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Monitoring energy performance improvement: insights from Dutch housing association dwellings

SPECIAL COLLECTION: RETROFITTING AT SCALE: ACCELERATING CAPABILITIES FOR DOMESTIC BUILDING STOCKS

RESEARCH

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ABSTRACT

The Energy Performance of Buildings Directive (EPBD) enhanced the sustainable improvement of dwellings in the European Union. Member states formulated measurable goals to improve the housing stock, and monitoring systems were developed to give insights into the improvements. In the Netherlands, non-profit housing associations agreed to improve the quality of their housing stock to an average Dutch energy label B (energy index (EI NV) = 1.40) by 2020. Research assessing this progress over time is presented using an annual monitoring system based on 2.0 million energy performance calculations of 264 Dutch non-profit housing associations between 2017 and 2020. The assessment includes: a detailed description of the development of the state of the stock over time; the effect of changes to the stock (construction and demolition) and changes within the stock (different types of retrofit measures); and the different characteristics of non-profit housing associations. Insights from this research show which specific retrofit and other measures are adopted and have substantial impact over time. This provides a useful frame of reference for building stock analysis and accelerating the improvement of the building stock. It also creates a baseline of information for the future sustainable development of this particular stock.

PRACTICE RELEVANCE

This research reveals which energy saving measures are most and least employed over time in Dutch non-profit housing associations sector. Large urban housing associations own a large share of the Dutch non-profit housing stock, and their dwellings have on average a lower energy rating. However, the improvement of their dwellings between 2017 and 2020 is higher than for smaller housing associations, which already have on average a higher energy rating. While the construction and demolition of dwellings contribute to 15.6% of the annual improvement, most of the improvement of the energy performance depends on retrofitting the existing stock. The trends are found to rely most on traditional measures (*e.g.* the installation of high-efficiency gas boilers and improved insulation). However, the rate of adding photovoltaic (PV) solar systems has increased rapidly in recent years, while futureproof systems (*e.g.* heat pumps and district heating) only have a steady adoption rate in this sector.

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1. INTRODUCTION

To stimulate a more sustainable built environment, the Energy Performance of Buildings Directive (EPBD) was developed and enforced in the European Union (European Commission 2010). The EPBD was adopted by member states into national legislation, and national goals were formulated to improve the energy performance of the housing stock. Several researchers share results from national monitoring systems to discuss sustainable developments in housing stocks of different European countries: Gangolells *et al.* (2016) analysed 130,000 dwellings in Spain from 2013 to 2014 in terms of energy label, building type and building year. They described the state of the stock, but did not give detailed information on building parameters, and did not describe developments over time. Csoknyai *et al.* (2016) analysed energy performance calculations from Bulgaria, Serbia, Hungary and the Czech Republic between 2004 and 2009 as part of the Episcope project. They described in detail the characteristics of the housing stock, but did not include developments over time. They included descriptive *U*-values and analysed domestic hot water and heating systems, although information is limited. In the Czech Republic, 32% of dwellings are connected to district heating, 31% use electric heating, 23% use natural gas and only 0.2% use solar thermal. Serghides *et al.* (2016) described the situation in Cyprus 2014. The dataset covers 2484 dwellings. They gave detailed information about the quality of parts of the envelope, ranging from 0.6 to 6.1 W/m^{2}K. Around 60% of the dwellings used decentralised electric heating and other dwellings used natural gas, oil and heating with wood/biomass. Hjortling *et al.* (2017) analysed 186,021 Energy Performance Certificates (EPCs) from Sweden issued between 2007 and 2015. They included a detailed description of the building stock, but it is a static description without developments over time. The analysis includes insights into energy demands by both building type and region. Streicher *et al.* (2018) analysed 10,400 EPCs issued in Switzerland between 2007 and 2015. They included a detailed description of the quality of the envelope of dwellings. *U*-values ranged on average from 0.4 to approximately 2.4 W/m^{2}K, also described in detail by average surface area and by building period for the floor, walls, roofs and windows. Also, heating systems are discussed by building type and building year. Oil and gas systems are most dominant, but electrical systems and also heat pumps are present in the Swiss building stock. Ahern & Norton (2019) discussed 463,582 EPCs from Ireland present in 2014. They described in detail the quality of the building envelope in terms of *U*-values by building type and building period, of floors, walls, roofs and windows, and the effects of renovations.

Although these assessments give useful insights about the sustainable state of (parts of) housing stocks in Europe, none of these studies assessed change over time or analysed the effects of construction and demolition on the stock. Improved monitoring and analyses of housing stocks could alleviate these knowledge gaps. Generating insights from longitudinal analysis enables the adaptation of strategies to accelerate the improvement of the building stock because it shows which measures currently (do not) have a substantial impact. To address this concern, this paper shows recent insights from a longitudinal monitoring system of the energy performance of the Dutch non-profit housing stock.

In the Netherlands, a large share of the housing stock is owned by non-profit housing associations. They own 2.4 million dwellings, which is one-third of the total housing stock. Other European countries have non-profit housing as well, but generally this represents a smaller share of the total housing stock (Housing Europe 2017). When the European Union agreed in 2008 on goals to reduce the impact of human activities on the climate by 2020 (European Commission 2007), these were translated into several sectoral covenants for the Dutch non-profit housing sector. Agreements made in 2008 (VROM 2008) and 2012 (VROM 2012) were incorporated into the Dutch Energy agreement in 2013 (*Energieakkoord voor duurzame groei* 2013). It was agreed to improve the average energy performance of dwellings of non-profit housing associations to an average energy label B in 2020 (energy index (EI) = 1.25). EI is the Dutch translation of the EPBD (European Commission 2010). Progress until 2015 was published by Filippidou *et al.* (2017). In 2015, the determination method of the EI changed (NEN 2014), and also the related goal towards an average energy label B changed to an average EI NV of 1.40 in 2020 (Blok 2016) (***Table 1***).[1] Since the change in method and goal in 2015, no further scientific research has been published to give insights into the development of the energy performance of Dutch non-profit housing associations.

PERIOD	CALCULATION METHOD FOR ENERGY PERFORMANCE	PUBLISHER	INDICATOR ENERGY LABEL AND UNIT	SECTOR GOAL 2020 AVERAGE FOR ENERGY LABEL B
2009–14	NEN 7120	NEN (2009)	EI (–)	EI = 1.25
2015–20	NEN 7120 NV	NEN (2014)	EI NV (–)	EI NV = 1.40
2021–	NTA 8800	NEN (2020)	Primary fossil energy demand (kWh/m^2)	–

Table 1: Dutch calculation method for the energy performance of dwellings over time.

Note: EI = energy index; NEN = Nederlands Normalisatie-instituut; NTA = Nederlands Technische Afspraak; NV = Nader Voorschrift

The EI NV is the main indicator used to measure the energy performance of dwellings in the Netherlands from 2015 to 2020. It is a dimensionless number, calculated with the following formula:

$$\text{EI NV} = \frac{E_{\text{Ptot}} * 0.84}{248 * A_g + 87 * A_{vl} + 5844}$$

where E_{Ptot} is building-related energy use (MJ); A_g is floor area (m^2); and A_{vl} is heat loss area (m^2).

The building-related energy use is calculated with a theoretical building energy model. The denominator determines an energy budget based on the floor area and heat loss area of a dwelling. EI NV is a division of the building-related energy use and the energy budget. EI NVs translated to corresponding energy labels are presented in the results section in ***Table 3***.

Several studies show that estimation of the building-related energy use with a theoretical building energy model can deviate strongly from actual energy consumption and could lead to the systematic overestimation of potential energy savings (Sunikka-Blank & Galvin 2012; Laurent *et al.* 2013; Saunders 2015; Galvin & Sunikka-Blank 2016; Summerfield *et al.* 2019). These studies describe the performance gap both as a 'rebound' effect (the theoretical overestimation of the energy consumption of poor energy labels compared with actual energy consumption) and the 'prebound' effect (the underestimation of the energy consumption of good energy labels compared with actual energy consumption). The performance gap was found in the Dutch context as well (Santin 2010; Majcen *et al.* 2016; Filippidou *et al.* 2019). Nonetheless, the average EI NV is the formal indicator used to assess the improvement of the energy performance of dwellings of Dutch non-profit housing associations.

Filippidou *et al.* (2017) concluded, based on the progress made from 2010 to 2014, that the goal of an average EI = 1.25 for the Dutch non-profit housing stock will not be met by 2020. Filippidou *et al.* (2016) concluded that housing associations in the period up to 2014 generally did not carry out major renovations, but many smaller investment projects, mostly as part of planned maintenance work. The most frequently applied changes were heating, hot water installations and glazing. Other researchers have differing views to what extent energy performance measures need to be implemented in small- or large-scale renovations or whether demolition and new construction are better alternatives (Thomsen & Flier 2009; Nieboer 2016).

Several elements in the development of the energy performance of Dutch non-profit housing associations were unclear in the literature. First, it was not clear how the energetic quality developed between 2017 and 2020. Second, the effects of changes in the stock (construction and demolition) were not examined in previous studies. Third, it is unknown which characteristics of housing associations, *e.g.* size, financial position or location, explain the improvement of the average energy performance of the non-profit housing sector. Fourth, it is not clear if the agreed goal for the Dutch non-profit housing stock was met in 2020. These unclear elements lead to the following research questions for the Dutch non-profit housing stock for the period 2017–20:

- How did the energetic quality of this stock develop over time?
- How do changes to the stock (construction and demolition) and changes within the stock (retrofit) effect the energy performance of the stock?
- How do characteristics of the owners of this stock (the Dutch non-profit housing associations) influence the progress of energy performance?
- Did the Dutch non-profit housing sector meet its agreed goal on the average energy performance in 2020?

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2. DATA AND METHOD

In Europe, countries have their own data and methods to monitor the energy performance of their building stock. In the Netherlands, Aedes (the Dutch umbrella organization of housing associations) started a monitoring system in 2010 for dwellings of non-profit housing associations called *Sociale Huursector Audit en Evaluatie van Resultaten Energiebesparing* (SHAERE—Social Rented Sector Audit and Evaluation of Energy Saving Results), which was used by TU Delft for research purposes (Filippidou *et al.* 2017). After the change of the method in 2015, the structure of data collection changed. In collaboration with Aedes, data collection started in 2017. Every housing association was asked to voluntarily deliver a structured dataset of their dwellings annually. This was supported by two software providers which offer data management software for the energy performance of dwellings in the Dutch non-profit housing sector. The data collected are not the official energy label, which is stored in the national energy label database, as opposed to other researchers using national energy label databases (*e.g.* Hjortling *et al.* 2017; Streicher *et al.* 2018; Ahern & Norton 2019). The Dutch national database contains the energy labels of dwellings which are approved mostly once every 10 years and have different underlying calculation methods (***Table 1***). Differences between the calculation methods make it unreliable to compare dwellings.

The energy performance of dwellings and the underlying building characteristics were collected under the calculation method in force between 2015 and 2020, the NEN 7120 NV of the Nederlands Normalisatie-instituut. These are the latest, most up-to-date data, although not officially approved in the national energy label database. In these data, all dwellings are comparable under the same measurement scale, and with the average sector goal of an average energy label B in 2020, an average EI NV = 1.40.

Figure 1 shows the number of Dutch housing associations and dwellings analysed between 2017 and 2020. From every dwelling, the EI NV (NEN 2014) is available, with relevant clarifying indicators: building year, building type, thermal capacity, heat loss coefficient and heat loss area of floor, roof, facade, windows and doors, airtightness of the building envelope, ventilation system, heating system, heating system temperature, hot water system, cooling system, solar panels area, and solar heating area. This dataset is the main source of data for this paper.

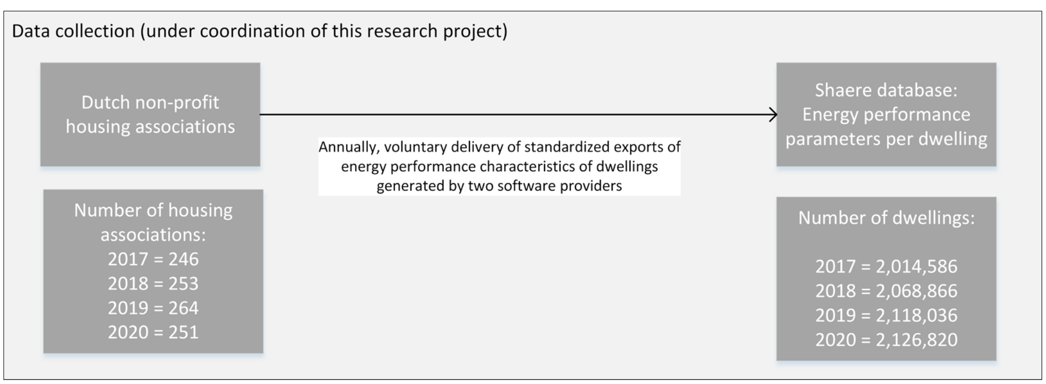


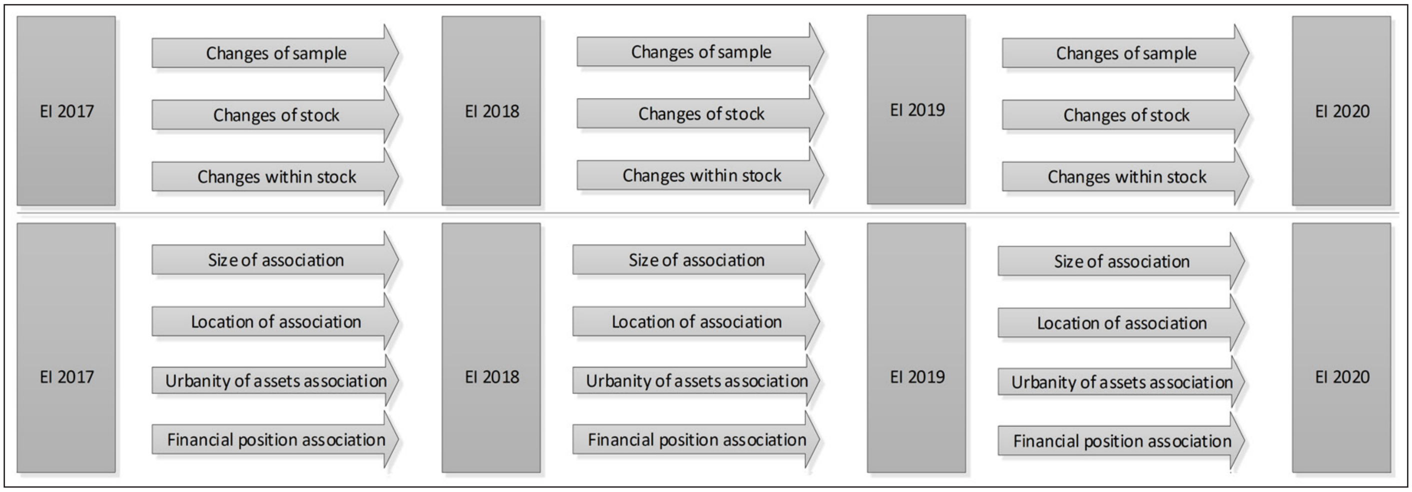
Figure 1: Data collection.

There are quality issues involving the reliability and discrepancies in EPCs and therefore caution must be advised when using these data. For example, Hårsman *et al.* (2016) and Hardy & Glew (2019) analysed the quality of official EPCs in Sweden and the UK, respectively. Hardy & Glew (2019) describe inconsistencies present in EPCs through lodgement errors and discrepancies in building characteristics by comparing registered EPCs from the same dwelling. They estimate an error range of 36–62% of all registered EPCs. Hårsman *et al.* (2016) conclude that the quality of firms that assess and issue EPCs has a big influence on the quality of the issued EPCs. These quality issues are expected to occur in the present dataset as well, although Dutch housing associations are obliged to use certified assessors for all energy performance calculations to assure data quality.

Second, a dataset with descriptive parameters of housing associations was made available for this research by Aedes. From every housing association systematic information is available on the size (classification of the number of dwellings), location (province), financial position (sufficient, mediocre, weak) based on information of the Dutch guarantee fund of the non-profit housing sector, and degree of urbanity (rural to urban).

The average EI NVs for 2017, 2018, 2019 and 2020 are calculated as the mean of the available dwellings in the SHAERE database. The improvement of the EI NV year by year is explained by discussing changes in the sample, changes in the stock and changes within the stock (***Figure 2***). Hereafter, the improvement of the EI NV year by year is explained by the characteristics of housing associations. The results are described in the next section.

Figure 2: Method.



3. RESULTS

The results are presented in four subsections. First, the average state of the Dutch non-profit housing stock from 2017 to 2020 is described to give insights into the sustainable development of the Dutch non-profit housing stock. Second, the changes in the sample, changes in the stock and changes within the stock are presented to give insights into the contribution of construction, demolition and the renovation of existing dwellings to the improvement of the average energy performance. Third, the characteristics of housing associations are considered to give insights into how the size and nature of housing associations influence the progress of the average energy performance. Fourth, the actual progress made between 2017 and 2020 is assessed in relation to the agreed goal of an EI NV = 1.40 in 2020.

3.1 THE STATE OF THE DUTCH NON-PROFIT HOUSING STOCK

The development of the stock from 2017 to 2020 is explained by the characteristics of the dwellings in the SHAERE database. This includes the EI NV, general characteristics, average level of insulation, heating and hot water systems, ventilation systems, solar systems, and cooling systems.

3.1.1 EI NV

Table 2 shows that the average EI NV improves between 2017 and 2020 from an average of 1.73 to an average of 1.51 in 2020.

Table 2: Energy index (EI NV).

Note: NV = Nader Voorschrift.

	2017	2018	2019	2020	Δ2017–20
Average EI NV	1.73	1.65	1.57	1.51	–0.22

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3.1.2 EPC

The EI NV is classified into classes. ***Table 3*** shows that dwellings with an EPC rating of A++ to B (which are better than the Dutch goal of an EI NV = 1.40) improve at a rate of approximately 6% annually to 47.8% of the total stock of dwellings of non-profit housing associations in 2020.

EPC CLASSES	2017	2018	2019	2020	Δ2017–20
Label A++ (EI NV ≤ 0.60)	0.3%	0.5%	1.0%	1.5%	1.1%
Label A+ (EI NV = 0.61–0.80)	0.9%	1.3%	1.8%	2.5%	1.6%
Label A (EI NV = 0.81–1.20)	13.9%	17.2%	21.1%	24.5%	10.6%
Label B (EI NV = 1.21–1.40)	15.5%	17.5%	18.8%	19.3%	3.8%
Label C (EI NV = 1.41–1.80)	31.7%	31.5%	30.0%	28.3%	–3.3%
Label D (EI NV = 1.81–2.10)	16.4%	14.8%	13.2%	11.9%	–4.4%
Label E (EI NV = 2.11–2.40)	10.1%	8.8%	7.5%	6.6%	–3.5%
Label F (EI NV = 2.41–2.70)	5.7%	4.6%	4.6%	3.1%	–2.7%
Label G (EI NV > 2.71)	5.5%	3.8%	3.8%	2.2%	–3.3%

Table 3: Percentage of dwellings in each Energy Performance Certificate (EPC) category.

Note: EI = energy index; NV = Nader Voorschrift.

3.1.3 General characteristics

The general characteristics of dwellings of non-profit housing associations change slightly over the years (***Table 4***). The share of apartments increases slightly, and also the average size of single dwellings increases by 2.0 m^2. The building type in the Netherlands is 98.6% heavy, which means the use of concrete or bricks. The airtightness of the dwellings improves significantly over the years.

CHARACTERISTICS	2017	2018	2019	2020	Δ2017–20
Apartments (% stock)	54.9%	56.8%	57.1%	57.5%	2.6%
Single dwelling (% stock)	45.1%	43.2%	42.9%	42.5%	–2.6%
Apartment size (m^2)	71.1	71.2	71.1	71.1	0
Single dwelling size (m^2)	92.8	93.7	94.3	94.8	2.0
Building type heavy (% stock)	98.0%	98.5%	98.6%	98.6%	0.6%
Airtightness QV10 ($dm^3/s.m^2$)	2.08	1.90	1.83	1.75	–0.33

Table 4: General characteristics of Dutch non-profit housing association dwellings.

Note: QV = air permeability.

3.1.4 Insulation

The degree of insulation of the dwellings improves between 2017 and 2020; however, the absolute levels of insulation are on average still quite low (***Table 5***). Looking at floor insulation, 50.8% of the stock has poor or no insulation present. Another 25.2% has an insulation degree up to R = 2.00 m^2K/W, which is still a poor insulation grade. Insulation levels of the facade are slightly higher, but still, large portions of the stock have a (very) poor quality, 26.3% and 46.8%, respectively. Insulation levels of the roof are a bit higher, but 20.5% and 42.0% have a (very) poor insulation quality in 2020. The insulation of glazing is measured using the U-value. The levels of insulation are for a large part better than double-glazing; however, in 2020 single-glazing can be found in 32.8% of the stock. In 2020, 1.6% of the dwellings have only single-glazing, 6.3% have more than 50% of the glazing area with single-glazing, and another 24.9% have double-glazing, but with less than 50% of the glazing area with single-glazing. The insulation of doors is not very common with only 5.3% being insulated. When compared with the minimum requirements in the Dutch building code 2015 for newly built dwellings, the floor (R = 3.5 m^2K/W), facade (R = 4.5 m^2K/W), roof (R=6.0 m^2K/W) and glazing/doors (U = 1.65 W/m^2K), a very large part of the stock, is below these requirements.

	2017	2018	2019	2020	Δ2017–20
	(% STOCK)				
Floor					
No or very poor (*R* = 0–0.99 m²K/W)	52.7%	52.0%	51.2%	50.8%	–1.8%
Poor quality (*R* = 1.00–1.99 m²K/W)	26.1%	25.8%	25.6%	25.2%	–0.9%
Weak quality (*R* = 2.00–2.99 m²K/W)	14.4%	14.7%	14.8%	14.8%	0.4%
Average quality (*R* = 3.00–3.99 m²K/W)	4.5%	5.0%	5.4%	5.8%	1.3%
Good quality (*R* = 4.00–4.99 m²K/W)	1.4%	1.5%	1.8%	2.0%	0.5%
High quality (*R* ≥ 5 m²K/W)	0.9%	1.0%	1.2%	1.5%	0.6%
Facade					
No or very poor (*R* = 0–1 m²K/W)	28.9%	28.0%	27.3%	26.3%	–2.6%
Poor quality (*R* = 1–2 m²K/W)	47.4%	47.1%	46.8%	46.8%	–0.6%
Weak quality (*R* = 2–3 m²K/W)	17.3%	17.7%	17.9%	18.2%	0.9%
Average quality (*R* = 3–4 m²K/W)	4.6%	5.0%	5.3%	5.5%	0.9%
Good quality (*R* = 4–5 m²K/W)	1.3%	1.5%	1.8%	2.0%	0.7%
High quality (*R* ≥ 5 m²K/W)	0.5%	0.6%	0.9%	1.2%	0.6%
Roof					
No or very poor (*R* = 0–1 m²K/W)	25.8%	23.9%	22.2%	20.5%	–5.4%
Poor quality (*R* = 1–2 m²K/W)	43.8%	43.7%	42.9%	42.0%	–1.8%
Weak quality (*R* = 2–3 m²K/W)	20.3%	21.3%	21.7%	22.0%	1.7%
Average quality (*R* = 3–4 m²K/W)	6.3%	6.8%	7.6%	8.3%	2.0%
Good quality (*R* = 4–5 m²K/W)	2.2%	2.4%	2.8%	3.2%	1.0%
High quality (*R* ≥ 5 m²K/W)	1.6%	2.0%	2.9%	4.0%	2.5%
Glazing					
Single-glazing (*U* > 5.11 W/m²K)	2.6%	2.1%	1.8%	1.6%	–0.9%
> 50% single-glazing (*U* = 4.01–5.10 W/m²K)	7.7%	7.2%	6.9%	6.3%	–1.3%
> 50% double-glazing (*U* = 2.91–4.00 W/m²K)	26.3%	26.2%	25.6%	24.9%	–1.4%
Double-glazing (*U* = 2.01–2.90 W/m²K)	40.3%	40.2%	39.5%	38.9%	–1.5%
HR+ or HR++ (*U* = 1.41–2.00 W/m²K)	22.7%	23.9%	25.6%	27.3%	4.6%
Triple-glazing (*U* < 1.40 W/m²K)	0.5%	0.5%	0.7%	1.0%	0.5%
Doors					
Uninsulated (*U* > 2.01 W/m²K)	95.0%	95.0%	94.9%	94.7%	–0.3%
Insulated (*U* ≤ 2.00 W/m²K)	5.0%	5.0%	5.1%	5.3%	0.3%

Table 5: Level of insulation in the Dutch non-profit housing association stock.

3.1.5 Heating and hot water systems

The heating systems in dwellings of Dutch non-profit housing associations are mostly condensing gas boilers (***Table 6***). The condensing HR107 gas boiler is most popular, with 79.8% of the total housing stock in 2020. This percentage is still increasing, while lower efficiency gas boilers such as the conventional non-condensing gas boiler (CR) and improved non-condensing gas boiler (VR) are replaced. More innovative heating systems such as combined heat and power systems (CHP), district heating, heat pumps, or biomass systems are slowly gaining ground in the Dutch non-profit housing sector, but the traditional heating system with gas is

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very dominant. The popularity of low-temperature distribution systems increases related to the uptake of innovative heating systems. However, with 4.7%, this is still a small percentage. Looking at the hot water systems, the popularity of the combined gas boiler systems is imminent and still rising (77.7%). The use of older systems, such as geysers and electric water heating systems, is decreasing.

Table 6: Heating and hot water systems in the Dutch non-profit housing association stock.

Note: CHP = combined heat and power; CR = conventional non-condensing gas boiler; VR = improved non-condensing gas boiler.

	2017	2018	2019	2020	Δ2017–20
	(% STOCK)				
Heating system					
Local or central electrical heating	0.1%	0.1%	0.1%	0.2%	0.1%
Local heating oil/gas/wood	2.5%	2.2%	1.7%	1.5%	–1.0%
CR non-condensing gas boiler	1.1%	0.9%	0.6%	0.5%	–0.6%
VR non-condensing gas boiler	10.8%	8.8%	6.9%	5.3%	–5.5%
HR100 condensing gas boiler	2.6%	2.1%	1.7%	1.4%	–1.2%
HR104 condensing gas boiler	1.1%	0.8%	0.7%	0.5%	–0.6%
HR107 condensing gas boiler	72.6%	75.6%	78.1%	79.8%	7.2%
CHP	0.2%	0.2%	0.2%	0.1%	–0.1%
District heating	7.3%	7.5%	7.7%	8.0%	0.7%
Heat pump	1.6%	1.8%	2.2%	2.6%	1.0%
Biomass	0.0%	0.0%	0.1%	0.1%	0.1%
Heating system temperature					
High	87.1%	86.9%	86.6%	86.0%	–1.1%
Low	3.6%	3.8%	4.3%	4.7%	1.1%
Unknown	9.3%	9.3%	9.2%	9.3%	0.0%
Hot water system					
Collective system	5.2%	5.5%	5.8%	5.9%	0.7%
District heating	6.0%	6.3%	6.7%	7.0%	1.0%
Electrical heating	5.1%	5.0%	5.0%	5.0%	–0.1%
Heat pump	0.7%	0.7%	0.9%	1.2%	0.5%
Gas boiler	77.3%	77.6%	77.7%	77.7%	0.4%
Geyser	5.8%	4.9%	3.9%	3.2%	–2.6%

3.1.6 Ventilation systems

Ventilation systems applied in the Dutch non-profit housing sector are still very traditional (***Table 7***). A total of 32.8% have no installed ventilation system, although this is decreasing. Some 61.2% have a mechanical outflow system installed. Only 6.0% has a balanced ventilation system, which has mechanical inflow and outflow. Heat from outgoing air is used to preheat incoming air, thereby lowering the energy demand of a dwelling.

Table 7: Ventilation systems in the Dutch non-profit housing association stock.

	2017	2018	2019	2020	Δ2017–20
Natural	39.5%	36.9%	34.8%	32.8%	–6.7%
Mechanical outflow	56.0%	58.1%	59.7%	61.2%	5.2%
Mechanical in/outflow	4.5%	5.1%	5.5%	6.0%	1.5%

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3.1.7 Solar systems

Solar systems (***Table 8***) are increasingly popular in the Dutch non-profit housing sector. Photovoltaic (PV) panels increase by 1.4%, 2.6% and 3.0% annually. This is a steep rise, and given that only 10.4% of the dwellings have PV panels in 2020, there is still a lot of potential to raise this level. Panels to generate solar heat are less popular. A total of 2.3% of the sector has panels for solar heating. The average size of 2.5 m^2 is smaller than the PV panels with 10.2 m^2.

Table 8: Solar systems in the Dutch non-profit housing association stock.

	2017	2018	2019	2020	Δ2017–20
Solar power					
Solar power (% stock)	3.4%	4.8%	7.4%	10.4%	7.1%
Solar power average area (m^2)	8.9	9.1	10.4	10.2	1.3
Solar heating					
Solar heating (% stock)	1.9%	2.1%	2.2%	2.3%	0.4%
Solar heating average area (m^2)	2.4	2.4	2.5	2.5	0.1

3.1.8 Cooling systems

Cooling systems are not popular in the Dutch non-profit housing sector, but are slowly being adopted. A total of 1.0% have a cooling system in 2020 (***Table 9***).

Table 9: Cooling systems in the Dutch non-profit housing association stock.

	2017	2018	2019	2020	Δ2017–20
Cooling system (% stock)	0.5%	0.6%	0.8%	1.0%	0.5%

3.2 HOW DO CHANGES TO THE STOCK IMPACT THE EI NV?

As shown in ***Table 2***, the average EI NV between 2017 and 2020 improves from 1.73 to 1.51 in 2020. The difference can be explained by changes in the sample, changes in the stock and changes within the stock (***Table 10***). The changes in the sample are responsible for a small increase in EI NV. Changes in the stock are responsible for 15.6% of the improvement of EI NV and the other 85.4% of the improvement is caused by changes within the stock. This is explained in the following sections.

Table 10: Improvement of the energy index (EI NV) in the Dutch non-profit housing association stock.

PROGRESS IN EI NV	ΔEI NV 2017–18	ΔEI NV 2018–19	ΔEI NV 2019–20	ΔEI NV 2017–20	%2017–20
Changes in the sample	+0.002	0.000	0.000	+0.002	0.9%
Changes in the stock	–0.013	–0.012	–0.009	–0.034	–15.6%
Changes within the stock	–0.071	–0.061	–0.054	–0.186	–85.4%
Total change	–0.082	–0.073	–0.063	–0.218	–100%

3.2.1 Changes in the sample

The change in the sample of housing associations in the SHAERE database in 2017 and 2018 has an effect on the average EI NV between 2017 and 2018. A total of 11 housing associations participated in 2017, but not in 2018, and 18 new housing associations delivered data in 2018. The effect on the change in EI NV between 2017 and 2018 is EI NV = +0.002. This effect is positive, and means that only because of the change in the sample, the EI NV in 2018 is 0.002 higher than in 2017. In 2019, one housing association did not participate and 13 new housing associations delivered data. In 2020, five new housing associations delivered data. However, these changes in the samples did not have a significant effect on the progress of the average EI NV.

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3.2.2 Change in the stock

Table 11 shows that 15.6% of the improvement of the EI NV is explained by changes in the stock. This consists of newly built dwellings, purchased, sold and demolished dwellings, or administrative corrections. These are described accordingly.

Table 11: Development of the energy index (EI NV) by changes in the stock.

PROGRESS IN EI NV	ΔEI NV 2017–18	ΔEI NV 2018–19	ΔEI NV 2019–20	ΔEI NV 2017–20	%2017–20
New-build dwellings	–0.007	–0.008	–0.006	–0.021	–9.7%
Purchase/merger/administrative	–0.001	+0.001	+0.002	+0.002	0.9%
Demolition/sale/administrative	–0.005	–0.005	–0.005	–0.015	–6.8%
Total change in the stock	–0.013	–0.012	–0.009	–0.034	–15.6%
Total change	–0.082	–0.073	–0.063	–0.218	–100%

3.2.3 New-build dwellings

Non-profit housing associations create new dwellings annually. These dwellings appear in the SHAERE database, however with a small time delay. In this assessment, newly added dwellings between 2010 and 2020 are seen as new-build and are together responsible for 9.7% of the improvement in EI NV (***Table 11***). The quality of these dwellings increases annually with accordingly a lower average EI NV. ***Table 12*** shows the main characteristics of new-build dwellings from 2017

Table 12: Characteristics of new-build dwellings in the Dutch non-profit housing association stock.

CHARACTERISTICS	2017	2018	2019	2020
Number of dwellings	11715	11286	8507	2477
Energy index (EI NV) average	0.70	0.63	0.60	0.49
Heating system: condensing gas boiler HR107	55.7%	48.0%	31.2%	17.9%
Heating system: electrical heating	1.2%	8.8%	6.4%	8.6%
Heating system: district heating	25.1%	20.9%	19.4%	24.9%
Heating system: heat pump	16.2%	20.9%	42.6%	48.6%
Heating system: other	1.7%	1.4%	0.5%	0.0%
Hot water system: gas boiler	58.1%	48.9%	32.0%	18.4%
Hot water system: electrical	1.3%	8.3%	13.1%	10.7%
Hot water system: district heating	29.5%	23.3%	23.4%	26.4%
Hot water system: heat pump	11.0%	19.6%	31.4%	44.5%
Hot water system: other	0.0%	0.0%	0.1%	0.0%
Insulation level floor (average R, m^2K/W)	4.0	4.2	4.5	4.4
Insulation level roof (average R, m^2K/W)	5.3	5.5	5.9	6.3
Insulation level facade (average R, m^2K/W)	4.4	4.6	4.9	5.1
Insulation level windows (average U, W/m^2K)	1.7	1.7	1.4	1.7
Insulation level doors (average U, W/m^2K)	2.7	2.6	2.6	2.3
Ventilation system: natural	7.2%	0.6%	0.1%	0.0%
Ventilation system: mechanical outflow	67.9%	65.9%	56.3%	46.3%
Ventilation system: mechanical in/outflow	24.9%	33.5%	43.7%	53.7%
Solar power system	61.5%	80.6%	86.2%	90.2%
Solar heating system	0.9%	0.9%	0.5%	3.3%
Cooling system	6.3%	10.3%	23.3%	22.2%

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to 2020. These characteristics can be seen as still quite traditional, although solar PV is a standard solution for new-build dwellings.

3.2.4 Purchase and administrative corrections

Dwellings can also be added to the stock by purchase or administrative corrections. It is not possible to distinguish between dwellings that are purchased or added by administrative corrections. However, at –0.9%, the impact on the sectoral improvement is low.

3.2.5 Demolition, sale and administrative corrections

Parallel to added dwellings, dwellings are also removed from the stock. It is not possible to identify which dwellings are demolished, sold or removed from the data for administrative reasons because this information is not differentiated in the database. However, the impact of the dwellings absent in the database can be calculated by measuring the effect as if they were present in the next year. This effect is EI NV = –0.005 for all years. The removal of dwellings has therewith a significant impact on the improvement of the average EI NV.

3.2.6 Changes within the stock

Besides changes in the sample and changes in the stock, the major part of the sectoral improvement of the EI NV is due to improvements of the existing stock (85.4%). In this section, the relative importance of changes within the existing stock is explained, expressed in the contribution to the improvement of the EI NV of applied energy-saving measures. The improvement of dwellings with multiple changes is attributed evenly over these changes. ***Table 13*** shows the absolute contribution of changes within the stock to the total development of the energy performance. Improved heating systems and improved insulation are responsible for a large part of the sectoral EI NV improvement. The contribution of solar systems is 10.1%, and its share is rising over the years. Other minor improvements that are not specified in the database (*e.g.* the installation of a thermostat in a dwelling) are responsible for 6.4% of the sectoral improvement.

Table 13: Development energy index (EI NV) by changes within the stock.

CHANGES WITHIN THE STOCK	ΔEI NV 2017–18	ΔEI NV 2018–19	ΔEI NV 2019–20	ΔEI NV 2017–20	%2017–20
Heating systems	–0.024	–0.016	–0.013	–0.052	–23.9%
Hot water systems	–0.009	–0.009	–0.005	–0.023	–10.6%
Ventilation systems	–0.006	–0.005	–0.005	–0.017	–7.8%
Solar systems	–0.006	–0.006	–0.010	–0.022	–10.1%
Airtightness	–0.003	–0.002	–0.003	–0.008	–3.7%
Insulation	–0.019	–0.015	–0.014	–0.049	–22.5%
Other	–0.005	–0.007	–0.002	–0.014	–6.4%
Total change within the stock	–0.071	–0.061	–0.054	–0.186	–85.4%
Total change	–0.082	–0.073	–0.063	–0.218	–100%

3.2.7 Innovative retrofits

Innovative retrofits are defined as those with an innovative heating solution (CHP, biomass, district heating, heat pumps), added balanced ventilation or added solar systems. ***Table 14*** shows the effect of these retrofits is 15.6% of the total sectoral EI NV improvement.

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INNOVATIVE RETROFITS	ΔEI NV 2017–18	ΔEI NV 2018–19	ΔEI NV 2019–20	ΔEI NV 2017–20	%2017–20
CHP, biomass, district heating, heat pumps	–0.004	–0.003	–0.004	–0.011	–5.0%
Balanced ventilation	–0.000	–0.000	–0.000	–0.001	–0.3%
Solar systems	–0.006	–0.006	–0.010	–0.022	–10.1%
Total innovative retrofits	–0.010	–0.009	–0.014	–0.034	–15.6%
Total change	–0.082	–0.073	–0.063	–0.218	–100%

Table 14: Development energy index (EI NV) by innovative retrofits.

Note: CHP = combined heat and power.

3.2.8 Administrative corrections

Not all improvements in the EI NV are expected to be related to the actual improvements of dwellings. A portion of the improvements shown in ***Table 13*** could be seen as administrative corrections. The total effect of these administrative corrections cannot be deduced from the dataset.

3.3 HOW DO HOUSING ASSOCIATIONS' CHARACTERISTICS EXPLAIN THE IMPROVEMENT OF THE EI NV?

This section explains how different characteristics of housing associations explain the improvement in the EI NV between 2017 and 2020. The key factors are size, location, degree of urbanity and financial position. Each characteristic is described in ***Tables 15–18***: the average EI NV for 2017–20, the average percentage of dwellings in the stock, the total improvement of the EI NV for 2017–20, and the percentage of the contribution of the EI NV's improvement to the improvement of the total stock.

3.3.1 Size of the housing association

Looking at the size of housing associations shows the importance of the order of magnitude (***Table 15***). On average large housing associations (XL > 25,000 dwellings) have a high EI NV. They are the only group higher than the average of the total sector in every year. Together they own 35% of the non-profit housing stock. However, because of their size, they are also responsible for a large part (39%) of the total sector improvement.

SIZE IN NUMBER OF DWELLINGS	AVERAGE EI NV 2017	AVERAGE EI NV 2018	AVERAGE EI NV 2019	AVERAGE EI NV 2020	AVERAGE % STOCK	ΔEI NV 2017–20	% ΔEI NV 2017–20
XL (≥ 25,000)	1.80	1.70	1.63	1.56	35%	–0.24	39%
L (10,000–24,999)	1.71	1.64	1.56	1.50	29%	–0.21	28%
M (5,000–9,999)	1.71	1.63	1.55	1.49	22%	–0.22	22%
S (2,500–4,999)	1.59	1.54	1.47	1.42	9%	–0.17	7%
XS (1,000–2,499)	1.59	1.53	1.46	1.40	4%	–0.20	3%
XXS (≤ 999)	1.62	1.58	1.48	1.42	0%	–0.19	0%
Total sector	1.73	1.65	1.57	1.51	100%	–0.22	100%

Table 15: Progress of the energy index (EI NV) by size of housing association.

3.3.2 Location of the housing association

Looking at the location of housing associations across the Netherlands by province also shows the order of magnitude (***Table 16***). Two provinces (Noord-Holland, Zuid-Holland) have 45% of the non-profit housing stock, and both have an average EI NV higher than the average. Together they are responsible for 49% of the progress between 2017 and 2020. In some provinces good progress has been made (Utrecht, Limburg, Groningen, Drenthe) or has been made in the past (Flevoland, Gelderland), but because of the order of magnitude, the impact of these provinces is overshadowed by the provinces Noord-Holland and Zuid-Holland.

PROVINCE	AVERAGE EI NV 2017	AVERAGE EI NV 2018	AVERAGE EI NV 2019	AVERAGE EI NV 2020	AVERAGE % STOCK	ΔEI NV 2017–20	% ΔEI NV 2017–20
Noord-Holland	1.79	1.68	1.58	1.52	22%	–0.27	27%
Zuid-Holland	1.81	1.72	1.66	1.60	23%	–0.21	22%
Noord-Brabant	1.64	1.58	1.54	1.48	14%	–0.16	11%
Limburg	1.74	1.67	1.58	1.48	7%	–0.25	8%
Utrecht	1.84	1.73	1.65	1.58	6%	–0.26	7%
Gelderland	1.56	1.51	1.46	1.41	10%	–0.15	7%
Overijssel	1.65	1.58	1.50	1.46	6%	–0.20	5%
Friesland	1.71	1.65	1.59	1.50	4%	–0.20	4%
Groningen	1.80	1.72	1.56	1.47	2%	–0.33	4%
Drenthe	1.63	1.55	1.46	1.35	2%	–0.28	3%
Zeeland	1.68	1.56	1.50	1.44	2%	–0.25	2%
Flevoland	1.41	1.35	1.28	1.24	1%	–0.17	1%
Total sector	1.73	1.65	1.57	1.51	100%	–0.22	100%

Table 16: Progress of the energy index (EI NV) by location.

3.3.3 Degree of urbanity of the assets of the housing association

Looking at the location density of dwellings of housing associations, the same pattern arises as with the size and location of housing associations (***Table 17***). A large part (almost 70%) of the stock is located in dense cities, which also have on average dwellings with the highest EI NV. Housing associations operating in areas with a lower location density have a better EI NV, but are still higher than the average goal of 1.40.

	AVERAGE EI NV 2017	AVERAGE EI NV 2018	AVERAGE EI NV 2019	AVERAGE EI NV 2020	AVERAGE % STOCK	ΔEI NV 2017–20	%ΔEI NV 2017–20
Urban	1.83	1.71	1.65	1.58	36%	–0.25	40%
Urban–suburban	1.72	1.65	1.55	1.50	33%	–0.22	34%
Suburban	1.61	1.55	1.50	1.46	12%	–0.15	8%
Suburban–rural	1.63	1.57	1.51	1.43	16%	–0.20	15%
Rural	1.69	1.60	1.51	1.44	3%	–0.24	3%
Total	1.73	1.65	1.57	1.51	100%	–0.22	100%

Table 17: Progress of the energy index (EI NV) according to location density.

3.3.4 Financial strength of the housing association

Looking at the financial strength of housing associations, it shows that the group of housing associations with weak financial strength has a high EI NV (***Table 18***). However, the sector impact is modest because it is a relatively small percentage of the total housing stock. Housing associations with sufficient and mediocre financial strength are largely responsible for the progress of the sector.

	AVERAGE EI NV 2017	AVERAGE EI NV 2018	AVERAGE EI NV 2019	AVERAGE EI NV 2020	AVERAGE % STOCK	ΔEI NV 2017–20	%ΔEI NV 2017–20
Sufficient	1.70	1.61	1.57	1.51	45%	–0.18	37%
Mediocre	1.74	1.67	1.56	1.49	51%	–0.25	56%
Weak	1.90	1.73	1.73	1.71	5%	–0.19	4%
Total	1.73	1.65	1.57	1.51	100%	–0.22	100%

Table 18: Progress of the energy index (EI NV) according to financial strength.

3.4 HOW DOES THIS RELATE TO THE GOAL OF AN ENERGY PERFORMANCE OF 1.40?

The research of Filippidou *et al.* (2017) shows that the annual improvement of the EI followed a linear line between 2010 and 2015. The goal was an average EI = 1.25 (***Figure 3***). In 2015, the method of determination for the EI changed (NEN 2014). Also, the related goal changed to an average EI NV = 1.40 for housing associations in 2020 (Blok 2016).

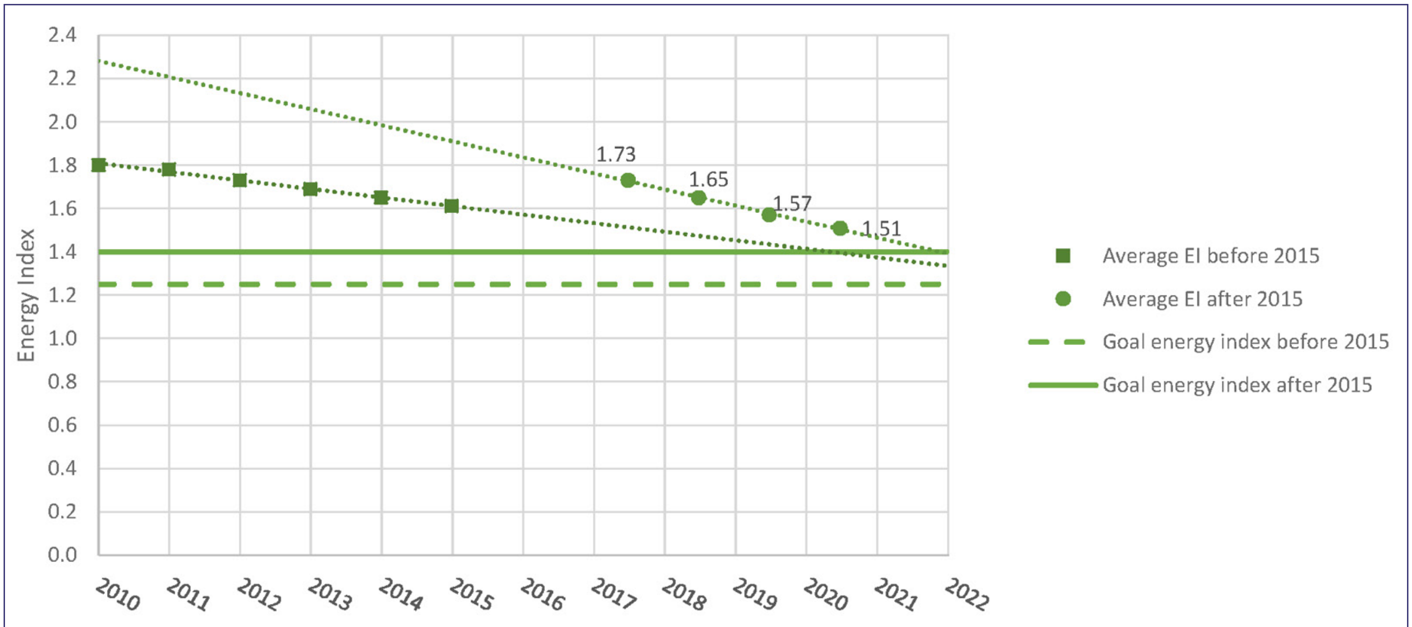

Figure 3: Progress of the average energy index (EI NV) in the Dutch non-profit housing sector.

With an average EI NV = 1.51 halfway into 2020, with linear extrapolation the goal of an EI NV = 1.40 will not achieved in 2020, but can be achieved at the end of 2021.

4. DISCUSSION

This assessment gives insights into the energy performance of the Dutch non-profit housing sector over the period 2017–20. The stated research questions could be answered with an analysis based on a large and consistent dataset. However, several studies have shown that the estimation of the theoretical energy consumption within the EI NV can deviate strongly from actual energy consumption and could lead to the systematic overestimation of potential energy savings. The realized savings in actual energy consumption are lower than expected, and thus also lower saved CO_2 emissions (Sunikka-Blank & Galvin 2012; Laurent *et al.* 2013; Saunders 2015; Galvin & Sunikka-Blank 2016; Summerfield *et al.* 2019). Based on previous research (Santin 2010; Majcen *et al.* 2016; Filippidou *et al.* 2019), this performance gap is expected to be present in the Dutch non-profit housing sector between 2017 and 2020 as well. Closing the performance gap between theoretical and actual energy consumption needs continuous efforts to improve the accuracy of predictions of actual energy savings by constructing new dwellings and renovating the existing housing stock.

As described in the introduction, other researchers also reported on the energy performance of (parts of) national housing stocks. These assessments of the sustainable state of (parts of) housing stocks in Europe give useful insights into the development of future policies. Without a comparable research framework and research period, is it difficult to draw conclusions about the differences between the energetic quality of the different housing stocks, and more specifically non-profit housing stocks. However, previous research presented static descriptions of housing stocks.

What the present research adds is the development of the energy performance over time, together with a description of the change in the underlying building characteristics and their contribution to the change in energy performance. Monitoring the annual rate of change enables adapting strategies to accelerate the improvement of the building stock as it shows which measures currently have, or do not have, a substantial impact. This is also true for monitoring the effects of demotion and construction of dwellings. Monitoring the contribution of characteristics of housing associations is especially useful within the Dutch context. Housing associations own one-third of all Dutch dwellings and have a high level of organization compared with private homeowners. Therefore, housing associations act as a flywheel in the acceleration towards a Dutch sustainable built environment. Although other European countries usually have a smaller non-profit housing stock (Housing Europe 2017), taking a closer look at the contribution of housing associations within their national context could be beneficial as well.

In 2021, the Dutch definition of the energy performance of dwellings changed once more with the new calculation method: Nederlands Technische Afspraak (NTA) 8800 (***Table 1***). This will make it more difficult to extrapolate findings based on the EI NV to future monitoring of the energy performance of dwellings of Dutch non-profit housing associations. However, the underlying building parameters will not change. Future policies for Dutch non-profit housing associations based on the Dutch National Climate Agreement (2019) will focus on building parameters of dwellings instead of average sectoral energy performance. Examples of these policies are the 'Startmotor' (100,000 dwellings on district heating), 'Renovatieversneller' (an acceleration of renovation by grouping projects) and 'Standaard' (a maximum energy demand for the building envelope). These policies benefit from the continuation of a detailed monitoring system such as SHAERE.

5. CONCLUSIONS

The role of Dutch non-profit housing associations was analysed for delivering change towards a more sustainable built environment, specifically to reduce the energy demand from the stock. Overall, the energy performance of this stock improved steadily between 2017 and 2020, nearly reaching the goal of an average energy index (EI NV) of 1.40 in 2020. Housing associations delivered this change by improving the energetic quality of their dwellings. The effect of changes in the stock (construction and demolition) to the improvement of the average energy performance is modest (15.6%). The improvement of the average sectoral energy performance happens for 85.4% within the existing stock, mostly with traditional retrofit improvements (*e.g.* changing heating systems and adding insulation). Innovative solutions (*e.g.* photovoltaic (PV) solar systems, combined heat and power systems, biomass systems, heat pumps, and district heating) are responsible for a relatively small part of the sectoral improvement (15.6%). The influence of these innovative systems in future could be significantly higher. The trend is increasing for the installation of PV systems and a steady growth rate exists for heat pumps and district heating.

Large urban housing associations drive the improvement in the performance of the average sectoral energy. These housing associations own a large share of the stock, have on average a lower energetic quality, but also made more progress between 2017 and 2020. Differences between housing associations in different regions demand a more diverse policy approach beyond 2020.

Future policies as pursued by the Dutch National Climate Agreement (2019) could accommodate this diversification. Future policies benefit from continuous monitoring of the energetic quality of the building stock, such as the *Sociale Huursector Audit en Evaluatie van Resultaten Energiebesparing* (SHAERE—Social Rented Sector Audit and Evaluation of Energy Saving Results) monitoring system. The monitoring system shows which measures currently have, or do not have, a substantial impact, therewith enabling the adaptation of strategies to speed up the improvement of the building stock. This applies not only to the Dutch non-profit housing stock but also to all building stocks moving towards a sustainable future.

NOTE

1 Nader Voorschrift means 'Further Regulation'.

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AUTHOR CONTRIBUTIONS

The first author was responsible for conceptualization, data collection, methodology, analysis and writing. The second author was responsible for funding, review and editing. The third and fourth authors contributed to the review and editing.

COMPETING INTERESTS

The authors have no competing interests to declare.

DATA AVAILABILITY

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