Comparison of actual and predicted (theoretical) energy savings for different label steps based on a before and after renovation comparison (Filippidou et al., 2016). 95% confidence interval shown with black lines.

The main outcome of the analysis is that in almost all groups of dwellings the gas consumed after renovation decreased significantly. Most of the dwellings had a combination of measures performed and the actual gas consumption savings depend on these combinations. The gaps between theoretical savings and actual savings are much lower for some of the label steps with even for some label steps about the same savings as expected theoretically (e.g. GE or GC). Even though gas savings after renovation were observed in all dwellings no pattern was found indicating that the better the predicted energy performance achieved, the more actual savings were realized after renovation, but this may be due to the relatively small size of the sample.

Other indicators monitored and/or evaluated

Aside from CO_2 reductions, the label improvements were also intended to achieve other positive effects for the occupants, namely:

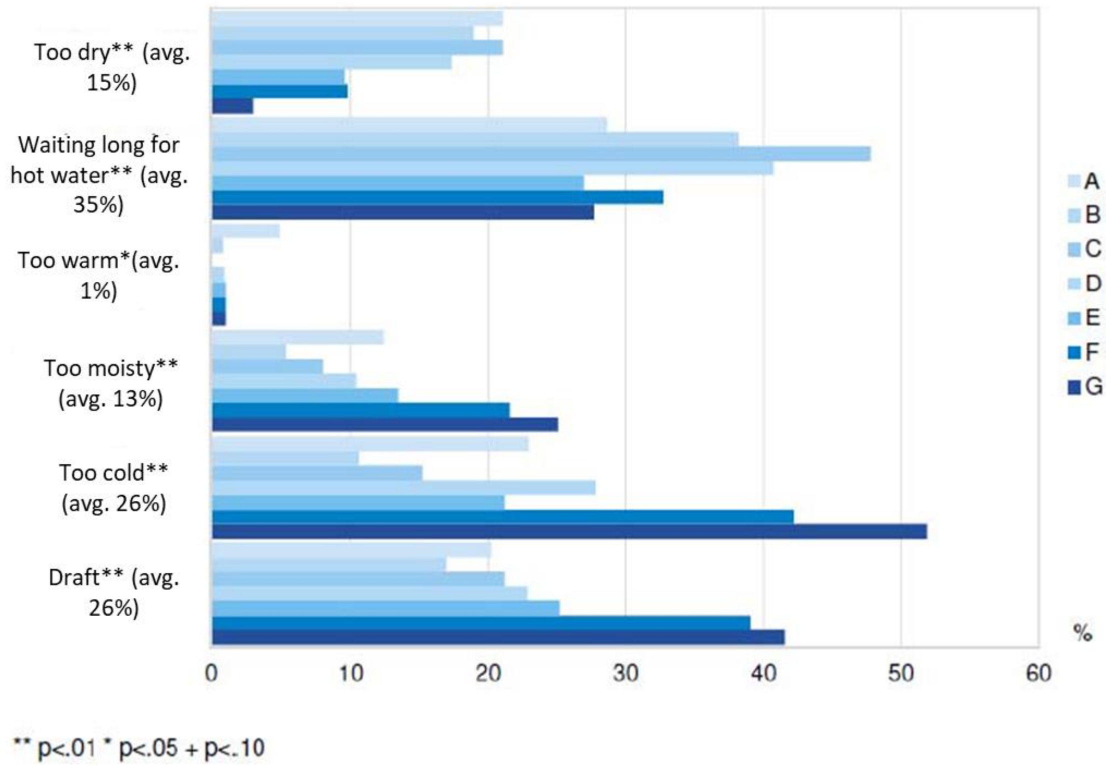
- Reduction of the energy bill
- Improvement of living comfort

For the city of Amsterdam, it is important that improvement of energy labels in the social housing sector will reduce the energy use and make low income households more able to pay their energy bill. In a survey of occupants this indicator was evaluated (Audit Office Amsterdam, 2014). The affordability of energy is calculated as the energy bill in relation to income. From the respondents 68% provided data on their income and 84% were aware on the amount of their energy bill. The results give a strong relationship between the energy label of the house and the affordability of energy. The average energy bill, the part of the income spent on energy, and the fraction of households that is paying more than 10% of their income to energy is lower for better energy labels. The average energy bill is reduced from €1,451 per year for a G label house to €1,148 per year for an A label house, a decrease of 25%. In addition, house occupants were asked in a survey whether they experience problems with paying the energy bill. Questions asked include whether they have problems with paying the energy bill, whether they have payment delays or whether they experience threatening closure of access to energy. In the results of the survey no relationships were seen with the energy label.

The survey of occupants was also used to evaluate living comfort indicators qualitatively (Audit Office Amsterdam, 2014). Occupants were asked how they experience the temperature and air humidity in their home, whether they experience draught or must be waiting long for hot water.

Figure 3 shows that occupants of inefficient homes with labels G and F experience their homes on average much colder than occupants of efficient homes with a better label. For example, 52% of households finds their G label house too cold, compared with 23% of households in an A label home. Incidentally, occupants in a B label house experience even less cold in their house: only 11% experience the house too cold in the winter. Also, occupants of inefficient dwellings have relatively much more trouble with drafts (feel of air leakage): 42% of the occupants in a label G home experiences drafts, against 20% of the occupants in an A label house. Occupants of inefficient homes also find their home relatively often too humid. For example, 25% of the occupants finds their G label house and 21% finds their F label house too humid, compared to 13% on average. Conversely to these positive links between energy efficiency of the home and the perceived living comfort it is found that households with energy labels A, B, C and D find the air in their house drier (around 20%) than households with energy labels E, F and G (3-10%). Households with energy label A appear to experience relatively more that the temperature is too high. However, this is only a very small group, 5% of households. The reason the temperature is too high has to do with technical installations and temperature control. For the availability of hot water, no clear relationship with the energy label was found.

The housing corporations also mentioned that replacement of older gas installations improves safety and health. These improvements were not monitored or evaluated.



Source: Audit Office Amsterdam, 2014 (figure 7.2)

Figure 3: Experienced lack of living comfort per label class.

Conclusion

The Amsterdam case shows the limitations of using energy labels as a base to estimate actual energy savings. By comparing different estimates from literature, this paper shows the limitations of these methods and highlights the importance to base estimates of real effects (as much as possible) on metered energy use data of the dwellings that took part in the subsidy scheme.

The Audit Office estimated that the effect of a label step on the "actual" gas use is much lower than expected by the energy labelling method. The gas savings are different for different label steps, from G to F, from F to E, from F to D etc. In the best case, a label step would save 3 m^3 gas per square meter, but in the worst case the "actual" gas use is higher after the label step according to the Audit Office. A decrease in gas use was only visible for houses with an energy label of C or better according to the results of the Audit Office. However, this method also has its own limitations. In the evaluation, the average metered gas use per label class from a sample of dwellings with similar labels was used to estimate savings. The differences in average energy use per label class may reflect differences in energy efficiency of the building envelope and heating systems, but also differences in the energy behaviors of the occupants.

To estimate the realized savings a before and after renovation comparison of the dwellings targeted by the subsidy scheme is required. A before and after comparison of the renovated dwellings reveals a different outcome as the one given by the Audit Office. The main outcome is that in most of the dwellings the gas use after renovation decreased significantly (see Figure 2). The gas savings are dependent of the amount and types of energy saving measures taken. The gaps between theoretical savings and actual savings are much lower for some of the label steps with even for some label steps the same savings as expected theoretically (e.g. GE or GC).

The causes for the difference between the theoretical savings and “actual” savings (based on metered energy use from dwellings with similar energy labels) could be due to the energy behavior of residents and in the heating and ventilation of the house. Households in energy-inefficient homes are more “economical” with the heating: they lower the temperature and heat relatively less rooms. This may especially be the case for low-income households such as those in this case study, as they cannot afford high energy bills. Households in energy-efficient homes, on the other hand, are heating more rooms in the dwelling and also seem to raise the temperature. But the differences between theoretical and “actual” energy use are much smaller for labels A to C (theoretical use slightly underestimated), than for labels D to G (theoretical use overestimated to a larger extent, especially for the least efficient labels).

There are a number of issues that make evaluative studies on label improvements difficult. The first is that the energy label should represent the current state of the building and is not outdated by renovation. If the latter is the case, then there will be mismatch between label and energy use. The evaluator needs to compare the subsidized label steps with the energy labelling registration database for the situation prior to the renovation, so good data quality of these databases is required. Secondly, the labels are sometimes insufficiently reliable, because the assumptions made in the assessment models are not always correct, for example the temperature or the assumed proportion of rooms that are heated. Thirdly, the Amsterdam case shows the limitations of using average values taken from different dwellings than the ones where the renovation works were done. This can indeed create large uncertainties. It is therefore more accurate to estimate gross energy savings based on metered energy use data using a before and after renovation comparison.

With a label step subsidy, it is not just about reducing energy use and CO_2 emissions. The municipality Amsterdam also expects that making housing corporations more energy-efficient contributes to keeping the energy bill affordable for the lower incomes. In addition, in making a home more energy-efficient this possibly also leads to more living comfort. Occupants would finally be able to decently heat their home after implementation of the measures. Occupants of G and F label houses more often experience their home as too cold and draughty than occupants of houses with a better energy label. Conversely, occupants of houses with an A, B, C or D label more often experience the air too dry and the temperature too high than occupants of houses with a E, F or G label. A full definition of cost-effectiveness of the subsidy scheme would at least take benefits (but also possible downsides) into account, such as improvement of living comfort and - therefore as this - improvement of health.

Possible alternative: Stimulating specific measures

So can greater achievements be realized by stimulating only specific saving measures? Research was conducted to investigate the usefulness of stimulating specific saving measures in Amsterdam housing corporations (OTB, 2016). Most homes of Amsterdam housing corporations are not well insulated, have double glazing and a highly efficient gas-fired condensing boiler (Dutch: HR-107 boiler). It has been shown that by insulating an un-insulated home, approximately 143 m^3 of gas per dwelling per year can be saved. The energy saving when replacing double glazing with high efficiency double glazing or triple glazing depends very much on the quality of the double glazing and the savings can vary from 21 to 80 m^3 (and even up to 143 m^3 with old double glazing). In summary, the conclusion was that there are no energy-saving measures for which there is robust evidence that specific stimulation has more effect than generic stimulation, such as the label step subsidy. OTB also concludes that it is difficult to say which individual measure should be given priority, because the energy saving is very dependent on the characteristics of the house. A recent study by Filippidou et al. (Filippidou et al., 2017) concludes that predicted savings cannot be considered accurate with the current calculation models when compared to the actual savings. Depending on the type of measure, the actual savings are for some measures overestimated (i.e. roof insulation, facade insulation) but sometimes also underestimated (i.e. ventilation). Individual building renovation roadmaps/passports based on a detailed energy performance assessment including metered energy use data are thus very important. In terms of single measures reductions, improvements in efficiency of gas boilers (heat and hot tap water) generally yield the biggest energy reduction, followed by deep improvements of window quality (OTB, 2016; Filippidou et al., 2017). Improving the ventilation system yields a relatively small reduction compared to other measures, however, it is still much larger than theoretically expected (OTB, 2016; Filippidou et al., 2017).

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