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Actual Energy Savings of Renovated Dwellings: the Case of Amsterdam

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Abstract

The existing housing stock plays a major role in the realization of the energy efficiency targets. The non-profit housing sector in the Netherlands dominates the housing market as it represents 31% of the total housing stock. In the municipality of Amsterdam, where this share is even 46%, subsidies were given to housing associations between 2011 and 2014 when an energy renovation of their rental property took place and resulted in a better energy performance. The aim of this paper is to examine the impact of thermal renovation on the actual and the predicted energy consumption of the dwellings concerned and to compare both types of consumption. For the non-profit rental dwellings that have undergone renovation in Amsterdam, we use longitudinal data from 2009 to 2013 to examine their actual and predicted gas consumption before and after renovation. 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. Despite the fact that 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.

Keywords - energy efficiency improvements, monitoring, actual energy consumption, non-profit housing

1. Introduction

The existing housing sector is already playing an important role towards achieving the energy efficiency targets worldwide and in the European Union (EU) [1] [2]. A large part of this energy consumption comes from the residential sector, as dwellings consume 30% of the energy of the total building stock on average in the EU [3]. The non-profit housing sector in the Netherlands dominates the housing market as it represents 31% of the total housing stock [4]. In the municipality of Amsterdam the share of the non-profit housing reaches 46% [5]. Energy renovations in existing dwellings offer unique opportunities for reducing the energy consumption and greenhouse gas emissions. Monitoring the energy improvements of the existing housing stock is necessary and can provide valuable information, concerning the energy savings that can be achieved both in terms of actual and predicted energy consumption. The patterns of the predicted energy reduction in most cases differ from the actual energy consumption [6].

This paper examines the impact of thermal renovation measures on both the predicted and actual energy consumption of the renovated non-profit stock in the municipality of Amsterdam. The actual savings reveal the true effect of renovations on the reduction of energy consumption. The actual energy also highlights the result of the number and combinations of measures on the dwellings' performance. First we analyze the energy efficiency measures realized and then their impact on the actual and predicted energy consumption. In the following background section 2 we discuss the subsidy scheme of the municipality of Amsterdam and our approach on what comprises an energy renovation. Section 3 focuses on the data and research methods used. In section 4 we present the results of the analysis and in section 5 we draw conclusions based on the outcomes of the research.

2. Energy Renovations in Amsterdam

In the Municipality of Amsterdam, in the framework of the agreement 'Bouwen aan de Stad II 2011-2014' (in English: "Building the City II 2011-2014") subsidies were given to housing associations when an energy renovation of their rental property took place and resulted in better energy performance [7]. The performance is assessed based on the energy label of the dwellings before and after the renovation took place. Specifically, the subsidy, named 'Bijzondere subsidieverordening verbetering energie-index 2011' (in English: "Special subsidy for the improvement of the energy performance 2011"), is given if at least 2 energy label steps are achieved (e.g. from a G label to at least an E label) [8]. The housing associations can apply for the subsidy when the energy renovation has already taken place and they can do so twice a year, in February and July. The subsidy refers to existing dwellings only, that were renovated after July 2011 and until July 2014 and the new energy label is registered officially to the Netherlands Enterprise Agency (RVO), prior to the application.

For the purpose of this paper we define an energy renovation as the improvement of the energy performance of a dwelling by at least two label steps, following the definition by the subsidy scheme in Amsterdam. In the Netherlands the energy performance of a building is expressed by the Energy Index (EI), which is a dimensionless figure, ranging from 0 (extremely good performance) to 4 (extremely bad performance). The calculation method of the EI is described in NEN 7120 [8] and in ISSO publication 82.3 [9]. Based on the EI an energy label is assigned to the dwellings.

3. Data and Research Methods

This study includes an inventory of energy saving measures of the non-profit rented stock in Amsterdam from July 2011 to the end of 2014. In addition, we examined the effectiveness of these measures based on actual and predicted energy savings. In the Netherlands, 85% of households are heated with natural gas [10]. Thus, for the purposes of this study we focus on the gas consumption data. We used three different datasets to achieve the identification of the measures and examine their effectiveness. In all three datasets an identifier variable for each dwelling is used, comprising of the address, postcode and city, in this case Amsterdam.

First, the official RVO energy label records for the specific renovated dwellings were used. This information was provided by the Rekenkamer Metropool Amsterdam (in English: the audit office of the Amsterdam Metropolitan Region) with the aim of researching the effect of the subsidy scheme on actual energy savings. As a result we were able to have the addresses and some technical characteristics, including the energy label, of the renovated dwellings. 9009 dwellings were present in the dataset from 2011 to 2014.

Second, we used the SHAERE database ("Sociale Huursector Audit en Evaluatie van Resultaten Energiebesparing" – in English: Social Rented Sector Audit and Evaluation of Energy Saving Results). SHAERE is the official tool for monitoring the progress in the field of energy saving measures for the non-profit housing sector. It is a collective database in which the majority of the housing associations participate [11]. The database includes data from 2010, 2011, 2012, 2013 and 2014 on the performance of the stock in the form of energy labels, without all of them being officially registered at RVO. The analysis is based on longitudinal data using the identifier variable to follow the energy saving measures of the dwellings. SHAERE is much richer than the RVO official energy label database. It includes information on the dwellings' geometry, envelope and installations characteristics and the predicted heating energy consumption based on ISSO publication 82.3 [9]. The data is available before and after the renovations of the stock. In order to identify the energy saving measures we follow seven variables. These include: heating system, domestic hot water system, ventilation system, floor insulation, roof insulation, façade insulation, and type of glass. However, due to the fact that some housing associations provided data only for 2014, and therefore past renovations could not be identified, the sample decreased to 7465 dwellings. When we matched the RVO data to SHAERE 7307 dwellings formed the final sample. This decrease is due to double address reports and missing cases.

Third, we matched the data from RVO and SHAERE databases to the actual energy consumption data, which is collected by Statistics Netherlands from energy companies. The companies report the billing data, which are calculated on the basis of annual meter readings annually. In order to compare the data of the predicted heating gas consumption and the actual gas consumption from the Statistics Netherlands a climatic standardization was applied. The Statistics Netherlands data corresponded to the different years of 2009, 2010, 2011, 2012 and 2013. The energy label calculation reported in SHAERE, on the other hand, assumes 2620-heating degree days [9], therefore we applied correction factors to the actual gas consumptions supplied by the Statistics Netherlands.

Data filtering was required from the beginning of the data analysis and especially when we coupled the datasets. In SHAERE we eliminated dwellings with double records, with default set values in all variables and with unrealistic area (when $<15m^2$ or $<700m^2$). Further, we noticed some discrepancies between the RVO and the SHAERE dataset. After testing the distribution of the energy labels for both datasets, we decided to select the dwellings where at least two label steps were achieved after the renovation, based also on the definition by the subsidy scheme. The representativeness of this smaller group of 3207 dwellings was better and in accordance with the official RVO energy labelling dataset. When coupled with the actual gas consumption data from the Statistics Netherlands, more dwellings had to be eliminated because they did not match on the address identifier variable. From the ones that matched several had missing values of gas consumption and were eliminated as well. Also, we had to exclude the dwellings that were renovated in 2013 or in 2014, as the actual gas consumption data are available until 2013. In addition, we removed the dwellings that had unrealistic values of gas consumption (<15m^3 and >6000m^3). The final sample comprised 819 dwellings. In the following section the results of the two-part analysis will be presented.

4. Results

First, the results of the energy efficiency measures that took place from July 2011 to the end of 2014 in the non-profit housing stock of Amsterdam will be presented and described. Next, the outcomes of the effect of these measures on the actual and predicted gas savings will be analyzed. In both cases, we will focus on the amount of measures performed and the combination of those measures. However, we will also describe briefly the most frequent individual energy efficiency measures.

4.1 Energy Efficiency Measures

In this part of the analysis, using the SHAERE and RVO databases, we investigated the energy-saving measures that took place in the non-profit stock of Amsterdam under the aforementioned subsidy scheme [8]. In order to get the subsidy the housing associations needed to improve the performance of the dwellings by at least two energy label steps and to register the new label to RVO.

In the SHAERE database, only 39% of the dwellings had an officially registered label to RVO after the renovation was realized. Of these, only 58% achieved two or more label steps. In 32% of the dwellings no label change was reported. 4475 out of the 7307 cases had information on the space heating systems. 48% of the dwellings (2155 cases) has not undergone any change of the heating system. In 47% of the dwellings (2122 cases) a conventional boiler (η<0.80-0.90) was replaced by a condensing boiler ($\eta \geq 0.95$). Only three boilers were replaced by a heat pump and 149 were replaced by district heating. For the domestic hot water system the facts are similar because in most cases in the Netherlands the two systems are combined. 48% of the dwellings (2180 cases) changed the domestic hot water system. 47% (2094 cases) of those switched to a condensing boiler ($\eta \geq 0.95$). 4474 dwellings had information about the ventilation system. 26% of the dwellings (1181 cases) replaced natural ventilation with mechanical exhaust ventilation. Mechanical supply and exhaust ventilation is rarely used in this sample. The values and boundaries used to distinguish between the levels of insulation derive from the ISSO publication 82.3 and presented in Table 1 and Table 2 [9].

Table 1. Insulation categories for floor, roof and façade based on the ISSO 82.3 [9]

Characterization	R_c value floor W/(m^{2}K)	R_c value roof W/(m^{2}K)	R_c value façade W/(m^{2}K)
No-insulation	$R_c \leq 0.32$	$R_c \leq 0.39$	$R_c \leq 1.36$
Insulation	$0.32 < R_c \leq 0.65$	$0.39 < R_c \leq 0.72$	$1.36 < R_c \leq 2.86$
Good insulation	$0.65 < R_c \leq 2$	$0.72 < R_c \leq 0.89$	$2.86 < R_c \leq 3.86$
Very good insulation	$2 < R_c \leq 3.5$	$0.89 < R_c \leq 4$	$3.86 < R_c \leq 5.36$
Extra insulation	$R_c > 3.5$	$R_c > 4$	$R_c > 5.36$

Table 2. Window categories based on the ISSO 82.3 [9]

Characterization	U value window W/m^2/K
Single glass	$U \geq 4.20$
Double glass	$2.85 \leq U < 4.20$
HR+ glass	$1.95 \leq U < 2.85$
HR++ glass	$1.95 \leq U < 2.85$
Triple insulation glass	$U < 1.75$

Only 1600 dwellings had information about the floor insulation. 18% of those (296 cases) had an improvement of the floor insulation. 1948 dwellings had a report for the roof insulation. In 21% of these dwellings (413 cases) the roof insulation was improved. 4465 dwellings had a reported insulation value of the façade. 19% of these (854 cases) improved the façade insulation. However, in the majority of them minimal insulation was placed. On the other hand, the distribution covered by the practice (ISSO 82.3) was weak: there are many small insulation measures realized without the insulation category changing. By refining these categories we showed that 26% of the facades (1160 cases) were somewhat insulated.

4460 dwellings had information about the windows U values. The type of glass is improved in 35% of the dwellings (1573 cases). The glass is usually replaced with HR + or HR ++ glass and sometimes by triple insulation glass. In addition, 207 dwellings added PV cells and 17 a solar boiler for hot water.

We also examined the number of measures realized per dwelling. The maximum amount of energy efficiency measures is, as aforementioned in section 3, 7. Table 3 depicts the amount of dwellings and the number of measures per dwelling. According to SHAERE, when we examine the percentage of dwellings with at least one measure (3250, right column in Table 3), the division is between 1 to 5 measures is flat. In 20% of the dwellings, the measures taken during the renovation are not known. In 35.5% of dwellings no action was taken.

Table 3. Amount of measures per dwelling

Amount of measures	Frequency	Percentage	% of dwellings with at least one measure
Not filled in	1459	20.0	
0	2598	35.5	-
1	559	7.7	17.2
2	786	10.8	24.2
3	695	9.5	21.4
4	535	7.3	16.5
5	584	8.0	18.0
6	91	1.2	2.8
Totaal	7307	100	100 (3250)

In Table 4 the most common combinations of measures are indicated. These combinations are not exclusive. The most applicable combination is to improve simultaneously the windows insulation and the heating system: low-hanging fruit. In the municipality of Amsterdam, according to the renovated non-profit housing stock, 17% had one measure implemented, 24% two measures and 59% over two measures. The most common combination of measures is the replacement of the heating system and the glazing.

Table 4. Combinations of measures

Packages of measures improving at least:	Frequency	Percentage
Heating system and windows	1161	15.9
Heating system and façade	651	8.9
Heating system and roof	374	5.1
Heating system and floor	203	2.8
Heating system and windows and façade	476	6.5
Heating system and windows, façade and roof	111	1.5
Heating system and windows, façade, roof and floor	0	0.0
Façade and roof	200	2.7
Façade and floor	91	1.2
Total	3267	44.7 (7307)

As shown in Table 3 a large number of dwelling reports in SHAERE indicate that no improvement has occurred. The uncertainty of the figures, mentioned above, is large and it seems likely that they give a pessimistic view of the reality. Checks by the Rekenkamer Metropool Amsterdam indicated that the renovations have taken place, but were probably not filled in, or only partially filled in SHAERE. On the other hand, a recent study revealed that the pre-renovation labels, too often, are not properly set (worse than actual), leading to an overly optimistic picture of the completed renovations

[12]. So, although we do not have exact data on these biases, it could be that they weigh each other more or less out.

4.2 Effectiveness of Measures on the Actual and PredictedEnergy Savings

This section, first, discusses the effect of label change on the energy savings. Then, the effect of the amount of energy efficiency measures and the various combinations of measures on the energy savings is analyzed. The average gas consumption in this paper is expressed in m^3/m^2 and as a result is not floor area weighted (for example a dwelling of 500 m^2 weighs the same as a 40 m^2 apartment). In this way, the scale effect is neutralized. We used the Statistics Netherlands dataset to determine the gas consumption pre- and post-renovation. We used the 2009 or 2010 gas data for the pre-renovation values and the 2012 or 2013 data for the post-renovation consumption values. Only the dwellings renovated in 2010, 2011 and 2012 were taken into account.

Groups of dwellings with less than 10 cases could not be exported from the Statistics Netherlands environment for privacy issues and are therefore excluded from the analysis. In all graphs the mean value per group of dwellings is shown. Figure 1, Figure 2 and Figure 3 show the gas consumption before and after renovation in different categories.

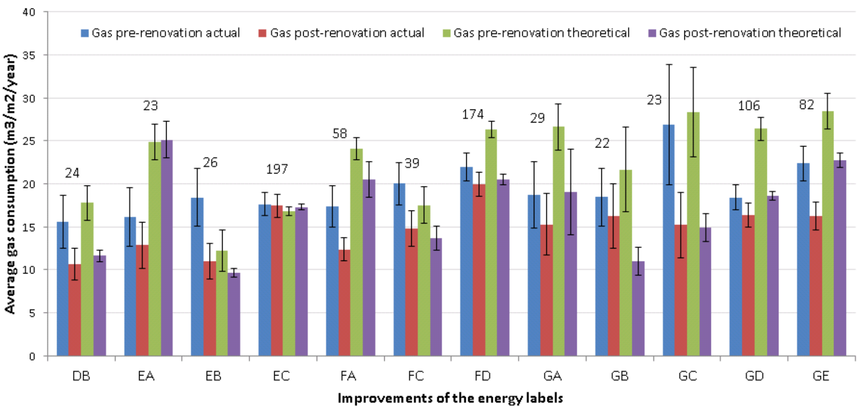

Figure 1. Improvements of the energy labels and the impact on the actual and predicted energy savings. The black lines are the 95% confidence intervals.

In Figure 1 the energy savings are depicted 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 from the official RVO dataset. The change in gas consumption is shown for both the actual gas consumption and for the predictedgas consumption in all three figures.

It is useful to notice the illogical results of the predicted gas savings in the EA and EC categories: there has been an increase in the predicted gas consumption, which is impossible. This has to do with the findings in section 4.1, where large discrepancies between the labels registered in SHAERE and in RVO were observed. For a large number of the 23 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. In short, the renovation was not registered in SHAERE. The same seems to happen with the 197 dwellings of category EC.

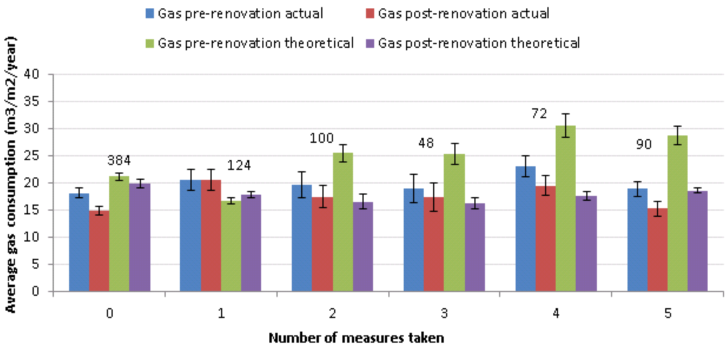

Figure 2. Number of measures realized and the impact on the actual and predicted energy savings.

Figure 2 shows the actual gas savings achieved as a function of the number of renovation measures taken. When only one measure is realized no gas savings are achieved. At the same time, the increase of the theoretical gas consumption highlights the indication that a lot of administrative corrections (meaning that housing associations probably have re-inspected their dwellings and corrected faults from the first inspection) were reported but not actual renovations. When two or three measures take place then the gas consumption decreases proportionally to the number of measures. The largest decrease as expected occurs when 5 measures are realized. Last, when observing the dwellings with no measures taken, according to SHAERE, we see a big reduction of gas consumption. This amount is significantly higher than the autonomous gas reduction of 0.4 m^3/m^2/year which was found in a control group of the non-renovated dwellings in Amsterdam. This indicates that indeed measures were taken, but are not reported in SHAERE.

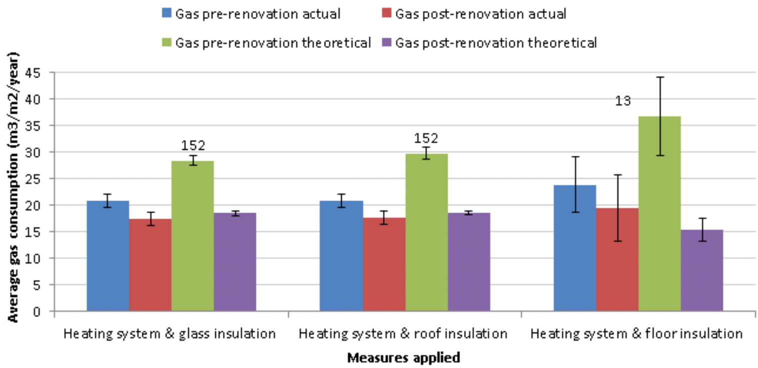

Figure 3. Combinations of measures realized and the impact on the actual and predicted energy savings.

Due to the fact that the majority of the dwellings had at least 2 measures realized we also examined the combinations of (non-exclusive) measures. The three most frequent combinations, with large enough size, are reported in Figure 3. The change of the heating system is present in all three packages of measures. This graph also shows that the predicted gas consumption after renovation is a lot closer to reality, which is in accordance with findings of [6].

5. Conclusions and Recommendations

The aim of this paper was to examine the impact of thermal renovation measures on the actual and predicted energy consumption of the non-profit housing stock in Amsterdam. This study, first, included an inventory of energy saving measures of the stock from 2011 to 2014. 17% of the dwellings had one measure implemented, 24% two measures and 59% over two measures. The most common combination of measures is the replacement of the heating system and the glazing. However, a large number of dwelling reports in SHAERE indicated that no improvement occurred. The uncertainty of the figures is large and it seems likely that they give a pessimistic view of the reality. As revealed by further interviews with housing associations by the Rekenkamer Metropool Amsterdam and the results of section 4.2, there are indications that the renovations were actually carried out. This fact, though, poses questions about the reliability of databases like SHAERE.

Then, we examined the effectiveness of these measures based on actual and predicted energy savings. The main outcome of the analysis is that in almost all groups of dwellings the gas consumed after renovation decreased significantly. The actual gas savings achieved depend on the number of measures in the sample of the renovated non-profit stock of Amsterdam. Most of the dwellings had a combination of measures performed and the actual gas consumption savings depend on these combinations. Despite the fact that gas savings after renovation were observed all over the sample no pattern was found indicating that the better the predicted energy performance achieved, the more actual energy savings were realized after renovation. However, as indicated by the confidence intervals in the graphics, the sample was too small to be generalized to larger samples.

Monitoring of the existing stock is of great importance to better understand the performance of dwellings and the actual energy savings that can be achieved from renovations. In addition, examining the effect of energy improvements on actual energy consumption is a valuable tool for the creation of successful policies in the future. In order to monitor such detailed processes, the gathering and processing of the data is essential. SHAERE is a useful example of a collective database including, to a big extent, most of the valuable information in order to examine energy renovations of the existing stock. Careful analysis of the data of such collective databases is crucial as this research showed.

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