Energy efficiency measures implemented in the Dutch non-profit housing sector

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Abstract

The existing housing stock plays a major role in the realization of 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 data necessary for the research are drawn from a monitoring system that contains data about the energy performance of more than half of all dwellings in the sector. The method followed is based on quantitative data analysis of physical properties regarding energy efficiency, general dwellings' characteristics and estimated energy consumption of the households. The outcomes of this research provide insight in the energy efficiency measures applied to the existing residential stock. In addition, the impact of these measures on the energy performance is discussed, along with indications about the energy renovation practices in the non-profit housing sector.

Introduction

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). The focus of this study is on the existing housing stock in Europe and specifically the Netherlands. Worldwide, depending on the country, the amount of the total energy consumed by the residential sector varies between 16 % and 50 % (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 (Kenemy, 2002). 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). In the Netherlands, based on 2009 data, households consume 425 PJ annually (CBS, 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 roughly 1 % of the existing residential building stock (Meijer et al., 2009).Energy renovations in existing dwellings offer unique opportunities for reducing the energy consumption and greenhouse gas emissions on a national scale concerning the Netherlands but also on a European and global level. Although there have been initiatives for energy renovations of the dwellings in the Netherlands, the assessment and monitoring of the nature of these renovations has been lacking. The monitoring of the energy improvements of the existing housing stock is necessary and can provide valuable information concerning the nature and the future potential of the measures applied. The main research question of this paper is what the energy improvement measures in the Dutch non-profit housing sector have been over the last years and their effects on the energy performance of the dwellings.

ENERGY EFFICIENCY MEASURES AND INTERPRETATIONS OF ENERGY RENOVATIONS

Several measures and policies have been applied over time 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 dimensionless figure, ranging from 0 (extremely good performance) to 4 (extremely bad performance). 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 (Senternovem, 2009). The primary goal of the 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 related to the total theoretical energy consumption of a building or a dwelling Q_{total}. According to the norm of the calculation for the EI, as shown in Equation 1, it is corrected taking into account the floor area of the dwelling and the corresponding heat transmission areas.

The EI is calculated as follows:

$$EI = Qtotal/(155 * Afloor + 106 * Aloss + 9560) \quad (1)$$

Q_{total} refers to modelled characteristic yearly primary energy use of a dwelling and includes energy for space heating, domestic hot water, additional energy (auxiliary electric energy needed to operate the heating system i.e. pumps and funs), lighting of communal areas, energy generation by photovoltaic systems and energy generation by combined heat and power systems under the assumption of a standard use. 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; Senternovem, 2009).

The calculation of the EI is directly connected with the calculation of the energy labels in the Netherlands. Table 1 shows the connection of the two elements. Throughout this article, all calculations and results are based on the energy index and not the energy label of the dwellings. However, in some cases we refer to the energy label as it facilitates communication, especially on an international level.

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

Energy Label	Energy Index
A (A+, A++)	<1.05
B	1.05–1.3
C	1.3–1.6
D	1.6–2.0
E	2.0–2.4
F	2.4–2.9
G	> 2.9

In the context of energy improvement of the housing stock, the term 'renovation' is often used. However, there is no specific definition of what an energy renovation is on a global, European or national level. On top of that there is no distinction between a single energy efficiency measure, a renovation or a major renovation. 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 a deep renovation is or consists of, 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 energy labels (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (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. Every measure is investigated individually and then for each dwelling the number of measures applied is examined. For the purposes of this paper we will refer to a major renovation when more than three energy efficiency measures (to the envelope or energy installations of the dwellings) have been realised in a dwelling. On the other hand, when referring to conventional energy efficiency measures we define them as the measures that would have been realised as part of a maintenance plan of the dwellings or business-as-usual.

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, there are three common elements 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).

As has been stated earlier in this paper, the focus of this study is on the non-profit housing sector of the Netherlands. In the Netherlands, the non-profit housing sector comprises 2.2 million homes, which is 31 % of the total housing market (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (BZK), 2013). This is a unique situation as the Netherlands have the highest percentage of non-profit housing sector 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 Rented 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 (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (BZK), 2012), which is within the bands of label B. The Covenant is 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 the 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) (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (BZK), 2014). In 2013 the average EI of the sector was 1.69. At the current rate of energy renovation, which is 4 % on average 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).

To date, there has not been a great amount of research performed on the progress of the non-profit housing sector towards its energy efficiency goals. 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 is increasing. 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 each year on the progress of the non-profit housing sector. 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 6.2 % of the dwellings in 2013 have had an improvement of the EI. At the same time, based on a detailed analysis performed by the authors, 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). In summary, based on previous literature, measures towards achieving energy efficiency in the non-profit sector in the Netherlands are taking place. However, the pace of change is too slow to reach the 2020 energy efficiency goals (Filippidou et al., 2014).

In this paper the specific energy efficiency measures that have been realised, between 2010 and 2013, are going to be identified. 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.

Data and methods

SHAERE DATABASE

To research the energy savings measures and their effectiveness on the energy performance of the dwellings a complete and detailed assessment of the current efficiency state of the social housing stock in the Netherlands is necessary. 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 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 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 'Vabi Assets', 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 in order to be used for their energy labelling. The data include: the U values (thermal transmittance, $W/m^2 \cdot K$) and Rc values (measure of thermal resistance, m^2 K/W) (ASHRAE 2009) of the envelope elements, estimated energy consumption, expected CO_2 emissions, and the EI. For 2013, data for 1,448,266 dwellings were available, 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 in the Netherlands between 2010 and 2013. First, the sample is described and then, based on this description, the method of analysis is presented.

METHODS

In order to pinpoint and to study the energy improvements performed each year, the focus of this study is on the dwellings that have been reported more than once (i.e. where data have been inputted by the housing associations in repeated years). It is observed whether or not the inputted data have changed and specifically for the start of the analysis the Energy Index indicator is altered.

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 %

At the beginning of the data analysis extensive data filtering was required. First the records for dwellings that were present in the database but contained no information had to be excluded from the analysis. Then the removal of potential duplicate cases from the data took place. When reports with exactly the same address, the same EI and reporting year were found, one of the duplicated records was removed. Cases with exactly the same address and same reporting year, but different EIs were removed completely 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 these 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.

Results

In this section of the paper the results of the analysis are presented. As mentioned before, every table in this section represents a measure to improve the energy performance of the respective dwelling. In total seven measures are taken into account. Before we move on to the specific energy measures it is worth mentioning that as a first step of the analysis the average EI of the total stock was calculated (see Figure 1).

In 2010 the mean value of the EI was 1.81 and in 2013 it is 1.69 – i.e. a drop of 0.12 over three years. A 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 0.16, which is nearly half the width of an average energy label band.

In order to better understand the energy efficient solutions that lead to this development of the EI, the energy efficiency measures of the dwellings reported in 2010 and 2013 are presented. Looking at a period of three years reveals the kind of measures that are preferred by the housing associations and which building characteristic is changing the most. In the next sub-section the impact of these measures on the EI of the dwellings is also reported.

ENERGY EFFICIENCY MEASURES APPLIED IN 2010–2013

In this sub-section the actual measures that have been applied between 2010 and 2013 are presented and further examined. 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 assessing the state of the dwellings in 2010 and in 2013 and thus being able to track 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, by this study, as administrative corrections and as a result they are left blank.

In Table 3 the change in the heating system in the dwellings that were reported in 2010 and in 2013 are depicted. 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 heat pump 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 as the total amount of dwellings that were part of the analysis. Observing the diagonal of the table, it is highlighted that the dwellings that have 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. Only 55.4 % of the "conventional" boilers have not been changed in the 3 years of investigation.

The table shows that the majority of the dwellings in 2013 have a condensing high efficiency boiler (η≥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 (≥0.95), which for the time is the most energy efficient heating system. The largest change is happening from the con-

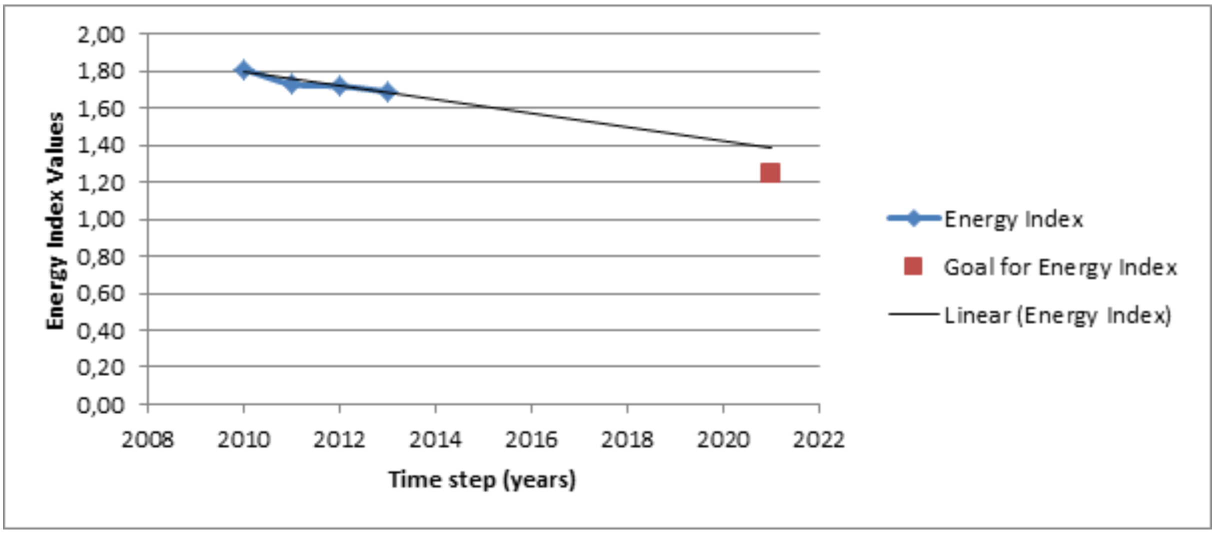

Figure 1. Development of the EI in the Dutch non-profit housing sector since 2010.

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	micro-CHP	Total
2013	Gas/oil stove	72,5							0,0	0,0	21,055
	Electric stove	0,0	96,6						0,0	0,0	257
	"Conventional" boiler (η<0.80)	1,2	0,8	55,4							11,044
	Improved non-condensing boiler (η= 0.80–0.90)	2,0	0,0	8,9	61,3					6,4	136,827
	Condensing boiler (η=0.90–0.925)	0,3	0,0	1,2	0,9	61,5			0,2	0,2	29,758
	Condensing boiler (η=0.925–0.95)	0,1	0,0	0,1	0,3	0,8	64,1		0,0	7,5	17,309
	Condensing boiler (η≥0.95)	23,7	2,7	33,1	35,6	34,9	34,0	99,3	0,4	3,1	487,801
	Heat pump	0,1	0,0	1,3	1,8	2,7	1,9	0,5	99,4		50,548
	micro-CHP	0,0	0,0	0,0	0,1	0,1	0,0	0,2	0,0	82,7	3015
	Total	29,025	262	19,283	219,210	44,644	25,092	374,553	43,038	2,507	757,614
	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.

densing boilers of 0.90–0.925 and 0.925–0.95 efficiency where for each category 35 % of the dwellings have changed their energy system to a condensing high efficiency boiler (η≥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 are from 0 % to 2.7 %. On the other hand the local electric stoves are not so many in the social housing stock and the local gas stoves are being changed and in their place high efficiency condensing boilers (η≥0.95) are being installed. The total percentage of change of the type of heating system is 19.8 % i.e. 1 in 5 heating systems is changing in a three year period.

In Table 4 the changes of the domestic hot water system (DHW) in the dwellings that were reported in 2010 and in 2013 are shown. As with Table 3, the table is best read from the horizontal line where the situation of the first year of report is shown. 2010. 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 heat pump 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, as a consequence represents the dwellings whose heating system remained the same these three years.

The number of dwellings with a reported hot water heating system is also 757,614. Starting with the diagonal of Table 4, it is highlighted that 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 typical 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 hot water. 40.9 % of the "conventional" boilers have been changed the last 3 years. As with the heating systems, the popularity of high efficiency boilers (η≥0.95) considerably increased.

A remarkable finding is that from the dwellings that had a heat pump in 2010 20.4 % have changed to a condensing high efficiency boiler (η≥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 micro-CHP is not obvious as the percentages are 0 % and 0.6 % respectively. On the other hand the geysers, gas boilers and "conventional" low efficiency boilers are decreasing in the social housing stock and in their place mostly high efficiency condensing boilers (η≥0.95) are being installed. The percentage of change for the type of

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	Micro-CHP	Total
2013	Tankless gas water heater	64,1									51,381
	Gas boiler	0,3	66,9	3,2	0,2	0,1	0,1	0,1	0,5	0,0	14,787
	Electric boiler (<20 L)	3,4	3,4	84,2	2,6	0,2	0,2	0,3	0,1	0,0	37,400
	Conventional " combi-boiler (η<0.80)	0,4	0,3	0,0	59,1			2,8	6,1	0,0	6,740
	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	117,030
	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	489,394
	District heating	2,2	8,7	4,7	3,3	1,1	0,2	94,2	2,4	0,0	38,295
	Heat pump	0,6	0,0	0,0	0,0	0,0	0,2	0,0	70,3	0,0	2,585
	Micro-CHP	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2
	Total	80,131	18,931	38,789	9,024	178,973	397,984	31,807	1,975	0	757,614
	Percentage change	35,9	33,1	15,8	40,9	38,0	0,6	5,8	29,7	0,0	15,5

DHW system is close to that of the heating system, which is 15.5 %.

In Table 5 the changes of the ventilation systems of the dwellings that were reported in 2010 and in 2013 are shown. As with Table 3 and Table 4, the table is best read from the horizontal line where the situation in 2010 is shown 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, (balanced) decentralised system. The diagonal line, as a consequence represents the dwellings whose heating system remained the same these three years. In ventilation, there are not many choices for the residential sector. The majority of the dwellings have either natural of mechanical exhaust ventilation systems. There are two main trends 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, (balanced) central to a simpler mechanical exhaust in 2013. Additionally, it is clear from the table that for the years of 2010–2013 almost no mechanical supply and exhaust, (balanced) decentralised ventilation systems were present in the non-profit housing stock. The total percentage of dwellings with a changing 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 (Senternovem, 2011) to characterise the types of windows based on their thermal transmittance. The categories include single glass windows, double glass, HR+ and HR++ glasses and triple insulation glass.

The diagonal, as in the previous tables that are presented, the dwellings with unchanged windows are shown. The triple insulation windows remain 100 % unchanged. On the other hand the single glazing windows have been replaced by 36.2 % in a three year period. The majority of the dwellings, both in 2010 and in 2013 have double glazing. At the same time, the dwellings with double glazing windows in 2010 are the ones, after the single glazing, that changed the most (9.4 %) 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.

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 is proven to be a rarity. The total percentage of change in the type of windows is almost 10 %.

In Table 7, the changes in type of wall insulation are presented. Again, based on the ISSO 82.1 publication (Senternovem, 2011) different insulation categories were created based on the Rc values of the walls. Taking into account the ISSO 82.1 guidelines a range of no-insulation for the dwellings that were built before the 1970's for example, to extra insulation of an nZEB level is depicted. On the table, the changes that were big enough to change a category of insulation are shown. 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 and the same is true for 2013.

The diagonal, as in the previous tables that are presented, the dwellings with unchanged wall insulation are shown. 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 %.

In Table 8, the changes in the level of roof insulation of the dwellings are depicted. 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 %

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	Mechanical supply and exhaust. (balanced) decentral	Total
2013	Natural	85.6	3.4	0.00	0.00	319,934
	Mechanical exhaust	14.3	96.4	2.9	0.00	435,353
	Mechanical supply and exhaust. (balanced) central	0.1	0.2	97.1	0.00	2,325
	Mechanical supply and exhaust. (balanced) decentralised	0.00	0.00	0.00	0.00	2
	Total	357,885	398,865	864	0	757,614
	Percentages of change	14.4	3.6	2.9	0.0	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					32,442
	Double glass (2.85≤U<4.20)	17.7	90.6				525,488
	HR+ glass (1.95≤U<2.85)	5.6	5.1	95.9			89,536
	HR++ glass (1.95≤U<2.85)	12.4	4.3	4.0	99.8		106,849
	Triple insulation glass (U<1.75)	0.5	0.1	0.0	0.2	100.0	2,877
	Total	50,837	570,368	59,819	74,063	2,105	757,192
	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					372,661
2013	Insulation (1.36<R_c ≤2.86)	11.3	98.9				352,338
2013	Good insulation (2.86<R_c ≤3.86)	0.2	0.9	98.3			22,796
2013	Very good insulation (3.86<R_c ≤5.36)	0.1	0.2	1.7	100.0		3,545
2013	Extra insulation (R_c >5.36)	0.1	0.0	0.0	0.0	100.0	467
	Total	421,959	308,162	19,326	2,281	79	751,807
	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					87,133
2013	Insulation (0.39<R_c ≤0.72)	1.6	80.5				12,303
2013	Good insulation (0.72<R_c ≤0.89)	1.8	2.7	79.7			29,232
2013	Very good insulation (0.89<R_c ≤4.00)	13.8	16.5	19.0	99.6		321,935
2013	Extra insulation (R_c >4.00)	1.2	0.3	1.3	0.4	100.0	5,509
	Total	106,817	13,148	33,854	299,747	2,546	456,112
	Percentage of change	18.4	19.5	20.3	0.4	0.0	6.64

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 type change is 6.64 % and the sample is smaller, so no definitive results can arise.

Finally, in Table 9 the changes of the floor insulation in the dwellings are presented. 469,123 dwellings had information for both years. The majority of the dwellings both on 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 (Senternovem, 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 %, a bit higher than the roof insulation.

NUMBER OF MEASURES APPLIED AND THEIR IMPACT ON THE ENERGY PERFORMANCE

In this part of the report the number of changes per dwelling is reported. 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, the dwellings that had no energy efficiency measure are also presented. These changes are allocated to the energy installations and the building envelope elements presented in the results section. In more detail based on the system for space heating, DHW, ventilation, the change of the system is perceived as a measure. That means that if a dwelling changes a condensing high efficiency

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

		2010					
		No-insulation ($R_c \leq 0.32$)	Insulation ($0.32 < R_c \leq 0.65$)	Good insulation ($0.65 < R_c \leq 2.00$)	Very good insulation ($2.00 < R_c \leq 3.50$)	Extra insulation ($R_c > 3.50$)	Total
2013	No-insulation ($R_c \leq 0.32$)	88.2					225,343
2013	Insulation ($0.32 < R_c \leq 0.65$)	3.1	85.9				52,592
2013	Good insulation ($0.65 < R_c \leq 2.00$)	4.7	9.7	94.9			114,276
2013	Very good insulation ($2.00 < R_c \leq 3.50$)	3.7	4.0	4.7	97.4		67,709
2013	Extra insulation ($R_c > 3.50$)	0.3	0.4	0.4	2.6	100.0	9,203
	Total	255,600	51,970	102,545	52,661	6,347	469,123
	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 estimated number of dwellings.*

boiler to a new condensing high efficiency boiler this would not be perceived as a change since it is not adding anything to 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 in order to track the changes was created. For every element different classification were created based on the Rc values reported in the ISSO Publication 82.1 (Senternovem. 2011) in accordance to a report on exemplary dwellings in the Netherlands from the Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland. 2010). In this way a change towards a different level of insulation is tracked and reported. If we were to track the changes only as positive or negative following just the Rc 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.

The method of the total amount of changes per dwelling as reported in this section was realized by following the changes in each of the eight elements already reported and summing 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.

In Table 10, in the second column the percentage of dwellings that had or not energy efficient measures achieved is shown. 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, which is what can be perceived as a "major renovation". In total, 268,577 dwellings had at least one measure realized.

In the right column the impact of the measures on the energy efficiency of the dwellings is shown. 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. As a weighted average, the dwellings that had at least one measure realised, had a decrease of 0.263 on the EI. Considering that a label band is around 0.4 wide, this implies that the energy performance of those homes that have undergone an improvement was in 2013, 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).

Conclusions and recommendations

There is a large energy saving potential in the non-profit housing stock in the Netherlands. Non-profit housing associations take decisions on a more collective basis compared to private housing owners. The energy efficiency of the stock seems to be more important the last years, since the Covenant was signed, and these actions are being subsidised by the government if at least three energy label levels are achieved. In this paper the specific energy efficiency measures that have been realised over the years 2010–2013 have been identified. The energy installations (heating, domestic hot water and ventilation) and the dwellings insulation elements (windows, walls, roofs and floors) were examined in order to follow the changes and as a result the energy efficiency measures chosen by the housing associations.

There is a tendency, in most of the seven physical characteristics that were examined, for conventional solutions. By conventional solutions the standard maintenance measures are defined. For example, the improvement of a boiler of $\eta=0.80$ to a condensing combi-boiler of $\eta=0.90–0.95$. Further, where energy improvements do take place, usually only one or two measures per dwelling are carried out. Housing providers generally do not seem to execute major renovations, but much smaller investment projects. This can be part of existing maintenance schedules. Most of the changes regard the heating and DHW systems, and the glazing. The rest of the building envelope elements are not improved at the same frequency. Taking into account the percentages of change, so far, the data show that the goals for this sector will be hard to achieve if the same strategy for renovation is followed.

So far, we have shown that the impact on the energy performance based on the theoretical energy consumption is as expected: the impact increases with the number of measures. Further research, on the impact of the energy efficient measures that have taken and will take place in the sector, still needs to be performed. For instance, it would be interesting to compare the theoretical impact of the energy efficiency measures to the impact on the actual energy consumption. Research published so far (Majcen et al., 2013; Guerra-Santin and Itard, 2012; Laurent et al., 2012) shows considerable differences between them, which makes the investigations on the specific energy efficiency measures in relation to their impact on the actual energy consumption of great importance.

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