2 Energy efficiency state of non-profit housing stock in the Netherlands

Note:
In this chapter, the energy efficiency state of the non-profit housing stock of the Netherlands is presented. The necessary data are drawn from the monitoring system SHAERE, that contains information about the energy performance of approximately 60% of all dwellings in the sector. The method used is based on descriptive statistics of the dwellings' physical properties and reported energy performance. The chapter sets the background needed to answer the main research question of the thesis – what is the energy efficiency progress of the non-profit housing stock through energy renovations and their impact on actual heating energy consumption.

This chapter material was used for the Aedes benchmark for the energy performance of the non-profit housing stock in 2016.

§ 2.1 Introduction

Improving energy efficiency of buildings is widely considered as the one of the most promising, fast and cost-effective ways to mitigate climate change and achieve the 2020 and 2050 goals set for the built environment (European Commission 2011; Aedes 2017). Energy efficiency of the building stock is hard to achieve if we only focus on the design of new dwellings. In this chapter, we will analyse the energy efficiency state of the existing Dutch non-profit housing stock using data from 2015.

We examine the energy efficiency state of the stock using data from the SHAERE monitoring system. The data from SHAERE include the age, type, useful floor area, thermal resistance (R_c-value) of the envelope (roof, facades and floor), thermal transmittance (U-value) of the windows, heating and domestic hot water (DHW) systems, ventilation system, the predicted heating energy consumption and energy production systems, if present. We also use actual heating energy consumption data from Statistics Netherlands to calculate the mean actual energy consumption of the stock.

The chapter aims at setting the current energy performance state of the Dutch non-profit housing stock. A complete and detailed assessment of the current efficiency state of the non-profit housing stock in the Netherlands is necessary in order to examine the energy renovation pace and energy saving measures realised. The following sections present the results and conclusions drawn from this chapter. Section 2.2 presents the development of energy efficiency policies in the built environment. The SHAERE monitoring system is presented in 2.3. Section 2.4 sums up the methods used. Section 2.5 brings attention to the results of the research study. Section 2.6 presents the conclusions of this chapter.

§ 2.2 Energy efficiency policies

In the Netherlands, the energy efficiency of buildings has been regulated since 1975 consisting of limits on transmission losses based on insulation values (Boot 2009). In 1995 these limits were expanded to include the national "EPC" (Energy Performance Coefficient), a non-dimensional figure expressing the energy performance of a building, which depends on the energy demand for space heating, hot water, lighting, ventilation, humidification and cooling. The Dutch EPC is calculated by dividing the calculated energy demand of a building by a standard energy performance. The standardized energy performance is based on the heat transfer surface and the total heated area of the dwelling (NEN 2012). At the beginning (1996) the EPC value was set to 1.4, a number easily reached by the construction techniques of the time. Later on EPC values were tightened to 1.2 in 1998, 1.0 in 2000, 0.8 in 2006, 0.6 in 2011 with a reduction at 0.4 in 2015 in order to achieve nearly zero energy buildings (nZEB) by 2020 as shown in Figure 2.1(Beuken 2012).

From 2008 onwards the energy label is a compulsory measure to be undertaken with the transfer of dwellings, as a result of the EPBD (Energy performance Buildings Directive) (European Commission 2010). The energy label was originally meant for dwellings older than 10 years (Koppert 2012). The idea is that the energy performance of dwellings built over the last 10 years is sufficient and insulation measures are not cost-effective for newly built dwellings. The enforcement of the energy label is put to practice in 2013, where owners are obliged to deliver an energy label at the notary when transferring a dwelling in the Netherlands (Koppert 2012). The second purpose of issuing the energy labels is the insight in the energy performance and the possibilities to improve it, based on the energy performance advice (EPA) which in turn can lead to actual energy efficiency measures. The energy label is based on an energy performance calculation or EPA provided by certified bodies according to the BRL9500-01/ 9501 building standard in the Netherlands (Koppert 2012). Advisors are authorised to deliver an energy label and give 'tailor made energy performance advice', EPA. As a result of the EPA, the EI (Energy Index) was created that is a performance coefficient for the existing building stock denoting the energy efficiency of a building.

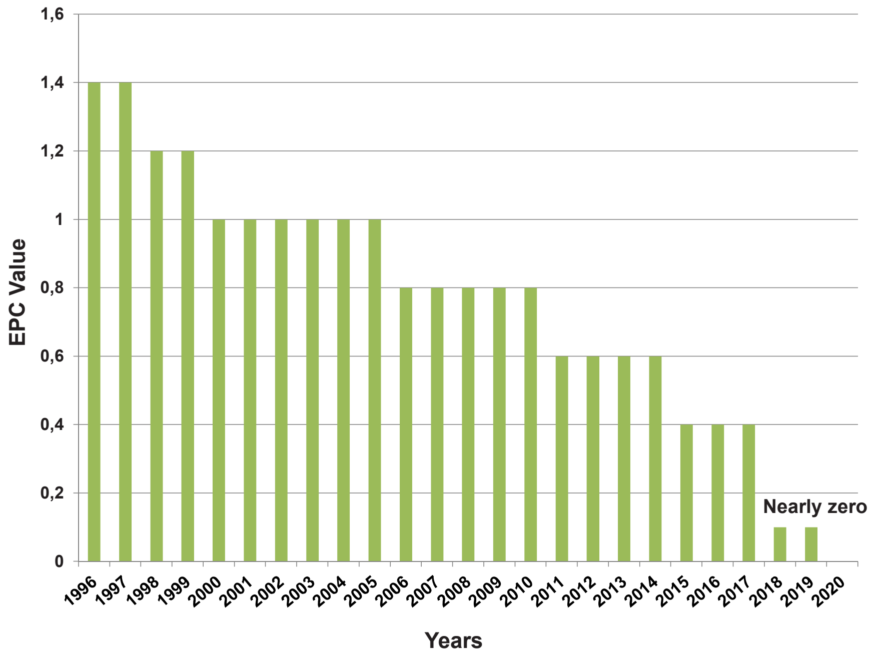

FIGURE 2.1 Evolution of the regulatory Energy Performance Coefficient (EPC) for new and extensively renovated buildings in the Netherlands

The EI is directly connected to the total predicted energy consumption. According to the calculation it is corrected for the floor area of the dwelling and the corresponding heat transmission areas, as shown in Equation 2.1, in order to not impede larger dwellings and dwellings with greater envelope proportions adjoining the unheated spaces at constant insulation properties and efficiencies of the heating/ventilation/lighting system (Visscher et al. 2012). A shape correction is applied as well taking into account the infiltration losses within space heating demand, while the air permeability coefficient depends on the buildings' shape factor. Such corrections for compactness are common also in other European countries, though it has been argued that not correcting would better promote energy efficient architectural designs (Visscher et al. 2012).

The EI is calculated as follows:

$$EI = \frac{Q_{total}}{(155 * A_{floor} + 106 * A_{loss} + 9560)} \qquad \text{Equation 2.1}$$

Q_{total} refers to the 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 (Filippidou et al. 2016; Visscher et al. 2012; ISSO 2009). A_{floor} refers to the total heated floor area of the dwelling, whereas A_{loss} refers to the transmission heat loss area in the dwelling, such as a cellar (Filippidou et al. 2016; Visscher et al. 2012; ISSO 2009). The numerical values in the denominator are: 155 is the factor for the reference energy consumption per m^2 correction, regarding the useful living area (MJ/m^2); 106 is the correction factor compensating for the transmission losses (MJ/m^2); and 9560 is a standard amount of energy used for existing dwellings (MJ) (NEN 2012).

Energy savings and sustainability are set as a priority in the non-profit housing sector, especially since 2008, with the implementation of the EPBD (Aedes 2017). The main energy efficiency policy for the sector is described in the Energy Saving Covenant for the Rental Sector (Convenant Energiebesparing Huursector 2012). The short term goal of the non-profit housing sector is to achieve an energy label B, corresponding to an average EI of 1.25, by the end of 2021 (BZK 2014; Aedes 2017). The Covenant is a voluntary agreement between Aedes – the umbrella organisation of housing associations – the national tenants union, and the national government. The goal of the agreement means a reduction by 33% of energy consumption compared to the 2008 levels (BZK 2014).

In 2015, the method for the EI-Energy label (ISSO 2009) calculation was changed and a point system was introduced. In Table 2.1, we compare the two systems. The new method is the "Nader Voorschrift" (English: Further prescription) and it is linked to the WWS [Woningwaarderingsstelsel (English: Housing evaluation system)] system. This new method is thought to be more detailed and updated than the EI-Energy label method (Vabi 2016; RVO 2018). We refer to this change of method because it can have an impact on the realization of goals and the decision making in terms of energy renovations from housing associations. For a full calculation of the EI NV (Energy Index Nader Voorschrift) see NEN 7120 documentations (NEN 2017). According to the new method and the first results, depicted in Figure 2.2, there is a deviation between the mean EI and the mean EI NV in 2014 in the non-profit housing stock – the only year that both were present in SHAERE. Based on the first evaluation, commissioned by the Netherlands Enterprise Agency, there is a clear link between the two mean values (EI and EI NV) but also an obvious spread of values making the deviation that we see in Figure 2.2 expected (Berben & Kuijpers 2014). Nevertheless, the short term goal of the non-profit housing stock for an average energy label B by the end of 2020 remains, just the EI value for the goal has changed from 1.25 to 1.40 (Aedes 2017).

TABLE 2.1 Comparison of the EI values to the newly introduced EI NV, since 2015 (Berben & Kuijpers 2014)

ENERGY LABEL	ENERGY INDEX (EI)	EI NV – AFTER 2015
A++	EI ≤ 0,5	EI ≤ 0,6
A+	0,5 < EI ≤ 0,7	0,6 < EI ≤ 0,8
A	0,7 < EI ≤ 1,05	0,8 < EI ≤ 1,2
B	1,05 < EI ≤ 1,3	1,2 < EI ≤ 1,4
C	1,3 < EI ≤ 1,6	1,4 < EI ≤ 1,8
D	1,6 < EI ≤ 2,0	1,8 < EI ≤ 2,1
E	2,0 < EI ≤ 2,4	2,1 < EI ≤ 2,4
F	2,4 < EI ≤ 2.9	2,4 < EI ≤ 2.7
G	EI > 2.9	EI > 2.7

There are several studies supporting the fact that the regulations on energy consumption and the application of the national EPC have driven households to lower their consumption in the country (Guerra-Santin & Itard 2012; Beerepoot & Beerepoot 2007). On the other hand, several other recent studies argue that the estimated energy consumption is different than the actual consumption and so the impact of the EPC on the energy consumption of the dwellings can be lower than reported (Majcen et al. 2013, Balaras et al. 2016). Monitoring is essential to examine the energy performance of housing stocks. Descriptive statistics were used in this chapter to determine the energy efficiency state of the non-profit housing stock of the Netherlands and the estimated and actual mean heating energy consumption.

TOC

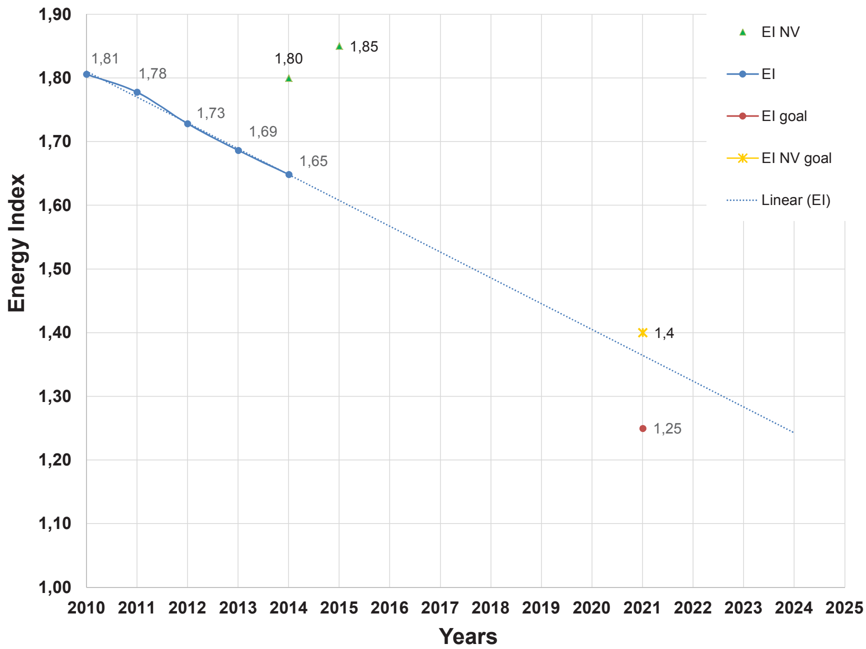

FIGURE 2.2 EI development 2010-2015 following the difference in the methods (data from SHAERE)

Two sources of data were used: the SHAERE database and the actual heating energy consumption data from Statistics Netherlands. SHAERE is a monitoring database of the energy performance of the non-profit housing stock in the Netherlands. A considerable part of the non-profit housing stock is included in SHAERE – the response rate is more than 50% of the population, each year. The actual heating energy consumption data from Statistics Netherlands are collected, annually, from energy companies since 2009 (Majcen 2016). The datasets include values from gas and electricity use. The existence of district heating is also included without, however, values of heat used, due to the lack of individual meters. The data is collected on a dwelling level based on the address, which is encrypted.

§ 2.3 SHAERE monitoring system

In 2008, after the formulation of the Covenant on energy saving targets, Aedes started the monitoring system of dwellings called SHAERE. The monitor became operational in 2010. Housing associations report their stock to Aedes at the beginning of each calendar year accounting for the previous year (e.g., in January 2014 reporting for 2013). They report the energy status of their whole dwelling stock, every year, using the Vabi Assets software, whose basis is the Dutch energy labelling methodology (ISSO 2009). The participation of housing associations is voluntary, resulting in the variation of the amount of dwellings included in the database each year. On average, more than 50% of the population of non-profit dwellings is reported each year. As a result, SHAERE consists of the actual characteristics of all dwellings of the participating housing associations at the end of each calendar year. SHAERE is the first monitoring database of the energy efficiency evolution of the building stock in the Netherlands with microdata information, on a dwelling level.

The data included in SHAERE differ from the official energy labelling data (Energy Performance Certificates) registered at the Ministry of the Interior and Kingdom Relations of the Netherlands. The monitor includes all detailed information required for an energy label calculation. However, it does not include the official registered energy labels, only, but “pre-labels” (Majcen 2016). A pre-label is an unofficial label certificate of a dwelling that may have not been registered to the Dutch state but is recorded and updated internally, by the housing association according to Aedes, whenever a renovation measure is realised. The recording of the energy renovation measures and the consequent update of the pre-label is performed due to the fact that the housing associations perform these updates as a form of asset management of their stocks (Visscher et al. 2013).

SHAERE is the official tool for monitoring the progress in the field of energy saving measures for the non-profit housing sector. It includes information on the dwellings’ geometry, envelope, installations characteristics and the predicted heating energy consumption based on ISSO publication 82.3 (ISSO 2009). In more detail, the data include the U-values (thermal transmittance, W/m^2K) and R_c-values (thermal resistance, m^2K/W) of the envelope elements, the type of installation for heating, domestic hot water (DHW) and ventilation and the predicted heating energy consumption. The data are categorized as variables per dwelling. It is a collective database in which the majority of the housing associations participate (Filippidou et al. 2015). More information about the variables can be found in Appendix A where a list of variables included in SHAERE is recorded.

§ 2.4 Methods

We approach the efficiency of the stock, in 2015, in terms of descriptive statistics of the main elements of dwelling characteristics, thermo-physical characteristics, installations, modelled and actual heating energy consumption. It is important to investigate the efficiency state of the stock in order to further examine the process of energy renovations and their effect on the buildings' performance and final energy consumption.

Using SHAERE, three main groups of variables are examined in this chapter. These are the dwelling characteristics (area, construction year etc.), the envelope insulation values (roof insulation, façade insulation etc.) and the installation variables (space heating system, DHW etc.). In the first group, we use descriptive statistics of the net floor area, the construction year and type of dwelling of the 1,374,095 dwellings reported in 2015.

The second group of variables, from SHAERE, consists of the envelope insulation values. Four variables are used – the R_c-values (thermal resistance, m^2K/W) of roof, floor and façades and the U-value (thermal transmittance, W/m^2K) of windows. These R_c- and U-values are nominal variables. We use descriptive statistics of the aforementioned nominal to present the energy efficiency state of the non-profit housing stock and we also categorize the variables to provide an understanding and "translation" of the values, based on the ISSO publication 82.3 (ISSO 2009). Table 2.2 and Table 2.3 depict the classification of R_c- and U-values based on the Dutch standardization institute.

ISSO publication 82.3 lays out the methodology to calculate and characterise the energy performance of Dutch dwellings. It connects the building regulations, applied through several building decrees in the country, to the practical characterization of insulation values, among other topics. The basis of the classification system used in this chapter and the thesis, is the abovementioned method. The classification systems founds on the construction periods, used in the Netherlands, insulation thickness used in each construction period and the distribution of the R_c-values. We choose to treat the envelope elements separately in order to correspond to the application of energy saving measures, as performed in practice.

TABLE 2.2 Insulation categories created for floor, roof and façade based on the ISSO 82.3 Publication (ISSO 2009)

CHARACTERIZATION	R_c-VALUE ROOF [m^2K/W]	R_c-VALUE FLOOR [m^2K/W]	R_c-VALUE FAÇADE [m^2K/W]
No-insulation	$R_c \leq 0.39$	$R_c \leq 0.32$	$R_c \leq 1.36$
Basic insulation	$0.39 < R_c \leq 0.72$	$0.32 < R_c \leq 0.65$	$1.36 < R_c \leq 2.86$
Good insulation	$0.72 < R_c \leq 0.89$	$0.65 < R_c \leq 2$	$2.86 < R_c \leq 3.86$
Very good insulation	$0.89 < R_c \leq 4$	$2 < R_c \leq 3.5$	$3.86 < R_c \leq 5.36$
Extra insulation	$R_c > 4$	$R_c > 3.5$	$R_c > 5.36$

TABLE 2.3 Window categories created and based on the ISSO 82.3 Publication (ISSO 2009)

CHARACTERIZATION	U-VALUE WINDOW [W/m^2K]
Single glass	$U \geq 4.20$
Double glass	$2.85 \leq U < 4.20$
HR+ glass	$1.95 \leq U < 2.85$
HR++ glass	$1.75 \leq U < 1.95$
Triple insulation glass	$U < 1.75$

The third group of variables refers to the energy installations in dwellings. These include the type of space heating system, the DHW system, the ventilation system and the solar energy system (solar boilers or photovoltaic systems). The energy installation systems are categorical variables.

Next, we matched the data from SHAERE, on microdata level, to the actual heating energy consumption data, which is collected by Statistics Netherlands from energy companies. The companies report the billing data, which are calculated on the basis of the dwellings' meter readings annually. In order to compare the data of the predicted heating gas consumption and the actual gas consumption from the Statistics Netherlands a climatic standardization was applied. The Statistics Netherlands data correspond to the years of 2009, 2010, 2011, 2012, 2013 and 2014. For this research, we worked with the latest available dataset, which was the 2014 one.

§ 2.5 Results

Based on the 2015 data from SHAERE, the mean net floor area of the non-profit housing stock dwellings was 80.44 m^2. The mean building year is 1972 and the median 1974. Figure 2.3 shows the distribution of the variable construction year of the non-profit housing stock. We can observe that in certain periods more dwellings were built than in other – especially after the end of the second world war.

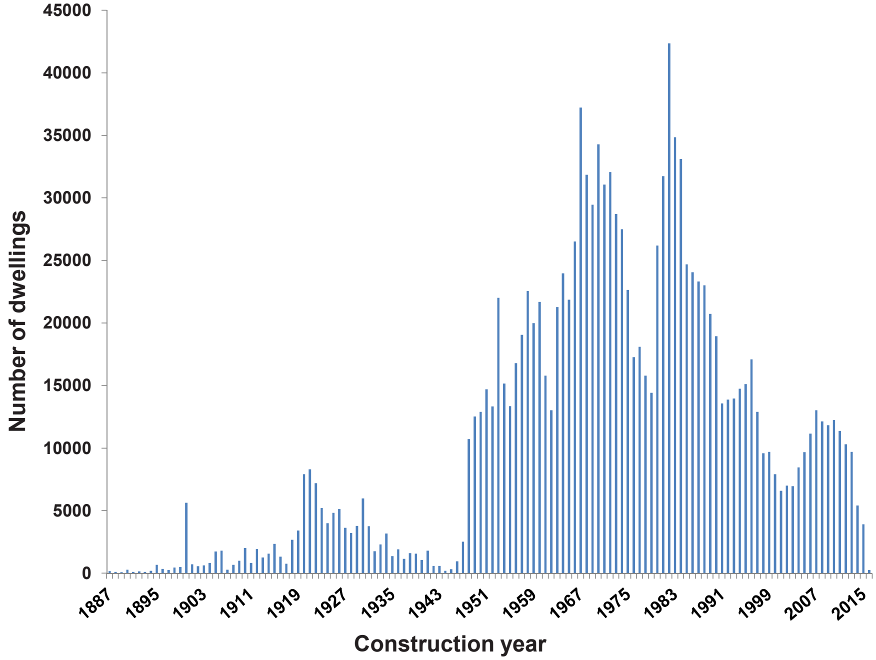

FIGURE 2.3 Construction year distribution based on SHAERE 2015

The total amount of dwellings in the Netherlands is 7.5 million. The owner occupied sector amounts to 55.8% of the total, whereas the rental sector comprises 43.5% of the total (BZK 2016). The ownership type is unknown for the remaining 0.7% (BZK 2016). The majority of the non-profit housing stock, 53.3%, are multifamily dwellings. The rest 46.7% single family dwellings are in their vast majority terraced houses. Figure 2.4 depicts the distribution of the construction period and type of dwelling for the non-profit housing.

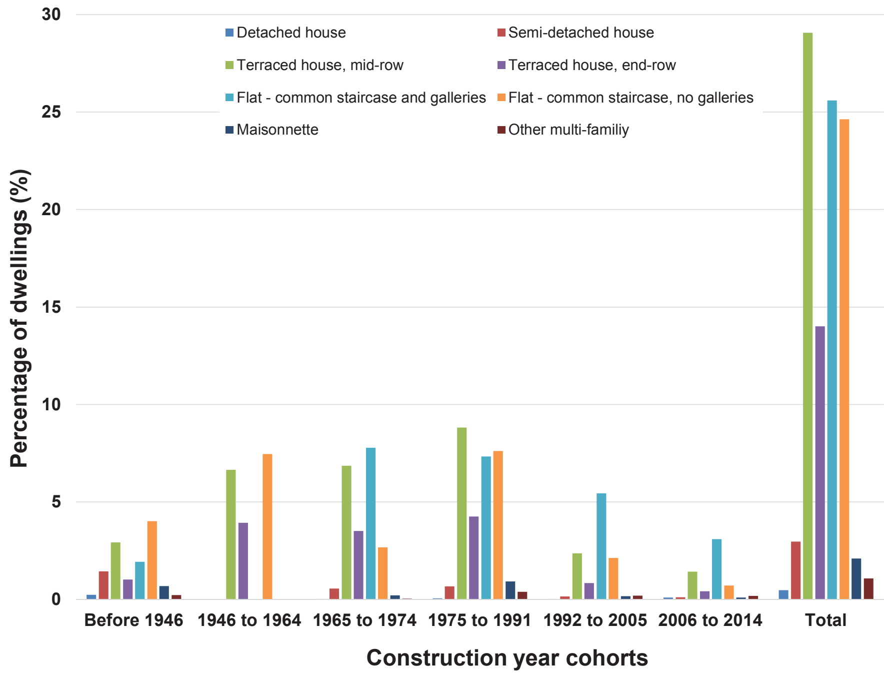

FIGURE 2.4 Age and type of dwelling distribution based on SHAERE 2015

§ 2.5.1 What are the insulation levels of the envelope?

The level of insulation of the envelope has a big impact on the energy performance of the dwellings. In Table 2.4 we present the mean, median and standard deviation values of the thermal resistance values of the roof, floor and façade and the thermal transmittance value of the windows. The average R_c-value of the roof was 1.49, classified as very well insulated, whereas the Rc of floors was 0.94, classified using the specific classification system as well insulated. The average R_c-value of walls was 1.37 which classifies as poorly insulated, based on the classification system whose foundation is the ISSO 82.3. The average U-value of windows was 2.88 – which classifies as double glazing.

TABLE 2.4 Descriptive statistics for Rc-values of roof, floor, facades and U-value of windows 2015

		Rc-VALUE ROOF [m²K/W]	Rc-VALUE FLOOR [m²K/W]	Rc-VALUE FAÇADE [m²K/W]	U-VALUE WINDOW [W/m²K]
N	Valid	869254	867131	1358544	1358464
	Missing	504841	506964	15551	15631
Mean		1,49	0,94	1,37	2,88
Median		1,30	0,41	1,30	2,90
Std. Deviation		1,04	1,02	0,91	0,79

Table 2.5 to Table 2.7 show the distribution of the envelope insulation values in categories, based in the ISSO 82.3 publication. The majority of dwellings are equipped with very well insulated roofs (41.4%) whereas the second largest group of dwellings is not insulated (13.2%). The majority of dwelling floors, on the other hand, is not insulated (27.9%) and the largest group of dwellings after that is well insulated (14.6%). The situation is different for the façades. The largest share of dwellings (52.7%) are not insulated and following, 40.9% of the dwellings are poorly insulated. Here, for clarification purposes we need to state that the nominal values presented in Table 2.4 are showing a more detailed view of the levels of envelope insulation.

TABLE 2.5 Rc-value roof categorized, based on the ISSO 82.3 Publication (ISSO 2009), from SHAERE 2015

		FREQUENCY	PERCENT (%)
Valid	No-insulation ($R_c \leq 0.39$)	180875	13,2
	Basic insulation ($0.39 < R_c \leq 0.72$)	28056	2,0
	Good insulation ($0.72 < R_c \leq 0.89$)	69787	5,1
	Very good insulation ($0.89 < R_c \leq 4$)	568236	41,4
	Extra insulation ($R_c > 4$)	22300	1,6
	Total	869254	63,3
Missing	System	504841	36,7
Total		1374095	100,0

TABLE 2.6 Rc-value floor categorized, based on the ISSO 82.3 Publication (ISSO 2009), from SHAERE 2015

		FREQUENCY	PERCENT (%)
Valid	No-insulation ($R_c \leq 0.32$)	382709	27,9
	Basic insulation ($0.32 < R_c \leq 0.65$)	132065	9,6
	Good insulation ($0.65 < R_c \leq 2$)	199989	14,6
	Very good insulation ($2 < R_c \leq 3.5$)	134241	9,8
	Extra insulation ($R_c > 3.5$)	18127	1,3
	Total	867131	63,1
Missing	System	506964	36,9
Total		1374095	100,0

TABLE 2.7 Rc-value façade categorized, based on the ISSO 82.3 Publication (ISSO 2009), from SHAERE 2015

		FREQUENCY	PERCENT (%)
Valid	No-insulation ($R_c \leq 1.36$)	724362	52,7
	Basic insulation ($1.36 < R_c \leq 2.86$)	561927	40,9
	Good insulation ($2.86 < R_c \leq 3.86$)	52785	3,8
	Very good insulation ($3.86 < R_c \leq 5.36$)	17361	1,3
	Extra insulation ($R_c > 5.36$)	2109	0,2
	Total	1358544	98,9
Missing	System	15551	1,1
Total		1374095	100,0

Table 2.8 presents the distribution of glazing categories. The vast majority of dwellings (60.0%) are equipped with double glazing, 14.2% have HR+ glass and 18.2% have HR++ glass. Only 0.4% of dwellings are equipped with triple insulated glass and 6.1% have single glazing. The following sub-section will shed light in the distribution of the energy installation of dwellings in order to get a better idea of the energy performance of the non-profit housing sector.

TABLE 2.8 U-value window categorized, based on the ISSO 82.3 Publication (ISSO 2009), from SHAERE 2015

		FREQUENCY	PERCENT (%)
Valid	Single glass (U≥4.20)	84396	6,1
	Double glass (2.85≤U<4.20)	824428	60,0
	HR+ glass (1.95≤U<2.85)	194810	14,2
	HR++ glass (1.75≤U<1.95)	249577	18,2
	Triple insulation glass (U<1.75)	5253	0,4
	Total	1358464	98,9
Missing	System	15631	1,1
Total		1374095	100,0

§ 2.5.2 Which are the most frequent installations – space heating, domestic hot water and ventilation?

The energy installations of dwellings are an important factor determining their energy performance and ultimately the final heating energy consumption. In this sub-section we are presenting the distribution of the space heating system, DHW system and ventilation system. Moreover, we are introducing the amount and square meters of solar boiler and photovoltaic systems installed in the non-profit housing stock in 2015.

The distribution of the heating system is shown in Table 2.9. The table presents a detailed image of the space heating installations. It includes the numbers of dwellings and percentages that are equipped with each of systems. The vast majority of non-profit dwellings (74%) operate a condensing gas boiler with η≥0.95. Other space heating solutions in the sector include improved non-condensing boilers with 0.80≤ η≤0.90 and condensing boilers with efficiencies of 0.90-0.95. In the Netherlands, 85% of households are heated with natural gas (ECN 2015). Solutions like heat pumps or µCHPs [6] are still rare with only 1% of dwellings having installed one.

6 µCHP is a micro-Combined Heat and Power energy system producing heat and electricity

TABLE 2.9 Distribution of heating system – frequencies and percentages from SHAERE 2015

TYPE OF HEATING SYSTEM	FREQUENCY	PERCENT (%)
Condensing boiler (η≥0.95)	930127	74%
Improved non-condensing boiler (η= 0.80-0.90)	178557	14%
Condensing boiler (η=0.90-0.925)	42026	3%
Gas/oil stove	40548	3%
"Conventional" boiler (η<0.80)	29973	2%
Condensing boiler (η=0.925-0.95)	19595	2%
Heat pump	16722	1%
µCHP	2751	0%
Electric stove	484	0%
Total	1260783	100%

The picture is similar for the domestic hot water installations. Usually, the condensing gas boilers are combined systems and include the DHW installation a well. The majority of the non-profit housing dwellings have a condensing combi-boiler with 0.90≤ η≤0.95 installed. The rest of the distribution is similar to the space heating installation. However, 6% of dwellings are connected to a district heating system for the provision of DHW. Table 2.10 shows the number of dwellings distributed to each DHW system.

TABLE 2.10 Distribution of DHW system – frequencies and percentages from SHAERE 2015

TYPE OF DHW SYSTEM	FREQUENCY	PERCENT [%]
Condensing combi-boiler (η=0.90-0.95)	859253	66%
Improved non-condensing boiler (η=0.80-0.90)	172310	13%
Tankless gas water heater	100625	8%
District heating	76228	6%
Electric boiler (<20L)	74557	6%
Conventional" boiler" (η<0.80)	2979	0%
Heat pump	6402	0%
Gas boiler	697	0%
µCHP	4	0%
Total	1293055	100%

Table 2.11 shows the distribution of the ventilation systems in the non-profit housing sector based on data reported in SHAERE. Mechanical exhaust systems (54%) and natural ventilation (41%) are the most widely used systems. Only 4% of dwellings have balanced – mechanical supply and exhaust – system installed with the possibility of heat recovery.

TABLE 2.11 Distribution of ventilation system – frequencies and percentages from SHAERE 2015

TYPE OF VENTILATION SYSTEM	FREQUENCY	PERCENT [%]
Mechanical exhaust	739199	54%
Natural	557910	41%
Mechanical supply and exhaust. (balanced) central	57859	4%
Mechanical supply and exhaust. (balanced)	2193	0%
Total	1357161	100%

Two solar energy systems are reported, if installed, in SHAERE. These are solar boilers, either for DHW, space heating or both, and photovoltaic systems – amorphous, multicrystalline and monocrystalline. Unfortunately, the amount of dwellings with either system is quite low in the non-profit housing sector. The application of solar systems for the production of thermal energy or electricity is not popular. Only 189,335 m^2 of solar boilers are installed in the non-profit housing sector.

TABLE 2.12 Distribution of solar boiler systems – frequencies and percentages from SHAERE 2015

TYPE OF SOLAR BOILER	FREQUENCY	PERCENT [%]
No solar boiler	1344709	98%
Solar boiler for DHW	28467	2%
Combi solar boiler (DHW and space heating)	710	0,1%
Solar boiler for space heating	90	0,0%
Total	1373976	100%

The distribution of photovoltaic systems is not very different from the solar boilers. Less than 2% of dwellings have a photovoltaic system installed. This amounts to 186,574 m^2 of installed photovoltaic systems.

TABLE 2.13 Distribution of photovoltaic systems – frequencies and percentages from SHAERE 2015

TYPE OF PHOTOVOLTAIC SYSTEM	FREQUENCY	PERCENT [%]
No system	1343251	98%
Multicrystalline	16824	1%
Monocrystalline	6561	0,5%
Amorphous	903	0,1%
Total	1374095	100%

§ 2.5.3 What is the modelled and actual final heating energy consumption?

The actual heating energy consumption data, acquired from Statistics Netherlands, are collected by energy companies since 2009. Yet, the submission of meter readings by the companies is obligatory every 3 years in the Netherlands (Majcen 2016). As a result, estimated 10-20% of dwellings instead of a meter reading are filled in with the average energy consumption of a similar building (Majcen 2016). While this fact can be problematic for our analysis, we did not evaluate individual dwellings but worked with mean values. Subsequently, we are confident that our results are accurate. For this research we are working with gas consumption data. As mentioned before, the majority of Dutch dwellings are heated with gas and in the non-profit housing sector this percentage is more than 95%.

In all calculations, regarding actual gas consumption, a degree day correction was applied. This correction was set to the number of degree days used in the national calculation method (SHAERE data) to be able to compare the predicted and actual values. The number of degree days used in the method are set based on the assumption that when the indoor temperature is below 18 °C then heating is needed. Still, this method may introduce small discrepancies since the heating practice does not only depend on the air temperature outside but also on the chosen heating season for each dwelling.

TABLE 2.14 Comparison of predicted and actual gas consumption in the non-profit housing sector

	PREDICTED GAS CONSUMPTION (N = 1151720)	ACTUAL GAS CONSUMPTION (N=1097812)
Mean value	178,95 (kWh/m²/year)	119,30 (kWh/m²/year)

Table 2.14 presents the results of the comparison between predicted ,from the energy labelling method, gas consumption as reported in SHAERE and the actual gas consumption of dwellings as reported in Statistics Netherlands. The mean values difference between predicted and actual gas consumption is 60 kWh/m^2/year. The mean gas actual gas consumption for the Dutch households, as reported by Statistics Netherlands in 2015, is 151.80 kWh/m^2 (using 80m^2 mean net floor area) (Statistics Netherlands 2017). It appears that the non-profit housing stock is consuming less gas than the total housing stock in the Netherlands.

§ 2.6 Uncertainties and limitations

This research was based on the dwellings' physical properties and the reported energy consumption, in order to examine the improvements and pace of energy renovations using SHAERE. Concerning the quality of data used and the impact on the results of this study, two points should be mentioned. First, we cannot be completely confident about the quality of the inspections taking place in the sector. As a result, concerns have been raised about accuracy of the input data in SHAERE. Although there has not yet been a study regarding the quality of SHAERE, a series of studies carried out by the Inspection Service of Ministry of Housing, for the official energy labels database of the Netherlands, report that in several samples studied from 2009 to 2011deviations from the reported to the actual energy label are decreasing (VROM-Inspectie 2009; VROM-Inspectie 2010; VROM-Inspectie 2011). Hence, there seems to be a trend of improvement. However, further research is required to determine the amount of wrongly reported values of dwellings. We recommend that input methods be tested and validated in future monitoring systems.

The actual energy consumption data, acquired from Statistics Netherlands, are collected by energy companies since 2009. Yet, the delivery of meter readings by the companies is obligatory every 3 years in the Netherlands. As a result, estimated 10-20% of dwellings instead of a meter reading would be filled in with the average energy consumption of a similar building (Majcen 2016). While this fact can impede with our analyses, we did not analyse individual dwellings but worked with groups of dwellings. We are confident that our results are accurate. Moreover, we worked with data before and after renovation measures were realized and tried to select the most past energy consumption data and the most recent, which often was 3 or 4 years apart.

The classification system used in our methods is based on the ISSO 82.3 publication – describing the methodology to evaluate the energy performance of Dutch dwellings. The classes are based on construction year periods and insulation thickness. Based on the construction period tables and the insulation thickness the specific boundaries were chosen. We follow the construction periods which correspond also to the energy renovation targets that once should follow and comply with. This method may not be the optimal for the characterization of the insulation levels. However, it was chosen to correspond to the building practise, building regulations and their evolution in the Netherlands. Different methods, using either the nominal values of the variables or a more detailed classification (more classes) could be studied in further research projects.

Last, in all calculations, regarding actual energy savings and consumption, a degree day correction was applied. This correction was set to the number of degree days used in the national calculation method (SHAERE data) to be able to compare the predicted and actual values. The number of degree days used in the method are set based on the assumption that when the indoor temperature is 18°C then heating is needed. Still, this method may introduce small discrepancies since the heating practice does not only depend on the air temperature outside but also on the chosen heating season for each dwelling.

§ 2.7 Conclusions

Research for energy performance in the built environment can provide information to aid the achievement of goals set and is a cornerstone for the design of effective policies. Dynamic databases using longitudinal data prove to be extremely useful. Longitudinal data are very important to follow the energy performance progress of housing stocks. Datasets and monitoring systems with detailed information, like SHAERE or EPC (Energy Performance Certificate) databases, are necessary to evaluate policies, predict future renovation rates and conclude on best practices for different housing stocks.

This chapter aimed at determining the energy efficiency state of the non-profit housing sector, analysing the latest available data. The main research question of the chapter was how efficient is the Dutch non-profit housing stock in terms of energy performance. We have concluded that the stock is not efficient, in terms of energy performance. Based on the EI, the “assigned” energy label would be D for the non-profit housing in 2015. The envelope insulation levels are not adequate – especially when considering the façade insulation values. In addition, the energy installation of the dwellings can be characterized rather "traditional" with high efficiency gas boilers dominating the stock. Last, the mean predicted gas consumption is 178.95 kWh/m^2 whereas the mean actual gas consumption is 119.30 kWh/m^2 – lower than the Dutch average of 151.80 kWh/m^2.

One of the strengths of SHAERE is the very large amount of data (more than 50% response rate in all years studied) and its representativeness of the non-profit housing sector. The large dataset is important since in this chapter we aimed at describing the energy performance of the non-profit housing sector. As such, the monitoring system can set an example for the rest of the housing sectors. SHAERE has proven to be a rich database on the energy performance of the non-profit sector.

In conclusion, we determined the energy efficient state of the non-profit housing stock. This chapter brings together the background knowledge needed in order to track the energy renovations, calculate the energy savings and evaluate the degree of implementation of current policies.

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