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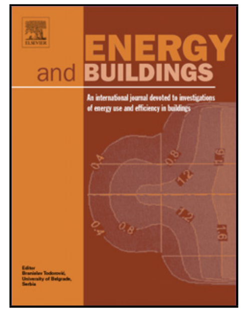

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Highlights

- The non-profit housing sector represents 31% of the total housing stock in the Netherlands and has a large potential of energy efficiency renovations.
- The majority of the energy efficiency measures regard the heating and domestic hot water systems, and the glazing.
- The data show that the goals for the non-profit housing sector will be hard to achieve if the same strategy for energy renovations is followed.
- A combination of longitudinal and cross-sectional data analyses is the necessary approach on the matter of energy efficiency in the building sector.

Abstract

The existing housing stock plays a major role in meeting the energy efficiency targets set in EU member states such as the Netherlands. The non-profit housing sector in this country dominates the housing market as it represents 31% of the total housing stock. The focus of this paper is to examine the energy efficiency measures that are currently applied in this sector and their effects on the energy performance. The information necessary for the research is drawn from a monitoring system that contains data about the physical state and the energy performance of more than 1.5 million dwellings in the sector. The method followed is based on the statistical modeling and data analysis of physical properties regarding energy efficiency, general dwellings' characteristics and energy performance of 757,614 households. The outcomes of this research provide insight in the energy efficiency measures applied to the existing residential stock. Most of the changes regard the heating and domestic hot water (DHW) systems, and the glazing. The rest of the building envelope elements are not improved at the same frequency. The results show that the goals for this sector will be hard to achieve if the same strategy for renovation is followed.

Keywords: energy efficiency improvements, monitoring, energy performance, non-profit housing

1. Introduction

Worldwide, the residential sector consumes an amount of energy that varies between 16% and 50% of the total , depending on the country (Mata et al., 2010b). Existing buildings account for approximately 40% of the energy consumption in the European Union and are responsible for 30% of the CO_2 emissions (Kemeny, 2002). The existing housing sector is already playing an important role towards achieving the energy efficiency targets in the European Union (EU) (SER, 2013; Ürge-Vorsatz, 2007). 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 (Itard and Meijer, 2009). This study focuses on the existing housing stock in Europe and specifically the Netherlands. Based on 2009 data, households consume 425 PJ annually, in the Netherlands (Statistics Netherlands, 2012).

Existing buildings will dominate the housing stock for the next 50 years based on their life cycle; in the Netherlands the annual rate of newly built buildings is 0.6 of the existing residential building stock in 2014 (Meijer et al., 2009; TNO 2009; Statistics Netherlands 2015).Energy renovations in existing dwellings offer unique opportunities for reducing the energy consumption and greenhouse gas emissions on a national scale in the Netherlands but also on a European and global level. Although there have been initiatives for energy renovations of dwellings in the Netherlands, the assessment and monitoring of these renovations has been lacking. Monitoring the energy improvements of the existing housing stock is necessary and can provide valuable information concerning the technical characteristics and the future potential of the measures applied. This paper investigates what the energy improvement measures in the Dutch non-profit housing sector are over the last years and how they impact the energy performance of the dwellings.

1.1 Energy efficiency measures and interpretations of energy renovations

Several measures and energy efficiency policies have been applied both on a European and a national level. In 2008, the Netherlands implemented the EU Energy Performance of Buildings Directive (EPBD). Under this directive, all member states must establish and apply minimum energy performance requirements for new and existing buildings, ensure the certification of building energy performance and require the regular inspection of boilers and air-conditioning systems in buildings (Beuken, 2012). The Dutch energy performance measurement system, based on the 'Decree on Energy Performance of Buildings' (Besluit energieprestatie gebouwen – BEG) and the 'Regulation on Energy Performance of Buildings' (Regeling energieprestatie gebouwen – REG), was introduced in 2008. The energy performance of a building is expressed by the Energy Index (EI), which is a figure ranging from ≤0.5 (extremely good performance) to >2.9 (extremely bad performance). The EI is calculated on the basis of the total primary energy demand (Q_{total}). The calculation method of the EI is described in NEN 7120 (published by the Dutch Standardisation Institute) and in ISSO publication 82.3 – ISSO, The Dutch Building Services Knowledge Centre (ISSO, 2009). Based on the EI an energy label is assigned to the dwellings. The primary goal of the energy labels is to provide occupants and homeowners with information on the thermal quality of their dwellings. In addition, the theoretical energy use of the dwelling is also mentioned on all Dutch labels issued after January 2010, expressed in kWh of electricity, m^3 of gas and GJ of heat, for the dwellings with district heating (Majcen et al., 2013).

The EI is calculated as follows:

$$\mathrm{EI} = \frac{\mathrm{Qtotal}}{(155*\mathrm{Afloor}+106*\mathrm{Aloss}+9560)} \qquad \text{Equation 1}$$

The EI is related to the total theoretical energy consumption of a building or a dwelling Q_{total} (MJ), in the nominator, and corrections applied (based on m^2), in the denominator. According to the norm of the calculation, as shown in Equation 1, the EI is corrected taking into account the floor area of the dwelling and the corresponding heat transmission areas in order not to disadvantage larger dwellings and those that have greater part of envelope areas adjoined to unheated spaces.

Q_{total} is the modelled characteristic yearly primary energy use of a dwelling adding up the energy for space heating, domestic hot water, additional energy (auxiliary electric energy needed to operate the heating system such as pumps and funs), lighting of communal areas and subtracting the energy generation by photovoltaic systems and/or energy generation by combined heat and power systems assuming a standard use as shown in Equation 2 (ISSO, 2009). It is possible that the photovoltaic systems contribution is greater than the consumption of the rest of the systems and as a result the Q_{total} can be negative (ISSO, 2009). A_{floor} refers to the total heated floor area of the dwelling whereas A_{loss} refers to the areas that are not heated in the dwelling such as a cellar (Visscher et al., 2012; ISSO, 2009).

$$Q_{total} = Q_{space\ heating} + Q_{water\ heating} + Q_{aux.energy} + Q_{lighting} - Q_{pv} - Q_{cogeneration} \quad \text{Equation 2}$$

The Energy Label is based on the calculation of the EI (see Table 1). Table 1 also depicts the correlation of the EI to the energy label and the mean actual primary energy consumption per label category based on a research performed on 200,000 Dutch dwellings (Majcen et al., 2013), since there is no direct connection of the EI and the theoretical energy consumption. Since January 1 2015 the calculation of the EI has changed in the Netherlands and is based on a point system . However, in this study we use the existing calculation method of the EI. This choice is based on the fact that all available data were collected before January 2015, when the new calculation method was not yet in effect. According to the new method for the EI calculation, the impact on the dwellings based on their typology would be different (distinction between single- and multi-family dwellings) (ISSO 2014). In a first sample of 27,500 dwellings, 60% of them maintained the same EI and 34% of them acquired a better or worse EI (ISSO 2014). In addition, the renovation year plays a major role in the new EI and other details that are more precisely calculated. Instead of a number, that is the case with the old method, the dwellings are characterized by a score of points for their energy performance that corresponds to an energy label after the registration to the Netherlands Enterprise Agency (RVO) (ISSO 2014).

In the context of improving the energy efficiency of the housing stock, the term ‘renovation’ is often used. However, there is no clear definition of what an energy renovation is on a global, European or national level. On top of that, there is no definition of the (amount of) improvements that a renovation should include in order to be called like this. For the latter, the European definition refers to either the area that is renovated or the cost of the renovation. A "major renovation" in the EPBD means the renovation of a building where (The European Parliament and the Council, 2010):

(a) the total cost of the renovation relating to the building envelope or the technical building systems is higher than 25% of the value of the building, excluding the value of the land upon which the building is situated; or

(b) more than 25% of the surface of the building envelope undergoes renovation.

This definition does not describe what are the measures that ensure a nearly zero energy consumption of the refurbished dwellings, but rather sets out under what circumstances an energy efficiency renovation should be undertaken. On the national level the situation is similar. Until now, most of the policy measures applied refer to the reduction of the energy consumption and the reduction of specific indicators such as the EI (BZK, 2014), but there are no guidelines or definitions of an energy renovation. According to the national plans for the nearly Zero-Energy Buildings (nZEB) implementation in the Netherlands, the definition of large-scale renovations will be developed in more detail in the Building Decree Regulation.

However, this has not been realized yet (NPNZEB_NL, 2013). For the aforementioned reasons, in this paper the energy efficiency measures applied on the social housing stock of the Netherlands are going to be identified through individual changes of the dwellings' physical characteristics. We examine every measure individually and then we investigate the number of measures applied in each dwelling. Moreover, we define the energy renovation pace as the amount of dwellings with an upgraded energy performance (at least one energy label step, e.g., from D label to C label) in a specific amount of time (e.g., one year).

1.2 Progress in energy efficiency in the non-profit housing sector

Housing tenures differ across Europe and there is no common definition for the non-profit housing sector. However, three common elements are present across European non-profit housing sectors: a mission of general interest, offering affordable housing for the low-income population and the realization of specific targets defined in terms of socio-economic status or the presence of vulnerabilities (Braga and Palvarini, 2013).

In the Netherlands, the non-profit housing sector comprises 2.2 million homes, which is 31% of the total housing market (BZK, 2013). This is a unique situation as the Netherlands have the highest percentage of non-profit housing in the European Union. The non-profit housing organizations have several goals and criteria to fulfil. Energy savings and sustainability are high on their agenda, especially since 2008 (Aedes, 2013). According to the Energy Saving Covenant for the Rental Sector ("Convenant Energiebesparing Huursector"), the current aim of the social housing sector is to achieve an average EI of 1.25 by the end of 2020 (BZK, 2012), which is within the bands of label B. The Covenant was signed by, among other stakeholders, Aedes (the umbrella organisation of housing associations), the national tenants' union and the national government. The goal of the agreement means an energy saving of 33% on the theoretical/predicted energy consumption in the period of 2008 to 2021 (CECODHAS Housing Europe, 2012). In order to better regulate this subsidised scheme, the Dutch government stated recently that, for the non-profit housing sector, funding from the government will only be provided to the housing associations if they raise the dwelling's energy label by at least three energy label levels (e.g. from D label to A, or from G label to D) (BZK, 2014). In 2013 the average EI of the sector was 1.69. At the current rate of energy renovation, in this case the improvement by one label step, which has a mean value of 4% for the last three years, it does not appear that the Covenant's aims will be achieved by the end of 2020 (Filippidou et al., 2014; Majcen et al., 2014, Tigchelaar 2014). The mean value of 4% derives from the turnover of 1,537,554 dwellings in the period 2010-2013 with an improvement of one label step (Filippidou et al., 2014). This rate is considered to be high in comparison with other building stocks. However, it refers to the non-profit housing stock of the Netherlands that acts collectively and has promised to delivered an average EI 1.25, equivalent to an energy label B, by the end of 2020. In addition, the renovation activity measured is considered to be at least one label step improvement.

In a report about the 2012 version of the Energy module of the Dutch national housing survey (Woononderzoek Nederland – WoON), Laurent et al. (2013) state that since 2006 the energy performance increased. However, it was also found that, the energy performance in the non-profit sector was low in comparison to the rest of the residential stock (Tigchelaar and Leidelmeijer, 2013). The non-profit sector, therefore, has a large potential for improvement. In addition, Aedes, reports on the progress of the non-profit housing sector each year. In 2014, based on 2013 data and taking into account 60% of the stock, an increase of the energy performance was highlighted in 2013 compared to 2012, 2011 and 2010 data (Aedes, 2014). In this report the mean value of the EI is presented along with the energy labels, energy systems and insulation levels distribution. Aedes reported that in 2013 6.2% of the dwellings have had an improvement of the EI. At the same time, the fact of a 4% improvement of the energy performance of the non-profit housing sector is supported (Filippidou et al., 2014; Majcen et al., 2014). Concluding, many measures towards achieving energy efficiency in the non-profit sector in the Netherlands have been realized but, the pace of change is too slow to reach the 2020 energy efficiency goals (Filippidou et al., 2014).

In this paper we identify the specific energy efficiency measures that have been realised, between 2010 and 2013. In order to be able to assess the effect on the energy performance of the measures applied in the non-profit housing sector, an analysis of the changes in all of the energy systems and envelope elements of the dwellings is presented. In the next section the data and methods are presented, followed by the results in the third section and the conclusions and recommendations in the fourth.

2. Data and methods

2.1 SHAERE database

A complete and detailed assessment of the current efficiency state of the social housing stock in the Netherlands is necessary in order to research the energy savings measures and their effectiveness on the energy performance of the dwellings. In 2008, after the formulation of the earlier covenant on energy saving, Aedes started a monitoring system of the non-profit dwellings called SHAERE ("Sociale Huursector Audit en Evaluatie van Resultaten Energiebesparing" – in English: Social Rental 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 social housing sector. It is a collective database in which the majority of the housing associations participate. The database is filled with the software program 'EPA-W', which most of the housing associations (more than three quarters) use for the management of their stock (Majcen et al., 2014).

Since 2010, when the database became operational, housing associations report their stock to Aedes in the beginning of each calendar year, accounting for the previous year (e.g. in January 2014 for 2013). They report the status of their whole dwelling stock at the end of the preceding year.

The database contains the necessary information, per home, to calculate an EI. The data imported include physical characteristics and installations of the dwellings. The data include the U values (thermal transmittance, $W/m^2{\cdot}K$) and R_c values (measure of thermal resistance, $m^2{\cdot}K/W$) (ASHRAE 2009) of the envelope elements, estimated energy consumption, expected CO_2 emissions, and the EI. Data for 1,448,266 dwellings were available for 2013, representing 60% of the total non-profit housing stock (see Table 2).

This study presents a first analysis of the trends of the energy improvement measures in the social housing stock between 2010 and 2013 in the Netherlands. First, the sample is described and then, based on this description, the method of analysis is presented.

2.2 Methods

This study focuses on the dwellings that have been reported more than once (i.e. where data have been inputted by the housing associations in repeated years) in order to pinpoint and to study the energy improvements performed each year). We use longitudinal data to observe the changes of the energy performance of the same dwellings. We observe whether or not the inputted data have changed from 2010 to 2013. We start with the changes in the EI.

Extensive data filtering was required before the start of the data analysis. First, the records for dwellings that were present in the database but contained no information had to be excluded from the analysis. Second, we removed all the potential duplicate cases from the dataset. When reports with exactly the same address, the same EI and reporting year were found, one of the duplicated records was removed. Third, we removed cases with exactly the same address and same reporting year, but different EIs, because it was not possible to select the most recent or correct one.

The following step was to remove the cases lacking data regarding 2010 or 2013. After the filtering, 757,614 dwellings remained, being the number of dwellings reported in both 2010 and 2013. If a deterioration of the EI was observed, we assume this to be an administrative correction. In these cases, the EI for the year before the change has been corrected to the level of the EI afterwards.

3. Results

This section presents the results of the analysis. Every table represents a measure to improve the energy performance of the respective dwelling. In total seven measures are taken into account. First, the average EI of the 757,614 dwellings participating in the analysis was calculated (see Figure 1).

In 2010 the mean value of the EI was 1.79 and in 2013 1.74 – a drop of 0.05 over three years. The data are normally distributed and the function of the EI for 2010-2013 is approximately linear. As a result , Figure 1 depicts the mean EI value for 2010, 2011, 2012, 2013 and the extrapolation of the mean value of the EI if the same pace of energy renovations were to continue. The graph essentially depicts what the energy performance of the non-profit housing stock in the Netherlands would look like if the same type and amount of measures are maintained. The current EI improvement pace is not fast enough to reach the goals. This linear extrapolation indicates that the target for the EI in the national Covenant (namely 1.25) will not be reached by the end of 2020 if this pace continues: the gap would be 0.35, which is nearly the width of an average energy label band. Based on the development of the EI within this period more and “major” energy renovations need to be realized.

In addition to the linear extrapolation of the EI, we also calculate and depict the cumulative distribution function of the EI. In Figure 2, starting from the top left, the 2010 cumulative distribution is depicted and continuing to the right and the bottom part of the figure the 2011, 2012 and 2013 functions are shown. Two interesting phenomena are taking place in Figure 2. First, we observe that the spread of the EI values does not change when it comes to the larger EI's. This means that the worse performing dwellings do not get renovated or very small changes are only applied. Second, in the 2013 part (bottom right) for the first time negative values of the EI appear. This on the other hand, depicts dwellings that produce more energy than they consume based on Equation 1 and 2. The actual probability of a dwelling having an EI of 1.25 in 2010 is 8.8%, in 2011 the probability is 9.1%, in 2012 9.2% and in 2013 the probability rises to 10.9%. The normal probabilities follow a similar pattern (14.5% in 2010, 15.0% in 2011, 15.2% in 2012 and 16.3% in 2013). In order to better understand the improvements leading to this development of the EI, we present the energy efficiency measures of the dwellings reported in 2010 and 2013. Looking at a period of three years reveals the kind of measures that the housing associations choose and which building characteristic is changing the most. In addition we examine the impact of these measures on the EI of the dwellings.

3.1 Energy efficiency measures applied in 2010-2013

In this sub-section we present and further examine the actual measures applied between 2010 and 2013. We start with the energy systems and we move on to the building envelope characteristics. Tables 3 through 9 present the outcome of the analysis comparing the state of the dwellings in 2010 and in 2013 and thus following the changes in all variables (installation systems, building envelope elements and the EI). On Tables 3 to 9 the blank cells represent changes that are impossible (e.g. from a condensing boiler to a gas stove) to happen. They are considered, as administrative corrections and as a result are left blank.

Table 3 depicts the change in the heating system in the dwellings that were reported in 2010 and in 2013. The table is best read from the horizontal line where the situation of the first year of report is shown, in this case 2010, to the corresponding vertical side where the situation in 2013 is depicted. In both reference years the heating systems are the same, ranging from a gas stove to a high efficiency boiler to a μCHP system. The diagonal line represents the dwellings whose heating system remained the same these three years.

The number of dwellings with a reported heating system is 757,614. Observing the diagonal of the table, we highlight that the dwellings having a stove (electric or running on gas/oil), high efficiency boilers or heat pumps are the ones that remain the most stable. On the other hand, dwellings with heating systems as the "conventional" boiler with efficiency less than 0.80 tend to change more. 44.6% of the "conventional" boilers were changed in the 3 years of investigation (19,283 in 2010 to 11,044 in 2013).

The table shows that the majority of the dwellings in 2013 have a condensing high efficiency boiler ($\eta \geq 0.95$) and the trend is that the biggest movements from the rest of the energy systems are happening towards the direction of the high efficiency boilers ($\eta \geq 0.95$), which for the time is the most energy efficient heating system. The largest change is happening from the condensing boilers of 0.90-0.925 and 0.925-0.95 efficiency, where for each category 35% of the dwellings changed their energy system to a condensing high efficiency boiler ($\eta \geq 0.95$). The movement towards a more sustainable energy system such as a heat pump or a μCHP is still not obvious as the percentages range from 0% to 2.7%. On the other hand the local electric stoves are not a frequent choice in the social housing stock. The local gas stoves are changed and in their place high efficiency condensing boilers ($\eta \geq 0.95$) are installed. The total percentage of change of the type of heating system is 17.6% meaning 1 in 5 heating systems is changing in a three year period. On average 5.7% of heating systems are improved per year. The replacement of the heating system is considered as the low-hanging fruit of energy efficiency measures and often, in the Netherlands, is performed under maintenance plans. The older, less efficient boilers are being phased out in a rather short period. In addition, Table 3 does not provide any information on how old the heating systems are. As a result, we observe a relatively high turnover in the non-profit housing stock of the Netherlands compared to other housing stocks.

Table 4 shows the changes of the domestic hot water system (DHW) in the dwellings that were reported in 2010 and in 2013. As with

, the table is best read from the horizontal line where the situation of the first year of report is shown, to the corresponding vertical side where the situation in 2013 is depicted. In both reference years the DHW systems are the same ranging from a tankless gas water heater to a high efficiency combi-boiler to a µCHP system. It is important to highlight at this point that the heating systems and the DHW systems are often combined in the Netherlands. As a result, in many dwellings there is one main system that provides heat for both "sub-systems". The diagonal line, represents the dwellings whose heating system remained the same during these years.

The number of dwellings with a reported hot water heating system is also 757,614. Starting with the diagonal of Table 4, the dwellings that have an electric boiler, a high efficiency boiler or district heating mostly keep this type of generating hot water. Among these types, district heating is not very common. It is used in some cities only for DHW and occasionally for the heating system as the output temperatures are typically not very high.

Conversely, dwellings with DHW systems as the "conventional" or "improved" boiler are relatively often replaced by another system. This is in line with Table 3, where the heating systems were shown – a similarity that can be explained by the fact that many dwellings have combined systems for heating and DHW. 40.9% of the "conventional" boilers were changed the last 3 years. As with the heating systems, the popularity of high efficiency boilers ($\eta \geq 0.95$) increased considerably.

A remarkable finding is that from the dwellings that had a heat pump in 2010 20.4% changed to a condensing high efficiency boiler ($\eta \geq 0.95$) in 2013. This finding is counter-intuitive since heat pumps are perceived to increase the energy efficiency of a dwelling. An explanation might be that heat pumps have been found too slow in generating hot water, so that a boiler is installed to tackle this issue. The movement towards a more sustainable energy system such as a µCHP or a heat pump is not obvious as the percentages are 0% and 0.6% respectively. On the other hand the tankless gas water heaters, gas boilers and "conventional" low efficiency boilers are decreasing in the social housing stock and in their place mostly high efficiency condensing boilers ($\eta \geq 0.95$) are installed. The percentage of change for the type of DHW system is 15.5%, close to that of the heating system.

Table 5 shows the changes of the ventilation systems of the dwellings that were reported in 2010 and in 2013. As with Table 3 and Table 4, the table is best read from the horizontal line showing the situation in 2010 to the corresponding vertical side where the situation in 2013 is given. In both reference years the ventilation systems are the same ranging from natural ventilation to mechanical supply and exhaust, centralized and decentralised system (categories such as the heat recovery mechanical ventilation are so rare in the Netherlands that are eliminated from the analysis). The diagonal line, as a consequence represents the dwellings whose ventilation system remained the same for three years. In ventilation, there are not many choices for the residential sector. The majority of the dwellings have either natural or mechanical exhaust ventilation systems. Two main trends emerge in Table 5. The first one refers to the dwellings that had natural ventilation in 2010 and mechanical exhaust ventilation was placed in 2013 and the second one refers to the opposite. Another small, in percentage, change is the one of a mechanical supply and exhaust central system to a simpler mechanical exhaust system in 2013. Additionally, due to the fact that almost no mechanical supply and exhaust decentralised ventilation systems were present in the non-profit housing stock, this category was merged with the mechanical exhaust and supply central systems. The total percentage of dwellings with a change in the type of ventilation is 8.7%, much lower that the heating and DHW systems.

Table 6 refers to the type of windows (glazing and frame). This is one of the most popular energy saving measures. 757,192 dwellings were analysed as some of them did not have the information for both years (2010 and 2013). The categories of the types of windows are based on the U values that were inputted in SHAERE. The categories were created according to the guidelines of the ISSO 82.1 publication (ISSO, 2011) to characterise the types of windows based on their thermal transmittance. In order to extract the U values of the windows, we calculated the mean U value of all windows per dwelling. The categories include single glass windows, double glass, HR+ and HR++ glasses and triple insulation glass.

The diagonal shows the dwellings with unchanged windows. The triple insulation windows remain 100% unchanged. On the other hand 36.2% of the single glazing windows have been replaced in 2010-2013. The majority of the dwellings have double glazing, both in 2010 and in 2013. At the same time, 9.4% of the dwellings with double glazed windows in 2010 changed towards better quality windows in 2010-2013. The dwellings having single glass windows in 2010 changed with a percentage of 36.2% towards mainly double and HR++ windows. Only 0.5% of this 36.2% changed to triple insulation glass. The improvement of the glazing is common in the non-profit housing stock of the Netherlands due to the fact that in the country old uninsulated windows are being replaced on a national scale and is one of the low-hanging fruit of energy measures.

Based on the present results for the type of windows but also on the heating and DHW systems, a trend starts to form. The energy efficiency measures taking place in the non-profit housing sector are focused mostly on doing business-as-usual and mainly maintaining the housing stock. Realising more ambitious energy efficiency measures such as installing a μCHP or triple insulation glass proved to be a rarity. The total percentage of change in the type of windows is almost 10%.

Table 7 presents the changes in type of wall insulation. Again, based on the ISSO 82.1 publication (ISSO, 2011) different insulation categories were created based on the Rc values of the walls. Taking into account the ISSO 82.1 guidelines, we present a range of no-insulation for the dwellings that were built before the 1970's for example, to extra insulation of an nZEB level. The table shows the changes that were big enough to change a category of insulation. From this variable of the building envelope it is clear that the majority of the non-profit building stock is likely to have been built before the 1970s. For that reason we observe that the majority of the dwellings in 2010 have no wall insulation ($R_c \leq 1.36$) whereas for 2013 the majority of dwellings has insulation ($1.36 < Rc \leq 2.86$).

The diagonal shows, as in the previously presented tables, the dwellings with unchanged wall insulation. The very good and extra insulation dwellings remain 100% unchanged and then the non-insulated walls are the ones that change. The majority of the non-insulated dwellings change to the next category which is the insulated walls by 11.3% and only 0.2% to well insulated walls or 0.1% to very well insulated walls. The percentage of change for wall insulation is 7.06%.

Table 8 depicts the changes in the level of roof insulation of the dwellings. For the roof insulation 456,112 dwellings out of the 757,614 had data for both 2010 and 2013. On the diagonal the unchanged dwellings are present. Again, the very good or extra insulated dwellings regarding their roof remain almost entirely unchanged.

The non-insulated, insulated or good insulated dwellings, move by 13.8%, 16.5% and 19% respectively to very good insulation for the roofs. These percentages are quite large compared to the window or the wall insulation. However, the total percentage of roof insulation change is 6.64% and the sample is smaller. As a result, no definitive results can arise.

Last, Table 9 presents the changes of the floor insulation in the dwellings. 469,123 dwellings had information for both years.

The majority of the dwellings both in 2010 and 2013 have no floor insulation. The diagonal shows that few changes in the type of insulation are happening. The categories for the floor insulation are based on the Rc values of thermal transmittance according to ISSO 82.1 (ISSO, 2011). Here as well, the very well and extra insulated dwellings remain 100% unchanged. The rest of the categories (non-insulated, insulated and good insulated) move to well or very well insulated floors. The movements of the floor are quite different than that of the walls where only small steps towards less efficient solutions are taking place. The total percentage of change for the floor is 9.42%, higher than the roof insulation 6.64%.

3.2 Number of measures applied and their impact on the energy performance

In this sub-section we report the number of changes per dwelling. The data are presented in the form of the total number of dwellings that have performed one energy efficient measure, two measures, three measures or more. Additionally, we also present the dwellings that had no energy efficiency measure applied and treat them as a control group of dwellings. These changes are allocated to the energy installations and the building envelope elements, presented in the results section. In more detail we consider any improvement of the space heating, DHW, and ventilation systems as a measure. That means that if a dwelling changes a condensing high efficiency boiler to a new condensing high efficiency boiler this would not be perceived as a change since it is not affecting the energy efficiency of the dwelling.

When it comes to the insulation changes of the building envelope elements (windows, walls, floors, roofs) as stated in the results, first a classification scheme was created in order to follow the changes. For every element different classifications were created based on the Rc values reported in the ISSO Publication 82.1 (ISSO, 2011) and in accordance to the report on exemplary dwellings in the Netherlands from the Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland, 2010). In this way we follow and report any change towards a different level of insulation. If we were to track the changes only as positive or negative following just the R_c

value number we would not have at this point an indication of the level of insulation today but merely a count of the positive and negative changes.

We realized the method of the total amount of energy improvements per dwelling by following the changes in each of the eight elements reported and summed them up to a final number. Thus, it was possible to track the dwellings that have performed none, one, two, three or more than three energy efficiency measures. We calculated the mean value of the EI of the dwellings in 2010and then we repeated the same calculation for the mean value of the EI in 2013. Using longitudinal data (times series of 2010, 2011, 2012 and 2013) enabled the calculation of the impact of the energy efficiency improvements on the average EI.

Table 10 shows the percentage of dwellings where energy efficient measures were achieved. 64.5% of the dwellings had no change in three years. For the rest 35.5% the majority of them had one measure performed and only 3.0% had more than three measures implemented. In total, 268,577 dwellings had at least one measure realized.

The right column shows the impact of the measures on the energy efficiency of the dwellings. The impact is presented in the form of the EI. It is clear that the more the energy efficient solutions applied the more the impact is on the EI. The dwellings that had at least one measure realised achieved a decrease of 0.263 of the EI. We calculated the 0.263 decrease of the EI as a weighted average based on the number of dwellings. A label band is around 0.4 wide. This implies that the energy performance of the dwellings that have undergone an improvement in 2013 was ,on average, slightly more than half a label level higher than in 2010.

Further, Table 10 shows a positive correlation between the number of measures and the average EI before the measures are executed (third column). This suggests that less energy-efficient homes are regarded as more in need for improvement. After these improvements, the differences between the average EI are remarkably low (fourth column).

4. Discussion

The results presented in the previous section show a mixed picture. On the one hand, they show that the housing associations have taken many measures to improve the energy performance of their stock. This seems to be a result of the intensified discussions in the sector about energy saving and climate protection.   On the other hand, the progress in the energy performance of the housing stock is rather modest. We identified a tendency for conventional rather than innovative maintenance measures in most of the seven physical characteristics examined: An example is the improvement of a boiler of η=0.80 to a condensing combi-boiler of η=0.90-0.95

instead of a heat pump or a μCHP solution. Further, where energy improvements do take place, usually only one or two measures are carried out per dwelling. Housing providers generally do not seem to execute major renovations, but much smaller investments. Most of the changes concern the heating, DHW systems, and the glazing. The rest of the building envelope elements are not improved at the same frequency. The data show that the goals for this sector will be hard to achieve if the same strategy for renovation is followed, taking into account the percentages of change. The energy renovations, based on the easiest to achieve measures, do not yield the results that are expected towards the 1.25 average EI. One could also argue that the goals set for the non-profit housing sector are too ambitious and despite the efforts for energy renovations the goals remain too difficult to attain.

So far, we have shown that the impact on the energy performance based on the theoretical energy performance is as expected: the impact increases with the number of measures. However, we must be cautious when discussing the energy performance of dwellings. As previous research has shown (Guerra-Santin et al., 2012; Laurent et al., 2012; Majcen et al., 2013) it is crucial to consider the difference between the modelled energy performance of dwellings and the impact on the actual energy consumption. Further research is necessary to examine the impact of the energy efficiency measures implemented in the sector on the actual energy consumption of the dwellings.

5. Conclusions and recommendations

The goal of this study was to identify the energy improvements implemented in the non-profit housing sector in the Netherlands and assess their impact on the energy performance of the dwellings. We used longitudinal data and analysed the improvements of the stock for a three years' period, namely from ultimo 2010 to ultimo2013, based on seven different dwelling characteristics and systems. We were able to track accurately the energy improvements applied in the non-profit housing and analyse their impact on the EI for this period. The main outcome of this article is that there are many improvements applied, but that they are too small to attain the ambitious national goal of an average EI of 1.25 in 2020. More or deeper energy renovation measures are required in attain this goals.

Based on our outcomes, the non-profit housing sector should focus more on the energy efficiency of its dwellings through the implementation of carefully planned energy agendas. This way, instead of conventional solutions, based on maintenance plans, combinations of energy measures resulting in an overall improvement of the energy performance of dwellings could be achieved. The non-profit sector has a large potential for improvement. The support from governmental bodies through subsidies and other economic incentives is also important amidst the economic crisis of the housing sector. In cases were municipal support was offered it resulted in the application of more concrete energy renovation plans by the housing associations.

Last, the current longitudinal study on the energy improvements and the impact on the energy performance of the dwellings showed the progress of the non-profit housing sector. However, we also need to use cross-sectional data to analyse the impact of energy efficiency measures on the actual energy consumption. Using cross-sectional data and thus focusing on cases studies, we can assess more in depth the energy renovation practises. A combination of longitudinal and cross-sectional data analyses is the necessary approach on the matter of energy efficiency in the building sector. Both the quantitative and qualitative characteristics of the energy renovations are crucial to achieve the energy consumption savings.

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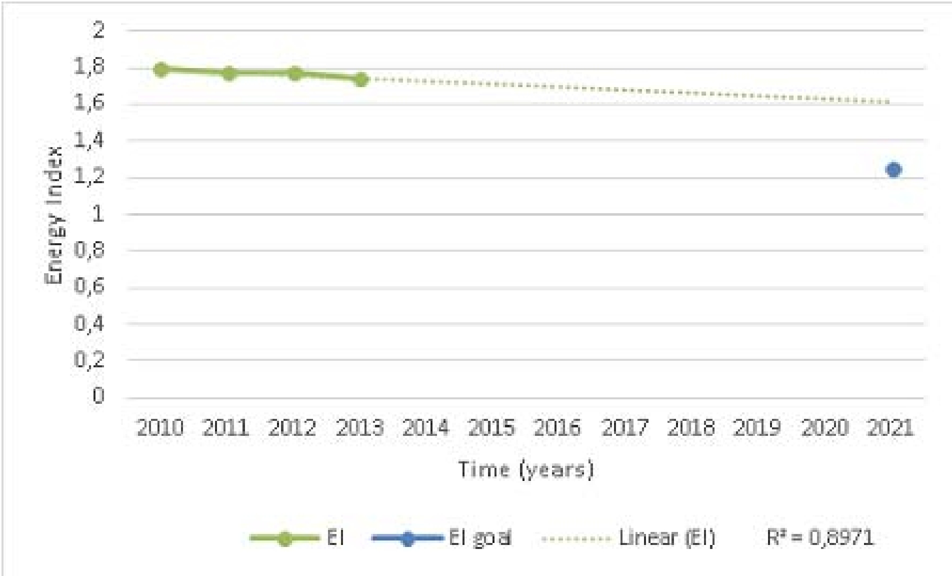

Figure 1: Development of the EI in the Dutch non-profit housing sector between 2010 and 2013

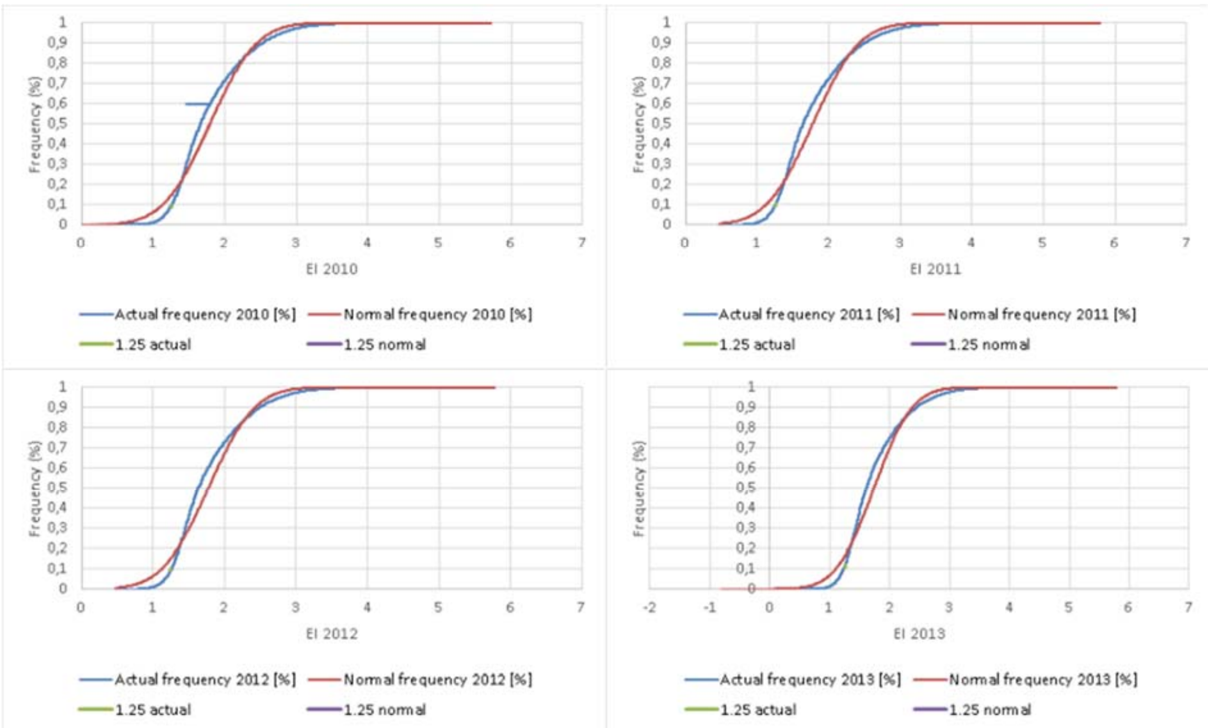

Figure 2: Evolution of the cumulative distribution function of the EI 2010-2013

Table 1: Connection of Energy Index with the Energy Label in the Dutch context

Energy Label	Energy Index	Mean actual primary energy consumption (Kwh/m^2/year) (Majcen et al., 2013)
A (A+, A++)	<1.05	138.48
B	1.06 – 1.3	162.08
C	1.31 - 1.6	174.27
D	1.61 - 2.0	195.60
E	2.01 - 2.4	211.55
F	2.41 - 2.9	223.83
G	> 2.9	232.10

Table 2: Number of dwellings reported in SHAERE per year

Year of reporting	Frequency	Percentage of the total non-profit stock
2010	1,132,946	47.2%
2011	1,186,067	49.4%
2012	1,438,700	59.9%
2013	1,448,266	60.3%

Table 3: Percentage of dwellings by type heating system in 2010 compared to 2013 (n=757,614)

		2010									
		Gas/oil stove	Electric stove	"Conventional" boiler (η<0.80)	Improved non-condensing boiler (η= 0.80-0.90)	Condensing boiler (η=0.90-0.925)	Condensing boiler (η=0.925-0.95)	Condensing boiler (η≥ 0.95)	Heat pump	μCHP	Total
2013	Gas/oil stove	72.5							0.0	0.0	21055
	Electric stove	0.0	96.6						0.0	0.0	257
	"Conventional" boiler (η<0.80)	1.2	0.8	55.4							11044
	Improved non-condensing boiler (η= 0.80-0.90)	2.0	0.0	8.9	61.3					6.4	136827
	Condensing boiler (η=0.90-0.925)	0.3	0.0	1.2	0.9	61.5			0.2	0.2	29758
	Condensing boiler (η=0.925-0.95)	0.1	0.0	0.1	0.3	0.8	64.1		0.0	7.5	17309
	Condensing boiler (η≥0.95)	23.7	2.7	33.1	35.6	34.9	34.0	99.3	0.4	3.1	487801
	Heat pump	0.1	0.0	1.3	1.8	2.7	1.9	0.5	99.4		50548
	μCHP	0.0	0.0	0.0	0.1	0.1	0.0	0.2	0.0	82.7	3015
	Total	29025	262	19283	219210	44644	25092	374553	43038	2507	757614
	Percentage change	27.5	3.4	44.6	38.7	38.5	35.9	0.7	0.6	17.3	17.26

Note: A blank cell means that either no changes took place or that observed changes are removed, as they are considered administrative corrections. A zero percentage means that no or almost no dwellings changed their heating system.

Table 4: Percentage of dwellings by type of domestic hot water system in 2013 compared to 2010 (n=757,614)

		2010									
		Tankless gas water heater	Gas boiler	Electric boiler (<20L)	Conventional” combi-boiler (η<0.80)	Improved non-condensing combi-boiler (η=0.80-0.90)	Condensing combi-boiler (η=0.90-0.95)	District heating	Heat pump	μCHP	Total
2013	Tankless gas water heater	64.1									51381
	Gas boiler	0.3	66.9	3.2	0.2	0.1	0.1	0.1	0.5	0.0	14787
	Electric boiler (<20L)	3.4	3.4	84.2	2.6	0.2	0.2	0.3	0.1	0.0	37400
	Conventional ”combi-boiler” (η<0.80)	0.4	0.3	0.0	59.1			2.8	6.1	0.0	6740
	Improved non-condensing combi-boiler (η=0.80-0.90)	4.3	6.7	2.2	3.5	62.0		0.6	0.3	0.0	117030
	Condensing combi-boiler (η=0.90-0.95)	24.6	14.0	5.6	31.3	36.6	99.4	1.9	20.4	0.0	489394
	District heating	2.2	8.7	4.7	3.3	1.1	0.2	94.2	2.4	0.0	38295
	Heat pump	0.6	0.0	0.0	0.0	0.0	0.2	0.0	70.3	0.0	2585
	μCHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2
	Total	80131	18931	38789	9024	178973	397984	31807	1975	0	757614
	Percentage change	35.9	33.1	15.8	40.9	38.0	0.6	5.8	29.7	0.0	15.5

Table 5: Percentage of dwellings by type of ventilation system in 2013 compared to 2010 (n=757,614)

		2010			
		Natural	Mechanical exhaust	Mechanical supply and exhaust. (balanced) central or decentralized	Total
2013	Natural	85.6	3.4	0.0	319934
	Mechanical exhaust	14.3	96.4	2.9	435353
	Mechanical supply and exhaust. (balanced) central	0.1	0.2	97.1	2325
	Mechanical supply and exhaust. (balanced) decentralised	0.0	0.0	0.0	2
	Total	357885	398865	864	757614
	Percentages of change	14.4	3.6	2.9	8.7

Table 6: Percentage of dwellings by type of windows in 2013 compared to 2010 (n=757,192)

		2010					
		Single glass (U≥4.20)	Double glass (2.85≤U<4.20)	HR+ glass (1.95≤U<2.85)	HR++ glass (1.95≤U<2.85)	Triple insulation glass (U<1.75)	Total
2013	Single glass (U≥4.20)	63.8					32442
2013	Double glass (2.85≤U<4.20)	17.7	90.6				525488
2013	HR+ glass (1.95≤U<2.85)	5.6	5.1	95.9			89536
2013	HR++ glass (1.95≤U<2.85)	12.4	4.3	4.0	99.8		106849
2013	Triple insulation glass (U<1.75)	0.5	0.1	0.0	0.2	100.0	2877
	Total	50837	570368	59819	74063	2105	757192
	Percentage of change	36.2	9.4	4.1	0.2	0.0	9.89

Table 7: Percentage of dwellings by type of wall insulation in 2013 compared to 2010 (n=751,807)

		2010					
		No-insulation (R_c ≤1.36)	Insulation (1.36<R_c≤2.86)	Good insulation 2.86<R_c≤3.86)	Very good insulation (3.86<R_c ≤5.36)	Extra insulation (R_c >5.36)	Total
2013	No-insulation (R_c ≤1.36)	88.3					372661
2013	Insulation (1.36<R_c ≤2.86)	11.3	98.9				352338
2013	Good insulation (2.86<R_c ≤3.86)	0.2	0.9	98.3			22796
2013	Very good insulation (3.86<R_c ≤5.36)	0.1	0.2	1.7	100.0		3545
2013	Extra insulation (R_c >5.36)	0.1	0.0	0.0	0.0	100.0	467
	Total	421959	308162	19326	2281	79	751807
	Percentage of change	11.7	1.1	1.7	0.0	0.0	7.06

Table 8: Percentage of dwellings by type of roof insulation in 2013 compared to 2010 (n=456,112)

		2010					
		No-insulation (R_c ≤0.39)	Insulation (0.39<R_c ≤0.72)	Good insulation (0.72<R_c ≤0.89)	Very good insulation (0.89<R_c≤4.00)	Extra insulation (R_c >4.00)	Total
2013	No-insulation (R_c ≤0.39)	81.6					87133
2013	Insulation (0.39<R_c ≤0.72)	1.6	80.5				12303
2013	Good insulation (0.72<R_c ≤0.89)	1.8	2.7	79.7			29232
2013	Very good insulation (0.89<R_c ≤4.00)	13.8	16.5	19.0	99.6		321935
2013	Extra insulation (R_c >4.00)	1.2	0.3	1.3	0.4	100.0	5509
	Total	106817	13148	33854	299747	2546	456112
	Percentage of	18.4	19.5	20.3	0.4	0.0	6.64

	change						

Table 9: Percentage of dwellings by type of floor insulation in 2013 compared to 2010 (n=469,123)

		2010					
		No-insulation ($R_c \le 0.32$)	Insulation ($0.32 < R_c \le 0.65$)	Good insulation ($0.65 < R_c \le 2.00$)	Very good insulation ($2.00 < R_c \le 3.50$)	Extra insulation ($R_c > 3.50$)	Total
2013	No-insulation ($R_c \le 0.32$)	88.2					225343
	Insulation ($0.32 < R_c \le 0.65$)	3.1	85.9				52592
	Good insulation ($0.65 < R_c \le 2.00$)	4.7	9.7	94.9			114276
	Very good insulation ($2.00 < R_c \le 3.50$)	3.7	4.0	4.7	97.4		67709
	Extra insulation ($R_c > 3.50$)	0.3	0.4	0.4	2.6	100.0	9203
	Total	255600	51970	102545	52661	6347	469123
	Percentage of change	11.8	14.1	5.1	2.6	0.0	9.42

Table 10: Percentage of dwellings where energy efficiency measures took place from 2010 to 2013 (n=717,614)

Number of measures	Percentage of dwellings *	Average EI before measure (s) were executed	Average EI after measure (s) were executed	Change of the Energy Index
none	64.5% (489,037)	1.75 (D)	1.73 (D)	0.015
one	15.0% (114,000)	1.78 (D)	1.65 (D)	0.127
two	12.7% (96,066)	1.91 (D)	1.65 (D)	0.257
three	4.7% (35,845)	2.07 (E)	1.66 (D)	0.411
more than three	3.0% (22,666)	2.28 (E)	1.54 (C)	0.739
at least one measure	*35.5% (268,577)*	1.87 (D)	1.60 (C)	0.263

* between brackets the number of dwellings is shown